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BOOK OF PROCEEDINGS

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ASSESSMENT OF THE ENVIRONMENTAL RESILIENCE OF FARMERS AND PASTORALISTS TO CLIMATE CHANGES IN THE SOUTHERN SAVANNA ZONE OF KATSINA STATE, NIGERIA

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Abstract- This paper aimed to assess the ability of the environment to support the livelihood of farmers and pastoralists in Funtua, Bakori, and Danja local government areas of Katsina state, in the face of climate changes, using components of environmental indicators of resilient by Food and Agricultural Organization (FAO). The study used a multi-stage sampling technique, stage one involved dividing the local governments into political wards level and randomly selecting two wards by applying a simple random sampling method. Stage two involved dividing the political wards into settlements and purposively selecting two settlements each of farmers and pastoralists, giving a total of six (6) settlements for farmers and six (6) for pastoralists. Stage three involved the random selection of ten households from each settlement of farmers and pastoralists and interviewing three respondents from each household selected. This gives a total of one hundred and twenty households from all three local government areas with each having forty households, and a total of 360 respondents. The data was collected using a questionnaire developed from the environmental indicators of the resilience of the SHARP TOOL, uploaded onto the open data kit which is an android based application that allows a digitally programmed questionnaire on a phone. Data for objectives A, B, and C were analyzed using descriptive statistics of percentages and frequencies, and results were presented using graphical statistical representations. Data for objective D were analyzed using correlation analysis and the use of spider diagrams to determine the Resilience of farmers and pastoralists in the study area. The result shows that although the environment is impacted by climate change, it can still support the livelihood of farmers and pastoralists in areas of water access, land, and energy while it's getting weak in areas of soil fertility and weather element changes. Hence there is the need to improve on conservative strategies of the respondents and encourage the use of local and ecological parameters in production to enable environmental regeneration.

***Keywords*:** Environment, Resilience, Climate Change, Farmers and Pastoralists.

INTRODUCTION

The impacts of climate changes on farmers and pastoralists cannot be over-emphasized as it manifests themselves in their social, economic, and environmental aspects of livelihood respectively. The International Panel on Climate Change (IPCC) defines climate change as statistically significant variations in climate condition that persists for an extended period, typically for decades or longer, which is as a result of global warming caused by the greenhouse effect (increase in greenhouse gases – notably carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), Ozone (O3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF6) and water vapor (H2O)); variations in earth's orbital characteristics (example: solar output, earth-sun geometry and interstellar dust); and volcanic eruptions - which invariably release large amounts of sulfur dioxide into the atmosphere (Ibe, 2011). Other contributory factors to global warming include some human activities like deforestation, desertification, pollution, land degradation, erosion, emission of greenhouse gases, bush burning, oil spills, gas flaring, waste disposal, and population growth (Adejo, Ibrahim and Onuche, 2010; Onumadu, 2012).

Globally, temperatures are rising and rainfall patterns are becoming increasingly unpredictable in many parts of Sub-Saharan Africa reducing arable and grazing lands; altering the length of the growing season, and limiting yields potential (Adejuwon, 2004). Extreme climatic events are multiplying in many regions (Debray, 2015), affecting agricultural production and access to food complicated by rising populations. The Agricultural sector's vulnerability is accentuated by existing challenges for development such as poverty and governance as well as limited access to capital.

In Nigeria, agriculture is the main source of food and an important employer of labour (about 60% engaged in agriculture) (Mayong et al. 2005). Since agriculture in Nigeria is mostly rain-fed, it follows therefore that any climate change is bound to impact crops and livestock productivity with consequences on the economic activities of the producers. The impact of climate change could be measured in terms of effects on crop growth and yield, availability of soil water, contribution to soil erosion, incidents of crops pest and diseases, and decrease in soil fertility (Adejuwon., 2004).

Studies have revealed that farming and pastoral populations are adapting to changing climates, thus their ability to sustain crop yields notwithstanding the negative effects on land and water quality and availability. This is an indication that the people had developed coping strategies to adapt and reduce their vulnerability (Nelson et al., 2009). For example, in a study of farmers in the northern part of Katsina, Abaje, et al., (2014) identified several coping strategies adopted by smallholder farmers in adapting to changing climatic conditions. Umar and Musa (2014), investigated the constraints hindering effective use of indigenous coping strategies among smallholder farmers, and were able to measure the resilience of irrigation farmers against climate change, which enhanced food security for the smallholder farmers in parts of Katsina State. The Southern Savannah zones of Katsina State are among the most densely populated rural areas in Northern Nigeria, with agriculture being the dominant socio-economic activity. Although several studies on climate change have been conducted in the area, the focus was mainly on the external practices by farmers and pastoralists to sustain production in the face of climate change. The studies did not explore the potential ability of the environmental system to self-regulate, as well as its resilience in the face of climate change. In this study, the Self-evaluation and holistic assessment of climate resilience of farmers and Pastoralists (SHARP) tool were adapted to study the resilience of farmers and pastoralists to climate change. SHARP was a research and analytical framework developed by the Food and Agricultural Organisation (FAO) to address the need to better understand and incorporate the situation, concerns, and interests of farmers and pastoralists relating to climate resilience and agriculture. Being a comprehensive tool of assessment, SHARP provides a holistic framework for data collection covering all aspects of production and environment as well as the social and economic variables within the target communities or project intervention sites. Due to the complexity and multiplicity of data requirements for holistic assessment, this study focused on investigating the environmental resilience of farmers and pastoralists.

RESEARCH QUESTIONS

STUDY AREA

The study is carried out in the southern Savanna zone of Katsina State, covering areas of Funtua, Bakori, and Danja local government's areas of Katsina state.

Based on the framework of SHARP for assessment of the resilience of farmers and pastoralists, the following research questions were raised to determine the environmental resilience within the Southern Savannah areas of Katsina State:

a. How accessible are farmers and pastoralists to environmental resources in the study area?

b. What are the land management practices adopted by farmers and pastoralists in the study area?

c. What are the effects of climate change on farmers and pastoralists in the study area?

d. What is the environmental resilience of farmers and pastoralists in the study area?

AIM AND OBJECTIVES

This research aims to assess the environmental resilience of farmers and pastoralists to climate variability and change. To achieve this aim, the objectives are to;

i. Examine the accessibility of farmers and pastoralists to environmental resources in the study area.
ii. examine the land management practices of farmers and pastoralists in the study area
iii. examine the impacts of climate variability and change on farmers and pastoralists in the study area
iv. Assess the environmental resilience of farmers and pastoralists in the study area.

Location and Size

The study area is located approximately between latitudes 11°15'N and 11°50'N and longitudes 7°10'E and 7°45'E. This area falls within the southern savanna zone of Katsina state. The area is bounded to the north by Kankara, Malumfashi, and Kafur local government areas, to the east and south by Kaduna state, to the west by Faskari and Dandume local governments respectively.

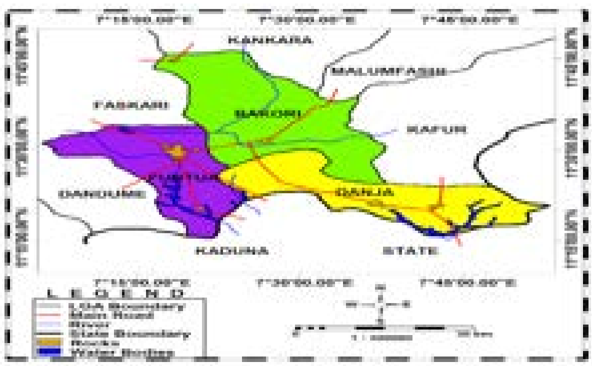

Fig 1.1 Funtua, Bakori, and Danja Local Government Areas (Source: GIS Lab, Geography Dept. BUK)

The Southern Savanna Zone of Katsina

This area covers the relatively wet southern parts of Katsina State, Nigeria. The local government areas include; Bakori, Dandume, Danja, Faskari, Funtua, musawa, Kafur, Kankara, Malunfashi and Sabuwa. It is located within Latitude11º 05´ north of the Equator and Longitude 7º 08´ east of the Greenwich Meridian. The study area is bounded in the north by Dan-Musa and Matazu local government areas, in the east by Kano State, in the west by Zamfara State, and in the south by Kaduna State. The area falls within the Sudan savanna type of vegetation (Adefila., 2014).

Climate

The area is characterized under the tropical climate zone of Nigeria with two main seasons; a rainy season which is from April to October and dry seasons (or Harmattan) for the remaining periods which is typical of northern Nigeria, and which is characterized by sharp regional variances depending on rainfall (Babsal and Co.,1998). Generally, the seasons are moved by the movement of the Inter-Tropical Air Mass or Inter-Tropical Convergence Zone (ITCZ) A zone where dry and often dust-carrying air from the Northern Hemisphere, known locally as harmattan collides with moist air from the southern Hemisphere or Atlantic ocean. The study area receives an average precipitation of 1,200 mm per year (Kankara, 2002). The dry season is marked by low humidity and has Harmattan wind that blows from Sahara. The mean monthly temperature is high reading 28.8°c in April and the lowest is 21.7°c in December. The area enjoys some four months of rainfall and has some eight months of dryness. Also, the relative humidity is always low about 40% in January and rises to about 60% in July (Odunze, 2006).

Physiography

The area generally falls under the high plains of Hausa highlands with gently rolling terrain. The highest places are due to gneisses and porphyroblastic granites which form a saddleback at the west. The lowlands are underlain by the more easily weathered quartz feldspar-biotite, Schist, and Serpentinite of the Basement complex. The gently undulating peneplain surface consists of an extensive superficial cover that rises to an altitude of between 570m and 600 m above mean sea level (Kankara 2014).

Soil and Vegetation

The Soils are largely clayey soils (locally called *"Laka"*) and about five meters in-depth, and fine in texture. The soil type in the area and the whole of Southern Katsina has been described as the most fertile land of the

Katsina area (Tukur 2009). Most of the soil is formed by alluvial material that is fairly rich in nutrients and has the capacity of retaining moisture for quite some time. This good moisture retention sometimes persists up to the dry season. The fertility of the soil in this zone makes agricultural production of cash crops such as sugar cane, cotton, tobacco, and pepper possible. The area is very popular in the production of food crops such as guinea corn, millet, rice, maize, beans, and groundnut (Tukur 2009).

The vegetation of the area is the savanna type of vegetation, influenced by the amount of rainfall received in the area and the relative humidity. It is predominantly woodland, characterized by short grasses and stunted trees that are scattered. The tallest trees in the area are the silk-cotton trees with a height of about 30ft. some of the typical food and economic trees in the area are the locust beans (*Dorawa*), shea nut (*Butyrospermum parkii*), Baobab (*Adansonia digitata)*, Tamarind (*Tamarindus indica*), Ebony (*Diospyros ebenum*), and Mahogany *(Swietenia macrophylla)*. Other species include the Neem tree (*Azadirachta indica*), African locust bean (*Parkia biglobosa)*, Mango (*Mangifera indica*), and Palm (*Arecaceae*) which are mostly exotic trees (Tukur 2009).

Land use and Population

Land use involves the management and modification of natural environment or wilderness into built environment such as settlements and semi-natural habitats such as arable fields, pastures, and managed woods (Abdulkadir, 2011). The major land use in built-up areas includes educational, health, and socioeconomic facilities like; games/sport viewing centers and shops, agricultural land use which encompasses both cultivated, irrigated lands and grazing lands, water Bodies which include Rivers and Streams (Tukur 2009). The area is drained by rivers Yagana and Ubangida which were dammed as lake Gwaigwaye and Mairuwa respectively. Transportation is another land use in this area. The transport systems include roads and rail with other minor roads and footpaths. Range lands are other land use of the area According to 2006 the area has a total population of 1337389 people (Tukur 2009).

The predominant tribes in this area are the Hausas' and Fulanis', as such the major agricultural activities are crops cultivation and livestock rearing. The Hausa's are being more into crop cultivation, while livestock grazing is done almost exclusively by the Fulanis who kept livestock for both themselves and on behalf of the Hausas. The Fulani's are primarily settled or semi-settled cattle herders with little engagement in crop cultivation.

MATERIALS AND METHODS

Sampling Procedure

The study area is purposively selected from the relatively wet southern parts of Katsina state as was attested by Adefila (2014). The research adopts the multi-stage sampling technique because of the unavailability of the exhaustive list of farmers and pastoralists in the study area. It is the characteristics of the multi-stage sampling method that when there is no exhaustive list of sample elements or good sampling frame for a dispersed population, then multi-stage sampling technique is appropriate (Neuman, 2004).

Stage one involved dividing the local governments into political wards level and randomly selecting two wards from each local government by applying a simple random sampling method. Stage two involved dividing the political wards into settlements and purposively selecting two settlements each of the farmers and pastoralists, giving a total of six (6) settlements for farmers and six (6) for pastoralists. Stage three involved the random selection of ten households from each settlement of farmers and pastoralists and interviewing three respondents from each household selected. This gives a total of 120 households from all three local government areas with each having 40 households, and a total of 360 respondents.

INSTRUMENT OF DATA COLLECTION

The instruments of data collection for this research work are the questionnaire and kobotool box. The kobotool box is an android based application that allows preparing a digitally programmed questionnaire, facilitates intense monitoring of the collection process, and gathering of data immediately after the survey in a format prepared for analysis.

Questionnaire

A structured questionnaire was designed comprising of closed-ended questions. The questionnaire elicited information on access to environmental resources and sufficiency, land management practices, and weather elements variation within the time frame of 10 years (2007 to 2016), among others. The questionnaire was uploaded onto an Android-supported Open Data Kit (ODK) software for ease of on-field digital data collection.

Methods of data collection

Six (6) field assistants were engaged to conduct field data collection using the **kobotool box** installed on mobile phones. To ensure quality data collection, the Research Assistants were trained for three days on how to collect data using the **kobotool box.** The respondents were asked questions from the tool and their responses is typed on the tool.

Data analysis

Descriptive and inferential statistics were employed for data analysis. Data for objectives A, B, and C were analyzed using descriptive statistics of percentages and frequencies, and results were presented using graphical statistical representations. For inferential statistics, correlation analysis is employed to analyze Data for objective D and represented using a spider diagram to determine the environmental resilience of farmers and pastoralists in the study area. The spider diagram enables the visual comparison of the components of the environmental resilience indicator. It was adopted from UNDP (2014).

RESULTS AND DISCUSSIONS

The information collected from the questionnaire survey was analyzed and presented in the following sections.

1. SOCIO-ECONOMIC CHARACTERISTICS OF RESPONDENTS

Table 1: Socioeconomic Characteristics of the Sampled Household

Variable	Category	Frequency	Percentage
Gender	Male	337	93.61
	Female	23	6.39
Age group	31+	209	58.06
	26-30	100	27.78
	21-25	46	12.78
	16-20	4	1.11
	0-15	1	0.28
Level of education	Qur'anic school	226	62.78
	Secondary school	68	18.89
	Tertiary institution	39	10.83
	Primary school	21	5.83
	No education	6	1.67
Household size	**Category**	**Frequency**	**Percentage**
Farmers	0-4	13	3.49
	5-9	54	14.92
	10-14	90	25.08
	15-19	11	3.17
	20+	5	1.27
	0-4	19	5.40
Pastoralists	5-9	74	20.63
	10-14	30	8.25
	15-19	9	2.54
	20+	8	2.22
Other (agro-pastoralists)	0-4	5	1.38
	5-9	19	5.27
	10-14	11	3.05
	15-19	8	2.22
	20+	4	1.11
Farming system practiced	**Category**	**Frequency**	**Percentage**
Farmers	Wet season cropping	134	37.22
	Irrigation farming	55	15.27
	Both systems	26	7.22
Pastoralists	Wet season cropping	19	5.27
	Irrigation farming	6	1.66
	Both systems	8	2.22
other (agro-pastoralists)	wet season cropping	52	14.44
	irrigation farming	32	8.88

(Source: *field survey 2017)*

The socio-economic information collected from the household survey includes gender, age, household size, level of education, dominant agricultural practices. The result is presented in table 1 Majority (93.61%) of the respondents are male, while (6.39%) are female. The large proportion of male respondents cannot be unrelated to the fact that cultural and religious values in this part of the country limit most women from engaging in farming and other related activities. This is in line with the study of Kiyawa (2016).

In terms of age distribution majority (58.06%) of the respondents are within the age range of 31 and above, followed by 27.78% with the range of 36-30 years). This indicates that the majority of the respondents fall within the economically active population that is industrious and productive, who will be able to speak on issues of the environment. This was agreed by Ahmad (2016).

The table also shows that the majority of the respondents (62.78%) have quranic education, 18.89% have secondary school certificates, 10.83% have tertiary institutions certificates, 5.83% are primary school leavers and only 1.67% are without any form of education. This turn out of respondents' level of education, with quranic education having the highest percentage, cannot be unconnected to the fact that the predominant religion in this part of the country is Islam and the prevalence of Islamic teaching schools in the rural communities. The positive turnout of western education cannot be unconnected with the establishment of universal basic education, which resulted in the establishment of many primary and junior secondary schools in rural communities.

Accessibility of Farmers and Pastoralists to Environmental Resources

The analysis below shows the access of farmers and pastoralists to their environmental resources of water, land, and energy.

2. Access to Household Water Sources

Table 2, shows that about 20.55% of farmers get their water for domestic use from hand-dug wells, and 17.31% of pastoralists and 4.93% of agro-pastoralists get their water for their daily use from hand-dug wells. The wells are found within the households that is to say every house has a well in their homes, 15.38% of farmers access tube wells, 11.66% of pastoralists also accessed tube wells, and 2.88% of agro-pastoralists access these tube wells. the tube wells are mostly found in a strategic location within the settlements of these farmers and pastoralists as a project from the government to make water available in these farmers and pastoralists' settlements. while 9.38% and 2.64% of farmers accessed rivers and dams, then 10.34% and 1.2% of pastoralists accessed rivers and dams respectively. While 3.13% and 0.6% of agro-pastoralists accessed rivers and dams. It can be deduced that the majority of the respondent depends heavily on hand-dug wells. The high proportion of farmers and pastoralists' access to rivers and dams cannot be unconnected to the fact that most of the farmers practiced irrigation farming along the rivers and dams while the pastoralists took their animals for water.

Table2: Household Water Sources Accessed by Farmers and Pastoralists

Respondent	Source of water	Frequency	Percentage
Farmers	Wells	74	20.55
	Tube wells	55	15.38
	Rivers	34	9.38
	Dam	10	2.64
Pastoralists	Wells	62	17.31
	Tube wells	42	11.66
	Rivers	37	10.34
	Dam	4	1.2
Other (agro-pastoralists)	Wells	18	4.93
	Tube wells	10	2.88
	Rivers	11	3.13
	Dam	2	0.6
Total		360	100

Source: Field work, 2017

3. Households Water Sufficiency

The results from fig 2; indicate that about 13.17% of pastoralists reported average sufficiency of water, 18.77% of farmers reported complete sufficiency of water and about 8.96% of agro-pastoralists reported complete sufficiency of water. This is because most of these farmers and pastoralists have their sources of water within their households, which are mostly wells and tube wells, the wells are found within households that is to say a majority of the households have their well in their homes, while the tube wells are mostly found in a strategic location within the settlements of these farmers and pastoralists as a project from the government to make water available in these farmers and pastoralists settlements. This was supported by Amina (2015), as she said "the areas of Southern Katsina state are less vulnerable to water scarcity due to the higher level of rainfall in the area when compared to the drier parts of the State

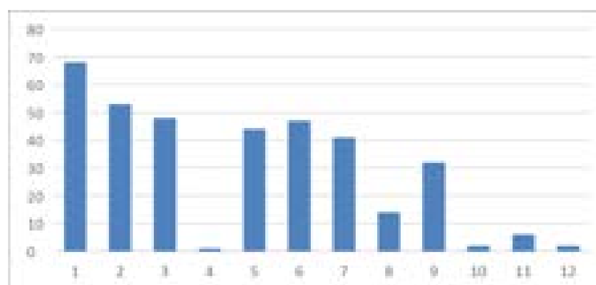

figure 2 Household Water Sufficiency (Source: *Fieldwork, 2017)*

4. Accessibility of farm/range-lands to farmer's households and pastoral livestock subsistence

According to this study, the accessibility here is the ability of the farm and rangelands to provide the needed yields for farmer's household subsistence and the available pastures for the subsistence of pastoral livestock Cabel and Oleofse (2013).

From table 3 below, 23.3% of the farmers' respondents report a lot of accessibility, the same applied to pastoralists and agro-pastoralists as can be seen below, this is followed by 8.6% farmers and 5.3% pastoralists, who reported complete accessibility to their farm and rangelands, while 6.5% farmers, 5.5% pastoralists, and 2.0% agro-pastoralists reported average accessibility to their farms and rangelands. 9.0% farmers, 2.7% pastoralists, and 1.2 % agro-pastoralists reported little access. While 0.8% farmers,1.6% pastoralists, and 0.8% agro-pastoralists testified their farms and rangelands accessibility is at all not sustaining their households and pastoral livestock.

From these results, it can be deduced that the majority of farmers in this area appreciate the yields of their crops as it sustained their households, this further indicates a typically rural households majorly depend on crops/livestock rearing for their livelihoods, but use the majority of their products for home consumption (subsistence-oriented farmers/pastoralists), (Ahmad,2015). The result further indicates the dependency of farmers and pastoralists on their environmental resources, indicating the pressure by farmers and pastoralists on their farms/ rangelands for their households and livestock subsistence. This shows a feature of a resilient system having a functional diversity, which refers to the variety of elements and the ecosystem services they provide within the ecological system (Altieri 1999, Swift et al. 2004, Moonen and Barberi 2008).

Table 3. Accessibility of Farm/Range-Lands to Farmers Households and Pastoral Livestock Subsistence

Respondent	**Response**	**Frequency**	**Percentage**
Farmers	alot	84	23.3
	completely	31	8.6
	not at all	3	0.8
	average	23	6.5
	a little	32	9.0
Pastoralists	alot	71	19.6
	completely	19	5.3
	not at all	6	1.6
	average	20	5.5
	a little	10	2.7
Other (agro-pastoralists)	alot	27	7.4
	completely	21	5.7
	not at all	3	0.8
	average	7	2.0
	a little	4	1.2
Total		**360**	**100**

Source: *Field work, 2017*

5 Factors limiting Access to Farmlands and range-lands.

From table 4, a majority of the respondents 19.1% and 18.3% farmers responded that inadequate fertilizer, inadequate income, and weed invasion respectively are major factors limiting their access to farmlands. While 8.9% and 7.0% pastoralists reported government policies on grazing, invasion by farmers, and pest invasion respectively are major factors limiting access to their rangelands. This reveals that farmers access to their farmlands is limited by majorly inadequate fertilizer and income while pastoralists access to their rangelands is limited or hindered majorly by farmers invasion, government policies on grazing, and pest invasion is agreed on by Sulaiman (2017) and Ayanda (2013) as they observed that farmers land productivity is dependent on majorly fertilizer application, while Kim (2015) disagreed with the fact that pastoralists are limited due to government policies and invasion by farmers and further observed that irregular rainfall pattern affects the availability of pasture which limit access to range lands causing pastoralists to migrate down south.

Table 4: Factors Limiting Access to Farm/Range Lands

Respondent	Response	Frequency	Percentage (%)
Farmers	Inadequate fertilizer	69	19.1
	inadequate income	66	18.3
	government policies on grazing	19	5.3
	pest invasion	17	4.6
	weed invasion	25	6.9
Pastoralists	Inadequate fertilizer	4	1.1
	inadequate income	11	3.05
	invasion by farmers	25	7.0
	government policies on grazing	32	8.9
	pest invasion	16	4.4
	weed invasion	9	2.5
Other (agro-pastoralists)	Inadequate fertilizer	14	4.0
	inadequate income	12	3.2
	invasion by farmers	10	2.9
	government policies on grazing	12	3.4
	pest invasion	9	2.5
	weed invasion	10	2.7
Total		**360**	**100**

Source: *Field work, 2017*

6 Adapted Land Management Practices

The analysis below shows the adapted land management practices of farmers and pastoralists in the study area to sustain their environmental resilience to climate changes.

7 Use of Leguminous Plants

According to Rajeev (2013) "Legumes are grown agriculturally, primarily for human consumption, for livestock forage and silage, and as soil-enhancing manure". From table 5, the result shows that 57.22%, 10.98%, and 14.72% farmers pastoralists and agro-pastoralists respectively reported the use of leguminous crops on their farms and rangelands, 9.72% of farmers and 6.27% pastoralists, responded to poor use of leguminous plants on their farms and rangelands. The result indicates that farmers and pastoralists use environmentally friendly means of managing their farms and rangelands. The use of legumes has a wide scope for restoring extreme soil loss and soil nutrients loss (Ibrahim and Lawal 2013). This will reduce the rate of inorganic fertilizer application that sometimes increase the rate of land degradation (Lawal 2017) From the high percentage of pastoralists response (10.98%), indicates that any short time recedes of forage for their livestock can be alleviated by supplementation through extending the grazing season by including leguminous crops in range management, this is agreed by FAO (2009).

Table 5: Use Of Leguminous Plants

Respondent	Response	Frequency	Percentage (%)
Farmers	% of farmers that have leguminous crops on their farms.	206	57.22
	% of farmers that do not have leguminous crops on their farms.	35	9.72
Pastoralists	% of pastoralists that have leguminous crops on their rangelands.	23	6.27
	% of pastoralists that do not have leguminous crops on their rangelands.	40	10.98
Other (agro-	% of agro-	54	14.9

pastoralists)	pastoralists that have leguminous crops on their farms.		
	% of agro-pastoralists that do not have leguminous crops on their farms.	3	0.78
Total		**360**	**100**

Source: *Field survey, 2017*

8 USE OF FERTILIZER

As shown in table 6, 35.55% of farmers, 3.33% pastoralists, and 20.55% agro-pastoralists report using synthetic or inorganic fertilizer on their farms and rangelands. While 20.83% of farmers, 4.16% pastoralists, and 10.55% agro-pastoralists respond to using organic fertilizer on their farms and rangelands. This indicates that the respondent depends highly on inorganic fertilizer for their farms/rangelands yields. The low use of organic fertilizer cannot be unconnected with their access to this type of fertilizer as every rural household keeps organic fertilizer for their usage. It can also be seen that farmers and agro-pastoralists use organic fertilizer more than pastoralists, thus, this can be due to their dominant crop cultivation. The results further indicate an average use of both organic and inorganic fertilizers, with inorganic being the most important source of nutrients as supported by Kabir, Sultan, &Attia (2015). The result shows that the environment requires less external inputs for farms and rangelands productivity. The use of fertilizer/animals dung to improve crop yield is a sustainable adaptation strategy (Abaje, Sawa, & Ati, 2014). Thus, a sustainable adaptation strategy enhances environmental resilience (Carpenter et al, 2001).

Respondent	**Response**	**Frequency**	**Percentage (%)**
Farmers	Synthetic fertilizer	128	35.55
	Organic or natural fertilizer	84	23.33
Pastoralists	Synthetic fertilizer	12	3.33
	Organic or natural fertilizer	15	4.16
Other (agro-pastoralists)	Synthetic fertilizer	74	20.55
	Organic or	47	13.05

	natural fertilizer.		
Total		**360**	**100**

Table 6 : Use of fertilizer Source: *Field work, 2017*

9 Agroforestry practice

Respondent	**Response**	**Frequency**	**Percentage (%)**
Farmers	Assisted natural regeneration	139	38.55
	tree planting	20	5.62
Pastoralists	Assisted natural regeneration	65	18.07
	tree planting	62	17.27
Other (agro-pastoralists)	Assisted natural regeneration	46	13.65
	tree planting	25	6.83
Total		**360**	**100**

Table 7: Agroforestry practice

Source: *Fieldwork 2017*

Agroforestry is a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels. By nurturing trees on their farms, pastures, and homesteads farmers have been managing agroforestry systems for millennia (ICRAF 2006). From table 7, it shows 38.55% of farmers, 18.07% pastoralists, and 13.65% agro-pastoralists reported practicing assisted natural regeneration as a form of agroforestry

While 5.62% farmers, 17.27% pastoralists, and 6.83% agro-pastoralists attested to practicing tree planting. The result indicates that farmers and pastoralists in the area practiced assisted natural regeneration on their farms and rangelands which is the maintenance of these trees on their farm/range, this is a natural conservation practice Koffa and Garrity, (2001). The practice of agroforestry enhances the functions of environmental diversity (Dangasuk et al., 2001).

10 Use of Cover Crops

According to Kaspar and Singer (2011), cover crops are used to manage soils for many different reasons and are known by many different names. Cover crops are literally "crops that cover the soil" and one of their first uses was to reduce soil erosion during fallow periods in annual cropping systems. Cover crops are also known as "green manures," "catch crops," or "living mulch." Green manure cover crops are usually legumes that fix N and are grown to provide N to crops. Catch crops are cover crops that are grown during fallow periods in cropping systems to take up nutrients, especially N, that would be lost if plants are not present. From table 8, 25.86% of farmers, 19.83% pastoralists, and 13.36% agro-pastoralists reported that they use cover crops on their farms/rangelands often. The use of cover crops by pastoralists cannot be unconnected with their need for the continuous supply of forages for their livestock feeds.

This was disagreed by Kim (2016) as he said that pastoralists use cover crops on their rangeland as a coping strategy to climate variability and change. The use of cover crops by farmers cannot be unconnected with the need to prevent soil degradation such as erosion and desiccation (Kabir, Sultan, & Attia 2015).

Table 8: Use of Cover Crops

Respondent	**Response**	**Frequency**	**Percentage**
Farmers	A lot	93	25.86
	Average	76	21.12
	Completely	20	5.6
	Not at all	9	2.59
	A little	6	1.72
Pastoralists	A lot	71	19.83
	Average	12	3.45
	Completely	2	0.43
	Not at all	6	1.72
	A little	2	0.43
Other (agro-pastoralists)	A lot	48	13.36
	Average	5	1.29
	Completely	6	1.72
	Not at all	0	0
	A little	3	0.86
Total		**360**	**100**

Source: *Field work, 2017*

11. Soil Fertility Status

From table 9, 23.05% farmers, 15.55% pastoralists, and 11.66% agro-pastoralists reported an average soil fertility status. While 6.94% farmers, 13.05% pastoralists, and 4.17% agro-pastoralists reported having a little soil fertility, while 5.27%, 1.94% & 4.44% farmers, pastoralists, and agro-pastoralists reported having a lot of infertility status of the soil. This result indicates the soil is averagely fertile and requires respondents' inputs. It also shows the need to devise an improved method of land management strategies for increasing productivity, as was agreed by Lawal and Yahaya (2018). the complete fertility status of the soil as reported by 2.77% pastoralists and 3.06% agro-pastoralists cannot be unconnected with the availability of pasture for their animals, as was disagreed by Kim (2016) as he reported that pastoralists face a shortage in forage availability and quantity in Katsina.

Table 9: Fertility State of the Soil

Respondent	Response	Frequency	Percentage (%)
Farmers	Average	83	23.05
	A Little	25	6.94
	Not At All	9	2.50
	A Lot	19	5.27
	Completely	6	1.66
Pastoralists	Average	56	15.55
	A Little	47	13.05
	Not At All	6	1.66
	A Lot	7	1.94
	Completely	10	2.77
Other (agro-pastoralists)	Average	42	11.66
	A Little	15	4.17
	Not At All	8	2.22
	A Lot	16	4.44
	Completely	11	3.06
Total		**360**	**100**

Source: *Field work, 2017*

12 Impacts of Climate Changes on farmers and pastoralists communities

Although the impacts of climate change can be socio-economic or climatic impacts Ahmad (2015), table 10 below presented the climatic impacts of climate variability and change. Climatic impacts are those impacts that are mostly the consequences of change in climate and weather conditions and to a very large extent anthropogenic activities (Ahmad 2015). from the table; 16.66% of farmers reported a decrease in soil fertility as the major impact of climate change, while 11.94% pastoralists who are the majority reported a decline in forest resources as a major impact of climate variability and change, and 5.00% agro-pastoralists also reported a decrease in soil fertility. This response by farmers' pastoralists and agro-pastoralists cannot be unconnected with their livelihood option. This also indicates the major impact of climate change on the livelihood options of farmers and pastoralists in the area. This is in line with the study of Abaje, Sawa, & Ati, (2014) as they observed that decrease in soil fertility and a decline in forest resources significantly impact climate variability and change as perceived by farmers in Katsina. The second major impact of climate change as reported by farmers is 14.72% is a decline in forest resources, while 9.17% and 4.17% of pastoralists and agro-pastoralists reported a decrease in grazing land. This cannot be unconnected with their livelihood options. The decline in forest resources and decrease in grazing in the area cannot be unconnected with deforestation, encroachment, and bush burning. This results in aggravating the impacts of climate variability and change which in turn will lead to the disappearance of trees species not adaptable to the environmental changes which according to Luck et al. (2003), Carpenter et al. (2006), and Peterson (2009) will affect the environmental regeneration. As cited by Gunderson and Holling (2002) and Folke (2006), the capacity of the environment to regenerate naturally is a major factor common to a resilient environment.

Table 10: Impacts of Climate Changes

Respondent	**Response**	**Frequency**	**Percentage (%)**
Farmers	Decline in forest resource	53	14.72
	decrease in soil fertility	60	16.66
	Decrease in grazing land	5	1.38
	Increase in animal pest and disease infestation	18	5.00
	Increase in death of livestock	12	3.33
Pastoralists	Decline in forest resource	43	11.94
	decrease in soil fertility	16	4.44
	Decrease in grazing land	33	9.17
	Increase in animal pest and disease infestation	27	7.50
	Increase in death of livestock	26	7.22
Other (agro-pastoralists)	Decline in forest resource	14	3.88
	decrease in soil fertility	18	5.00
	Decrease in grazing land	15	4.17
	Increase in animal pest and disease infestation	13	3.61
	Increase in death of livestock	7	1.94
Total		**360**	**100**

Source: *Field work, 2017*

13 Determination of Environmental Resilience Index

From table 11 and Figure 3; The correlation of the environmental indicator components to determine the environmental resilience index of the study area indicates that, in terms of water access and sufficiency, the environment provides farmers and pastoralists with sufficient water access for their households, crops and animals productions. This shows that the majority of the respondents have sufficient access to water throughout the season. This can be due to the amount of rainfall received in the area of southern katsina as testified by Amina (2015). The result also shows a significant relationship between water access and sufficiency. This is disagreed by the study of Ladan and Sule (2017), as they observed that during the dry season, irrigation farmers in Bakori local government area dug too deep to reach the water table to access water for their crops. The table also indicates a significant relationship between access to land and factors that limits it with the least resilient index of 0.031. This cannot be unconnected with the fact that although the land is accessible through the significant yields of crops and support of livestock pasture. The land access is also limited by several factors as mentioned in table 4 above, external inputs as major factors limiting access to land thus showing that without these inputs, the land accessibility is limited reducing its resilient capacity. In terms of weather elements variations and climate change impacts, it also indicates significantly how these changes affect the environment through its impacts as shown in table 10, where the decline in forest resources and decrease in grazing area quality are the major impacts affecting farmers and pastoralists in the area. The results further indicate an average resilient of the environment to these impacts. This cannot be unconnected to the fact that respondents reported having access from the environment upon these impacts on the environmental resources.

Table 11: Determination of Environmental Resilience Index

WAS	0.916***
ALFL	0.031*
SFLMP	0.618***
WEV&CCI	0.667***

Source: Data Analysis, 2017
Scale: **0.031-0.36 =least resilient*, 0.36-0.69=averagely Resilient***, 0.69&above=completely resilient**** > 0.031= not resilient**

WAS: Water access and Sufficiency; ALFL: Access to land and factors that limit it; SFS&LMP: Soil fertility and Land management practices; WEV&CCI: Weather element changes and climate change impacts

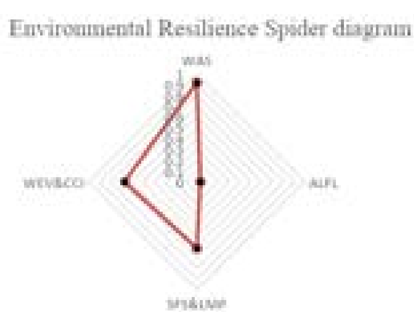

Fig.3, Spider Diagram Showing Areas of Resilience

Conclusion

The study reveals that the impact of climate variability and change on the environment is on the increase as highlighted by the decline in forest resources, decrease in soil fertility, decrease in grazing land, increase in animal pests and diseases. Although farmers and pastoralists are aware of climate variability and change and have their strategies to manage their farms/rangelands productivity, which are the use of leguminous plants, use of fertilizer, agroforestry practices, use of cover crops, and weed management practices as their buffer capacity to sustain their environmental productivity. Thus, the impacts of climate variability and change are affecting the environment as it shows the least resilient status in terms of access to land due to a decrease in soil fertility status.

Recommendations

The recommendations drawn will establish areas where intervention is needed to sustain the livelihood of farmers and pastoralists in the face of major climate stresses. They will also help to conserve the natural environment. These recommendations are;

1. Livestock, and viable land Farmers and pastoralists should be enlightened on management practices ideas to improve their buffer capacity and influence environmental resilience.
2. Invest to generate and disseminate in understandable format client-oriented climate information to help farmers and pastoralists make informed decisions on their management practices. This should be accompanied by relevant extension services e.g. on crops, management adaptation strategies.

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THERMAL EFFECTS ON ZOOPLANKTON DIVERSITY AND DISTRIBUTION OF RIVER RIMA, SOKOTO NIGERIA.

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Abstract: Temperature is one of those physicochemical parameters that affect zooplankton dynamics, including their distribution and abundance. Changes in temperature in aquatic ecosystems usually affect the metabolic reactions in their body. Though, their distribution signifies the status of such a water body. This study was carried out to evaluate the effects of temperature on the zooplankton distribution of River Rima. Zooplankton samples were collected from three sampling points designed for the study. Samples of both Zooplankton and water were collected in the morning and afternoon. Standard methods were used during the sample collection. Zooplankton samples were identified using standard identification keys and water physicochemical parameters were measured *in situ* and others in the laboratory. Results reveal that four groups of zooplankton are available in River Rima, represented by 25 species. The two dominant groups were; Cladocera (72%) and Crustacea (16%). Results also indicated a low distribution of zooplankton at temperature =>31.6^{0}C and the least temperature recorded was 29.8^{0}C, which has more distribution of these zooplanktons. Therefore, to study these zooplankton species, a low daytime temperature should be targeted.

Keywords: Dynamics, physicochemical, Rima, Zooplankton

1. INTRODUCTION

Zooplanktons are microscopic organisms that are suspended in water, they include many kinds of protozoans, micro-crustaceans, and other micro invertebrates that are planktonic in water bodies (Omudu and Odeh, 2006). These are heterotrophic planktonic animals that constitute an important food source for many species of the aquatic organism (Guy, 1992). They may serve as an indicator of water quality. Zooplanktons are heterotrophic planktonic animals floating in the water which constitute an important food source for many species of aquatic organisms (Guy, 1992). Cyclopoida, Ostracoda, and Cladocera are very important in the food chain of freshwater fish (Egborge, 1981). Their characteristics, coupled with high sensitivity to changes in environmental factors have drawn the attention of several hydrobiologists worldwide, who had investigated their occurrence composition, distribution, and their significant roles in the study of aquatic pollution. Zooplankton studies are of necessity in fisheries, aquaculture, and paleolimnological research as they have been known to leave an impression record of geological past (Stout, 1974; Aoyagui and Bonecker, 2004). They are globally recognized as pollution indicator organisms in the aquatic environment (Rutherford *et al*., 1999; Yakubu *et al*., 2000; Abowei and Sikoki, 2005).

Most species in the zooplanktons community fall into three major groups; *Crustacea, Rotifers,* and *Protozoans*. *Crustaceans* are generally the most abundant, especially those in the order *Cladocera* (water fleas), and the class *Copepoda* (the *copepods*), particularly the orders *Calanoida* and *Cyclopoida. Cladocerans* are typically most abundant in freshwater, with common genera including *Daphnia* and *Bosmina.* Commonly observed genera of marine calanoid include *Calanus, Pseudocalanus,* and *Diaptomus*, while abundant cyclopoid copepods include *Cyclops* and *Mesocyclops* (Carter *et al.*, 1986). Other crustaceans among zooplankton include species of *opossum shrimps* (order Mysidacea), amphipods (order Amphipoda), and fairly shrimp (order Anostraca). Rotifers (phylum Rotifera) are also among the protozoans belonging to Kingdom Protista (Fredrich *et al*. 1996).

Thermal is the transfer of heat from one stage to another. Thermal energy is the energy that comes from heat. This heat is generated by the movement of organic particles within the water bodies. Thermal effects have serious threats on the life of living organisms in water (Anon, 2017).

Temperature can also have a greater influence on the migration and movement of zooplankton. Consequently, temperature affects the overall development of zooplankton (Alain, 2009).

Light and temperature, of course, affect zooplankton productivity, which in turn, exert its effects on the development of the zooplankton population (Green, 1994).

Generally, there is a wide range of temperatures within which zooplankton survive. The effects are vital to be accelerated by warm temperature and decelerated by cold ones. Though sudden changes or temperature extremes are lethal, the elevated sub-lethal temperature may include hibernation. Temperature can also determine the success of species of zooplankton as well as their distribution within the water body (Alain, 2009).

1.1 Effects of Temperature on Zooplankton

Temperature can be defined as the degree of hotness or coldness of an organism or an environment. It is usually measured in degrees Celsius (^{o}C). Temperature affects enzymes function, which affects how living things carry out everyday metabolic processes, such as the synthesis of protein and other chemical reactions. At low temperature, enzymes function is lower, but it is still working, but at a higher temperature, the enzymes bonds are destroyed and the enzymes are denatured, so it cannot carry out its function of catalyzing reaction anymore (Michael, 1999).

All metabolic rates of zooplanktons are dependent on temperature. Temperature affects both the physiology and ecology of zooplankton. The physiological effects include mortality at high or low temperatures, which is the most drastic physiological effect. Similar research was carried out on the effect of temperature on the heart rate of Daphnia which is by examining Daphnia at three different temperatures, 4^{o}C, 20^{o}C, and 30^{o}C. Daphnia also known as water fleas, are small crustaceans that live in freshwater. They serve as an important source of food for fish and other aquatic organisms. They respond quickly to a change in environment because they are such tiny organisms and are transparent, so it is easy to observe their heart rate. Daphnias are ectotherms and conformers. This is because their internal temperature varies according to external temperature. As Daphnia's metabolic rate increases, so do the heart rate to supply oxygen to the heart and body. As heart rate increases temperature will also increase because more reactions will take place (Pennak, 1989).

As the temperature increases, more ATP is produced for the contraction of the heart muscles. Temperature facilitates enzymatic reaction which causes cell respiration, which produces ATP, ATP is what is used for energy in the body and what controls the heart rate of Daphnia. As body temperature decreases, less ATP is produced through cellular respiration because they are fewer reactions, and the reactions that are occurring slow down. This means the heart rate of Daphnia will also be lower, meaning less oxygen to the body. As the temperature increases, so do the enzyme's reaction. This means an increased amount of ATP will be used. Therefore, more oxygen is needed which leads to greater production of carbon dioxide. This acts on the heart's rate to increase delivery (Pennak, 1989).

As the temperature increased, so did heart rate increase, when the temperature was $4^{\circ}C$, the average heart rate of Daphnia was 152.4 beats per minute and when the temperature was $20^{\circ}C$, the heartbeat of Daphnia was 224.0 beats per minute. And when the temperature was $30^{\circ}C$, the heart rate of Daphnia was 250.4 beats per minute. This indicates that the heart rate of Daphnia increase with an increase in temperature. This means that their internal temperature is influenced by their external environment and they do not thermoregulate like a mammal. They are, thermoconformers with little control over their body temperature. Therefore, as the temperature of the environment increases, the metabolism of Daphnia will increase as well because chemical reactions occur faster at a higher temperature. This means that the heart rate will speed up to provide oxygen to the cells as metabolism increases. However, when the external environment reaches a certain temperature (around $40^{\circ}C$), enzymes break down and chemical reactions can no longer occur, so metabolism stops and Daphnia dies (Campbell, 2002).

2. MATERIALS/METHODS

2.1 STUDY AREA

River Rima is located in the Northwestern region of Sokoto State Nigeria, the area is located between Longitude 4°E and 6° 54’E and Latitude 12° 0’ and 13° 54’N (Mamman, 2000*).* The rainy season is usually between May/June to early October/November (Umar and Ipinjolu, 2001). River Rima is the most important perennial river network in Sokoto. It’s one of the major tributaries of River Bunsuru and Gangare. The river takes its course from Katsina State flows through Zamfara State and in Sokoto State joins River Sokoto before flowing to River Niger in Kebbi State (Ita, 1993).

River Rima plays important role in the lives of the surrounding inhabitants, fishing, bathing, washing/laundry, car washing, industrial wastes disposal, and other human activities are constantly going on within and around the river (Ita *et al*., 1982).

Map of River rima (Kwalkwalawa) (source: Google earth map)

2.2 Sample Collection

Water samples were collected in 1-liter capacity plastic bottles between 7:00 am to 9:00 am, from all the sampling locations for the period of 3 months (April to July 2017). The three different stations on the river namely: sites A, B, and C. Each sample collected was analyzed for physicochemical variables. Temperature, depth, and transparency were determined *in situ.*

The zooplanktons were collected from the three different stations with standard plankton net (25µm mesh size) which was transferred to 1-liter capacity plastic bottles with 10% formalin for preservation before transporting it to parasitology laboratory for zooplankton identification.

2.3 Determination of physicochemical variables

Transparency of water samples was determined using Secchi disc of 25cm by disappearance and reappearance method. The transparency was computed according to UNEP (2004). The temperature was determined with a mercury thermometer, and depth was measured accordingly (Panday *et al*., 2005). The pH was determined using the JENWAY pH meter 3015 model at 25^{o}C. A flame photometer was used to determine Sodium and Potassium (UNEP, 2004). The ethylene diamine tetra-acetate acid (EDTA) method will be used to determine Calcium and Magnesium (UNEP, 2004). Other physicochemical variables such as BOD, phosphorus, Calcium, Nitrogen, and Total Dissolved Oxygen were measured according to United Nations Environment Programme (2004).

2.4 Identification of Zooplankton

The Zooplanktons were identified to species level and each was compared with the Zooplankton identification chart. 1ml of the sample was taken on the slide with a dropper and observed under the microscope. Identification chart of freshwater zooplankton (Altaff *et al*., 2004). The following are the specific volumes for identification of different groups of zooplankton Rotifers (Dhanapathi, 2003); Cladocerans (Michael and Murugan, 1988); Copepods (Reddy and Dussart, 1994), the species name was counted and recorded. The data were subjected to analysis of variance (ANOVA).

2.5 Determination of Physical Parameters

2.5.1 Transparency

A Secchi disc of 25cm diameter was used to determine the transparency, by lowering it into the water until it disappears from view, the measurement of which was recorded as P_1. The Secchi disc was pulled out and the depth of reappearance was measured and recorded as P_2. The transparency was computed using the following formula:

Transparency= P_1+P_2 Which was recorded in centimeters (UNEP, 2004).

2.5.2 Temperature

The water temperature was determined with a mercury thermometer, calibrated to the nearest 1^{o}C. The temperature was taken by lowering the thermometer into the surface water for two minutes to allow equilibrium before recording. After which the reading was taken and recorded in degree Celcius (Panday*et al*., 2005).

2.5.3 Depth

The depth of each station was determined with mushroom string or Secchi disc. In this method, the depth of each station was measured by dipping the spring until it settles down. The measurement was taken using a measuring tape or ruler and recorded in metres (Panday *et al*., 2005).

2.6 Determination of water chemical parameters

The water chemical parameters such as Biological oxygen demand (BOD), Dissolved Oxygen (DO), Electrical Conductivity (EC), $_{P}$H, Nitrate (NO_3^-), Phosphates (PO_4^{-3}), Magnesium, and Sodium was determined using standard methods and procedures.

3. RESULTS AND DISCUSSION

3.1 Diversity and Distribution of Zooplankton

In all the collections of the morning, afternoon, and evening samples, twenty-five (25) species were identified which are *Hesperocorixacastanea, Synpetrumflaveolum, Dytiscuslatissimus, Anopheles gambiae, Sialislutaria, Dolpilodesdistinctus, Ischnuraheterostica, Hygrobatidae, Acroneuriainternata, Daphina magna, Baetisniger, Isopteratermopsida, Bosminialongirostris, Narpusconcolor, Sternoceraaequisignata, Pternonarcyidae, Acroneurialycorias, Limnorialignorum, Misophrioida, Palaemonhastatus, Secernentea, Hirudo medicinalis* and *lumbriculidae.* Cladocereans are found to be the most abundant followed by crustaceans and then the lowest species were found to be annelids.

Table 1. Temperatures recorded in May- July 2017.

Months	STATION A			MEAN	STATION B			MEAN	STATION C			MEAN
	M	A	E		M	A	E		M	A	E	
May	30	33	31	31.33	28	35	31	31.33	32	33	32	32.33
June	28	30	32	30	29	32	31	30.66	30	33	32	31.66
July	27	29	30	28.66	29	30	31	30	30	31	32	31

The table above shows how temperature varies slightly from May with 31.5^{0} and June recorded 30.8^{0} while July recorded the least temperature of 29.8^{0}. The results also show temperature similarity from May to June and a decrease in July. During the rainy season (June and July), the temperature was more steady. This fluctuation was due to changes in the weather especially during the rainy season when cloud covers reduce the intensity of the solar radiation, which means limited light rays reach the water surface.

In terms of temperature variability in both morning, afternoon, and evening sampling, there is no significant difference between the sampling unit (A, B, and C) because the computed F for both morning, afternoon, and evening sampling were higher than the tabulated F, therefore, no significant differences between the sampling unit, and the result was valid since there weren't many differences between temperature recorded.

Table 2. Morphometric and physical variables of River Rima from May-July, 2017.

Variables	Station A	Station B	Station C
Latitude	13°06'15N	13°06'14N	13°06'14"N
Longitude	5'12'26°E	5'12'22"E	5'12'21"E
Depth	13.5	14	12
Temperature	32.33	31.6	31
Mean depth	4.3	3.9	3.4

The temperature of River Rima varied monthly as the weather changes according to season. The least temperature obtained was 31°C in July, and the maximum recorded was 32.3° at Station C. The measured temperature reveals monthly fluctuations with a rapid increase from Station A to B while a decrease in temperature was observed in station C. Depth of the river increases as water volume increases.

TABLE 3. Showing variation in Chemical parameters of water samples from May – June in River Rima, 2017.

Parameters	May	June	July
Ph	8.36±0.05	8.23±0.05	7.88±0.06
BOD (mg/l)	15.60±4.23	22.97±7.30	3.4±1.78
DO (mg/l)	15.60±4.23	11.14±9.73	16.23±2.94
Nitrate (mg/l)	1.07±0.12	1.4±0.35	1.47±0.76
Ammonia(mg/l)	0.73±0.12	1.07±0.23	1.07±0.23
Phosphate(mg/l)	0.26± 0.12	0.34±0.07	0.43±0.27
Phosphorus(mg/l)	11.33±1.15	2.53±0.38	2.53±0.38
Potassium (mg/l)	1.13±0.12	0.87±0.12	0.3±0.1
Sodium (mg/l)	0.47±0.12	0.43±0.06	0.3±0

The range of p.H was 7.88-8.4, the river is said to be more or less alkaline. July has 7.8 and the highest 8.3 which was obtained in May. The present findings are similar to that of Magami, *et al.*, (2013) who obtained a minimum of 6.4 and a maximum of 8.1 while assessing physicochemical flux and phytoplankton diversity in Shagari reservoirs. Hence, the recorded pH value is suitable for aquatic animals such as fish. BOD levels increase in June and decrease drastically in July while DO experience slight variation in May and July and decrease in June. Ammonia, phosphate, and Ammonia concentration fluctuate monthly as seen on the table. The monthly variations of these elements were results of significant seasonal and spatial variation in the weather and other human activities near the river such as irrigation, other farming activities.

Table 4 Showing Zooplankton species identified and their relative abundance in River Rima from May-July, 2017.

SPECIES	MAY Cells/l	JUNE Cells/l	JULY Cells/l	Abundance %
Cladocerans				
Hesperocorixa castanea	9	7	6	8.30
Sympetrum flaveolum	4	2	3	3.39
Dytiscus latissimus	7	2	1	3.77
Anopheles gambiae	40	6	3	18.49
Sialis lutaria	7			2.64
Dolopilodes distinctus	8	1		3.39
Ischnura heterosticta	2	1	3	2.26
Hygro batidae	1	2	1	1.51
Acroneuria internata	12	3		5.66
Daphina magna	4			1.51
Baetis niger	6	2	4	4.53
Isoptera termopsida	1	5	3	3.39
Notholea			1	0.38
Bosminia longirostris		2		0.75
Narpus concolor		2		0.75
Sternocera *aequisignata*	4		2	2.26
Pternonarcyidae			2	0.75
Acroneuria lycorias		2		0.75
Crustaceans				
Limnoria lignorum	11	1		4.15
Misophrioida	15	1		6.04
Hyperia macrocephala			2	0.75
Palaemon hastatus		2	3	1.88
Nematodes				
Secernentea	22	23	4	18.49
Annelida				

Hirudo medicinalis		2		0.75
Lumbriculidae		1		0.38
TOTAL	**153**	**78**	**34**	

From the results obtained in the monthly collection, May has the most abundant species of 153 which represents (55.61%) followed by June which has 88 and is represented by (32%) species and July has 34 species which is represented by (12.36%) respectively.

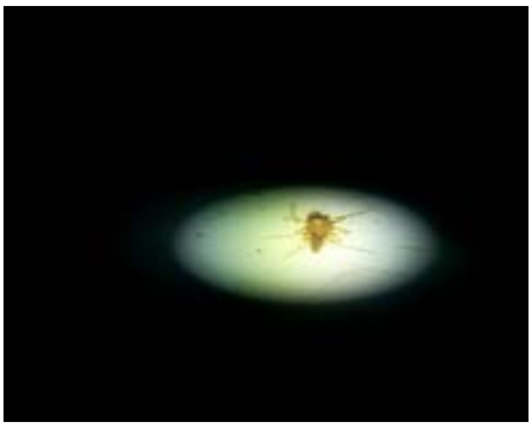

Plate.1 *Acroneuria internata*

Plate 2 *Isoptera termopsidae*

Plate3. *Secernentea*

4. DISCUSSION

In the present study, a total of 25 species of freshwater zooplankton are identified. The study revealed the presence of 18 species of cladocerans 4 species of crustacean, 1 species of nematodes, and 2 species. From the result obtained during the research work, it indicates that temperature recorded from the morning, afternoon, and evening sampling station, C station has the highest mean temperature of 32.3°C while station A has the lowest temperature recorded with 28.6°C.

Cladocera appears to have the highest abundance of zooplankton species identified, the second largest group was crustacean, the third group is annelida and the fourth or lowest group is nematode. The result obtained during this research shows similarity with that obtained by (Hashemzadeh and Venkataramana, 2012) and shows where they indicate that rotifers have (61%) followed by crustacean18%, nematoda 4%, and annelida was found to be 1%. More so, the results contradict that of Yakubu (2005) and show where they indicate that rotifers had the highest abundance of 47.5% followed by the second largest group which was found to be crustaceans (32.6%). The last group was found to be mollusk with (18.9%).

However, there is a little difference between the result obtained during this research work and that of (Hashemzadeh and Venkataramana, 2012), this may be as a result of environmental factors, changes within the river like the temperature, turbidity, salinity, and availability of food as well as time variation of the research work. Another important factor that may bring a little difference was the water movements (water currents). This is because some species of zooplanktons lack attachment devices while others such as the larvae form of certain insects e.g *Simulium spp* attachment device which they use in attaching themselves to the certain substratum (Needham, 1985).

Turbidity caused by the effects of agricultural run-off or other forms of erosion can severely affect zooplankton productivity. It can interfere with photosynthesis inhibiting algae food production and resulting in the elimination of certain filer feeders, such as cladocera and copepods (Whitton, 1995). Zooplanktons are affected by a variety of factors; these factors may affect them either directly or indirectly. Phytoplankton may also affect the distribution of zooplankton in the aquatic ecosystem. This may, in turn, affect the distribution of other organisms in the aquatic ecosystem, e.g. fish and other aquatic organisms, which are in turn consumed by humans as important amino acids and protein. Therefore, industrial wastes and all other forms of chemicals are harmful to the life of zooplanktons and must be kept at a minimum, this is because zooplankton are contributing from one trophic level to another (food chain), (Yakubu and Shelika, 2005).

Another important factor that may bring a little difference between the recent research and previous ones conducted by Yakubu and Shelika shows the unequal distribution of food which may promote the chance of having more species from one time to another.

5. CONCLUSION

The knowledge of plankton species composition and distribution to time and space are of great value especially in running water systems. The present study reveals some aspects of the zooplanktonic dynamic to explain their relationship with the physicochemical parameters of river water and the industrial area of Rima. Fluctuation of abiotic factors i.e., the concentration of dissolved oxygen, temperature, total alkalinity, total nitrogen, phosphate, and pH can influence the growth of zooplankton. The predominant cladocera over others has been reported earlier.

Temperature is one of the essential and changeable environmental factors since it influences the growth and distribution of flora and fauna. Water temperature ranging between 13.5^{0}C and 32^{0}C is reported to be suitable and development of the planktonic organisms (Kamat, 2000). From the above statement, we can conclude that in the present study that the increase in the number of zooplankton was according to the temperature of the habitat. The study also shows that zooplankton species survive in the neutral condition. Thus the river is said to be eutrophic as indicated by the diversity of zooplankton. Anthropogenic input may cause a slight variation in physicochemical parameters, and anthropogenic activities may also have effects on these variations. The variation could be as a result of fertilizer, insecticides, and pesticide applications at the catchment area by the farmers. While biotic and other factors were likely to have caused the observed spatial effects on the distribution of zooplankton species. Therefore, conducting further research on this area is essential to measuring the diversity of zooplankton.

6. RECOMMENDATIONS

More Experimental research work should be conducted to identify the key roles played by these organisms in the aquatic environment. More research work should be conducted on zooplankton.

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BIO-ETHANOL PRODUCTION FROM NEEM TREE LEAVES (AZADIRACHTAINDICA) USING ASPERGILLUS NIGER AND SACCHAROMYCES CEREVISIAE AS FERMENTING AGENTS

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Abstract: In this research, the leaves of the neem tree -*Azadirachtaindica*- possibilities for the production o bioethanol production was explored. Baker's yeast (*Saccharomyces cerevisiae*) and *aspergillus niger* were used as fermenting agents. Moreover, dried powder of the leaves was hydrolysed using a concentration of H_2SO_4 ranging from 2-10% and was further fermented using *Saccharomyces cerevisiae* and *Aspergillus niger*. After fermentation, the broths formed were distilled to obtain ethanol. Acidified $K_2Cr_2O_7$ was used to determine the bioethanol produced. Sugar content, specific gravity, and alcoholic content were determined using Brix from the refractometer. Also, the FTIR spectroscopy analysis of bioethanol produced confirms the presence of alcohol content in the sample. The results of the bioethanol content from the leaves using 10%, 5% and 2% H_2SO_4 were 40%, 19.3%, and 10% yield respectively. The results showed that the neem tree leaves that are lignocelluloses can be used to generate an appreciable percentage of bioethanol, with 10% H_2SO_4 showing an impressive yield of 40%.

Keywords: Neem tree, bioethanol, *Azadirachtaindica*, *Saccharomyces cerevisiae*, and *Aspergillus niger*.

INTRODUCTION

Energy availability, supply, and use play a central role in the way societies organize themselves, from individual welfare to social and industrial development. By extension, energy accessibility and cost is determining factor for economic, political, and social interrelations among nations. Considering energy sources, human society has dramatically increased the use of fossil fuels in the past 50 years in a way that the most successful economies like America and Japan are large consumers of oil. However, geopolitical factors related to the security of oil supply, high oil prices, and serious environmental concerns, prompted by global warming, the use of petrol for transportation which accounts for one-third of greenhouse gas emissions (Wyman, 1996), have led to a push towards a decrease in its consumption. Indeed, the world's strongest economies like Germany and Japan are deeply committed to the development of technologies aiming at the use of renewable sources of energy. Within this agenda, the substitution of liquid fuel gasoline by renewable ethanol is of foremost importance. Biomass-derived ethanol represents one of the more promising commodities for the long-term sustainability of transportation fuels (Chum and Overend, 2001).

Brazil has been a front-runner in the use of renewable fuels. The partial substitution of gasoline by ethanol started in 1975. Presently the Brazilian fleet of 20 million cars runs on either a gasoline blend containing 22-24% ethanol or on 100% ethanol. Ethanol consumption is forecast to increase as the number of “flex-fuel" cars, with engines able to run on either gasoline blend or ethanol, from 4 million to 15 million in 2013 (Elba and Maria, 1996). Currently, established technologies in the fuel-ethanol industry are primarily based on the fermentation of sugars derived from starch and sugar crops. However, the conversion of starch and sugars to ethanol also has concerns, since it draws its feedstock from food streams (Elba and Maria, 1996).

Interestingly, large amounts of lignocellulosic wastes are generated through agricultural practices, paper-pulp industries, yard wastes, animal and human waste, and many other agro-industries. Additionally, lignocellulose waste is often disposed-off by biomass burning, causing environmental pollution and consequently affecting public health, which is not only common to developing countries but is considered a global phenomenon (Cheng and Anderson, 1997).

Also, it is less expensive than starch and sugar crops and is also renewable and available in large quantities.

Bioethanol is seen as a good alternative to fossils fuel and it's termed a renewable energy source since its source crops can be grown renewably within almost all climates around the world with considerable lower emissions of poisonous gasses to our environment. Sufficient use of bioethanol as an energy source for transportation or in industries can considerably reduce the nauseating greenhouse gas emissions from transport and industries emission (Balat, M, Balat H. and Oz, C. 2008) More job opportunities can be created through bioethanol production as well as economic income and energy security (Correa da Silvio S. S, Maria G, et al. 2012).

In this research, an inedible plants source that is neem tree leaves is used in bioethanol production using *Aspergillus niger* and *Saccharomyces cerevisiae* (baker’s yeast) as a fermenting agent before acid hydrolysed substrate. To prevent a fuel food crisis lignocelluloses biomass, particularly agricultural residues are converted to useful products such as bioethanol. Lignocelluloses biomass consists mainly of lignin, cellulose, and hemicelluloses that are present in a different percentage according to the plant type and its parts. It was reported that the plant leaves contain 15-20% cellulose, 80-85% of hemicelluloses, and 0% of lignin (Humphrey, C.N & Caritas, A.O 2006). Presently, more research is focused on non-edible biomass due to its availability and low cost in procurement (Junchen, L., Muhammad, I. & Lin, F. 2012). Bioethanol is a volatile and flammable liquid produced through the microbial fermentation process, which has a molecular formula of C_2H_5OH (Priscila V. A., Milessi, T. S. S 2010).

Neem trees also grow in islands of the southern part of Iran (USDA, 2014). It grows widely in the northern Nigerian region, its fruits and seeds are the sources of Neem oil. The neem tree leaves were reported to have contained 60% of H_2O, 23% carbohydrates, 7% proteins, and more than 3% minerals and 1% fat (Mamta, A., Kauri, J. &Ramas, S. 2013).

Nonetheless, lignocellulosic conversion is not without its challenge. The crystalline nature of cellulose and the presence of lignin as cement in its structure are known to constitute a strong barrier to enzymatic activities. The keen interest of researchers in this field has resulted in several novel ways of mitigating this challenge.

Hence, this work focuses on using neem tree leaves to produce ethanol, being one of the most common lignocellulosic materials in the tropic. It is inedible, morphologically similar to sugar cane, and has very little patronage presently for any known commercial end-use. Furthermore, this investigation is based on the single pot fermentation technology i.e. simultaneous saccharification and fermentation due to its widely-reported advantages over the traditional two pots technology.

MATERIALS AND METHODS

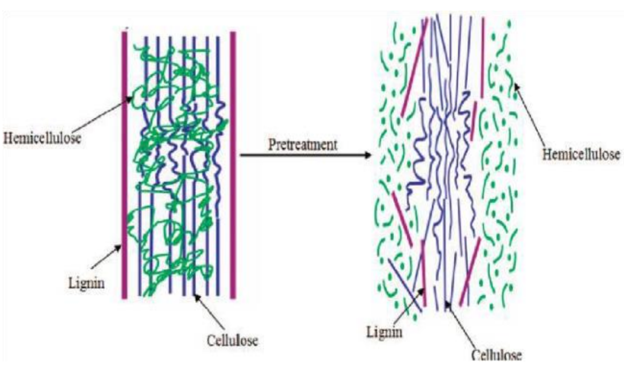


Figure 1.0: Pre-treatment of lignocelluloses Biomass
Source: Manta *et al.*, 2013

Sugar determination, alcohol content, and specific gravity

For reducing sugar determination, a refractometer was used. A refractometer is a laboratory or field device for the

The neem tree leaves were obtained from Kaduna State University, Kaduna Nigeria. Afterward, it was dried to a constant weight in an oven (Gallenkamp model) at a temperature of 105°C for 48 hours. Later, a laboratory mill was used to mill the leaves (Thomas white model 4). Next, a screen analysis was carried out using various sieve sizes to obtain desired particle sizes.

Subsequently, twenty (20g) of powdered leaves of the neem sample were taken into three conical flasks and 200cm^3 of 10% H_2SO_4 was added. The flasks were plugged with cotton wool and wrapped in aluminum foil and sterilized at 121°C for 15 minutes then allowed to cool. The same procedure was repeated using 5% and 2% H_2SO_4. After which the content of each flask was filtered and their pH values were then adjusted to 4.5 before the fermentation. (Kroumov et al., 2006)

measurement of an index of refraction (refractometry). The index of refraction is calculated from the composition of the material using several mixing rules such as the Gladstone-dale relation and Lorentz-Lorenz equation.

Standard refractometers measure the extent of light refraction (as part of a refractive index) of transparent substances in either a liquid or solid state; this is then used to identify a liquid sample, analyse the sample's purity and determine the amount or concentration of dissolved substances within the sample. The analysis only requires a sample size as small as 2 metric drops and is measured as Brix.

Degrees Brix (symbol °Bx) is the Sugar content of an aqueous solution. One degree

Brix is 1 gram of sucrose in 100 grams of solution and represents the strength of the solution as a percentage by mass. If the solution contains dissolved solids other than pure sucrose, then the °Bx only approximates the dissolved solid content. The °Bx is traditionally used in the wine, sugar, carbonated beverage, fruit juice, maple syrup, and honey industries.

A Refractometer calculator is used to convert Brix to Specific gravity, computes potential alcohol by volume, and has a direct and linear relationship to the sugar content.

Figure 2.0: Brix refractor meter
Culturing of *Aspergillus niger*

Preparation of culture medium (potato dextrose agar, PDA)

PDA (Potato Dextrose Agar) medium was used in culturing the micro-organism. It was composed of 200mg peeled Irish potato, 20g of dextrose (analytical grade), and 20g of Agar-agar powder (Analytical grade). The Irish Potato was cut into small pieces and boiled in 500ml of distilled water for about 20-25minutes. The extract was filtered through a muslin cloth into a 100ml flask, after which dextrose and agar were added and reboiled for 10 minutes to obtain complete dissolution. Distilled water was added to the potato extract-dextrose – agar solution and made up to 1 litre. The medium was corked properly and secured with aluminum foil paper after which it is sterilized in an autoclave (Griffing and George 31417 model) for 20 minutes at a pressure of 15psi and temperature of 121^{o}C to prevent contamination. The content of the flask was cooled to 45^{o}C and 5ml of Streptomycin Sulphate solution was added to prevent the growth of bacteria (Alexoponlus and Benke, 1984).

Pour Plating

Petri dishes were washed with detergent and rinsed with tap water. Thereafter they were arranged in a canister and dried in an oven (Gallenkamp model) for 2 hours. The mouth of the conical flask containing the medium was flame sterilized to destroy surface microorganisms and then the medium was poured into Petri dishes, covered, and left to solidify (Alexoponlus and Benke, 1984).

Isolation of Organisms

Maize grains were surface sterilized with sodium hypochlorite and then rinsed with distilled water. This was done to destroy secondary pathogens. The maize grains were then inoculated into the Petri dishes containing the PDA (Potato dextrose ager) medium using flame sterilized forceps. The Petri dishes were incubated at 28-30^{o}C for 3 days and observed for growth.

Identification of Fungus

A small amount of the growing colonies were taken and smeared on a glass slide. The slide was covered with a slip and heated slightly to remove air bubbles. This was viewed under a microscope (Sharmond Surgical model). The organism was identified as *Aspergillus niger* by observing its morphological structure through a microscope (Olympus venom-T-microscope model) this was compared with the standard structure of *Aspergillus niger* given by Robert and Ellen, (1988).

Sub-culturing

Sub-culturing from the parent culture was done to obtain pure colonies. A wire loop was sterilized using flame sterilization to kill surface bacteria to avoid contamination. The wire loop was used to take a portion of growing fungal cultures from the edge of the culture plates. This was transferred to a sterilized bottle containing a fresh PDA medium. Sub-culturing was repeated about 10 times to obtain a fairly pure colony before storing it in a refrigerator for subsequent use

Fermentation process

In this analysis, a conical flask containing the hydrolysed filtrate samples was covered with cotton wool wrapped in aluminum foil and sterilized at 121^{o}C. After cooling the flasks at room temperature the pH of each flask was adjusted to 4.5 then 2gof the *Saccharomyces cerevisiae* (dry baker's yeast) was taken into them and incubated aerobically at 37^{o}C for five days. After that, the broth obtained was distilled by taking the fermented broth into a round-bottom flask fixed to a distillation column enclosed in with running tap water and a heating mantle with the temperature adjusted to 78.3°C. To collect the distillate, a conical flask was fixed to the other end of the distillation column the process is shown using equation 1.0

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Yeast}} \underset{\text{Ethanol}}{2C_2H_5OH} + \underset{\text{Carbon dioxide}}{CO_2} \quad ....1$$

Qualitative test for Ethanol

Two (2) drops of acidified 0.1M $K_2Cr_2O_7$ were added to the 2cm^3 of distillate produced and heated for 30 minutes on a water bath. The content of the test tube changed to a green colour indicating the presence of ethanol. The equation of the reaction is represented using equation 2 (Agriculture, 2014).

$$4K_2Cr_2O_7 + 16H_2SO_4 + 4C_2H_5OH \longrightarrow 4K_2SO_4 + 4Cr_2\,(SO_4)$$

A quantitative test of Ethanol Produced:

The distillate collected was measured using a measuring cylinder and expressed as the quantity of ethanol produced in g/l by multiplying the volume of the distillate by the density of ethanol (0.8033g/cm3) (Caritas et al 2006).

RESULTS AND DISCUSSION

Determination of sugar content, specific gravity, and alcohol content.

Table 1.0 shows the sugar content analysis for the pre-treated samples, specific gravity, and alcoholic content which were all evaluated and calculated using a Brix calculator. The result showed that the sugar content has a direct and linear relationship to the Brix.

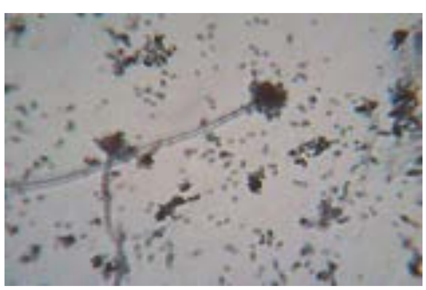
SERIAL NO.	SAMPLE	SUGAR CONTENT	SPECIFIC GRAVITY	ALCOHOL CONTENT (%)
1	Filtrate of 2% H_2SO_4	8.0	1.0318	4.1
2	Filtrate of 5% H_2SO_4	9.9	1.0396	5.2
3	Filtrate of 10% H_2SO_4	15.8	1.0646	8.7

Table 1.0 sugar content, specific gravity, and alcohol content for the pre-treated samples.

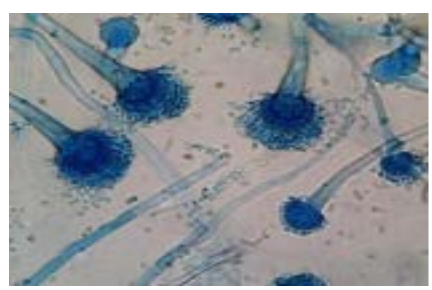
Isolation of *Aspergillus Niger*

The growth of *Aspergillus niger* was monitored on potato dextrose agar (PDA) at 30^{o}C. The spores initially observed as white turned to yellow which later become dense dark brown to carbon black mass. A sample of the black colony was sub-cultured ten times, which produced a fairly homogenous black colony. When viewed under a microscope (Olympus Vanox-T Microscope model) its morphological structure presented in plate

1.1a compared with the standard structure of *Aspergillus niger* given by Robert and Ellen (1988) shown in plate 1.1b.



(a)



(b)

Plate 2.1 (a) Morphological structure of *Aspergillus niger *250* and (b) standard morphological structure of *Aspergillus niger *300 (Robert and Ellen, 1988)*

Figure 2.1 *Aspergillus niger* in a petri dish

2.0 Simultaneous Saccharification and Fermentation of Neem tree leaves

Fourier Transform Infrared Analysis (FTIR)

The FTIR spectrophotometer was used for qualitative determination of ethanol, which works by exciting chemical bonds with infrared light and is best for the identification of organic materials. The different chemical bonds in this excited state absorb the light energy at frequencies unique to the various bonds. The types of bonds present are told by the wavenumber of the peaks. The result is presented in Figure 2.1, which showed the peaks at which the hydroxyl (O-H) bond and the carbon-hydrogen (C-H) bond is formed.

The O-H bond is present at a wavelength of 3388.08 cm^{-1} while the C-H bond is present at a wavelength of 2851.85 cm^{-1}

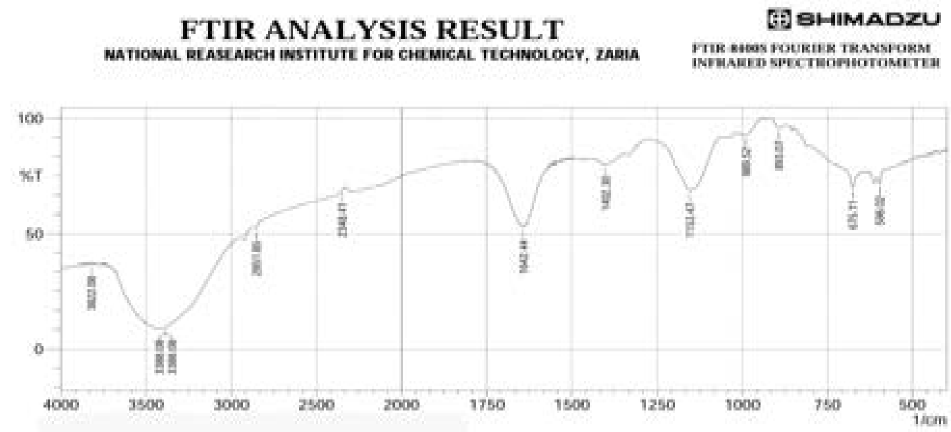


Figure 3.0: FTIR analysis result for ethanol

Confirmatory test for ethanol produced using potassium dichromate.

Production of bioethanol was further confirmed using the potassium dichromate test. The colour of the crude distillate changed from pink (dichromate colour) to green colour indicating the presence of ethanol (Caputi *et al.*, 1959).

TEST	OBSERVATION	INFERENCE
2ml of distillate + 2 drops of potassium dichromate + heated for 30mins on a water bath.	The formation of green color	Ethanol present

Table 3.0: Confirmatory test of bioethanol produced

Quantity of ethanol produced

The distillate collected was measured using a measuring cylinder and expressed as the quantity of ethanol produced. The result proved that the quantity of ethanol increased with concentration. The sample with maximum ethanol was treated with 10% H_2SO_4.

KEY

Q1	Quantity of ethanol after hydrolysis with 10% H_2SO_4
Q2	Quantity of ethanol after hydrolysis with 5% H_2SO_4
Q3	Quantity of ethanol after hydrolysis with 2% H_2SO_4

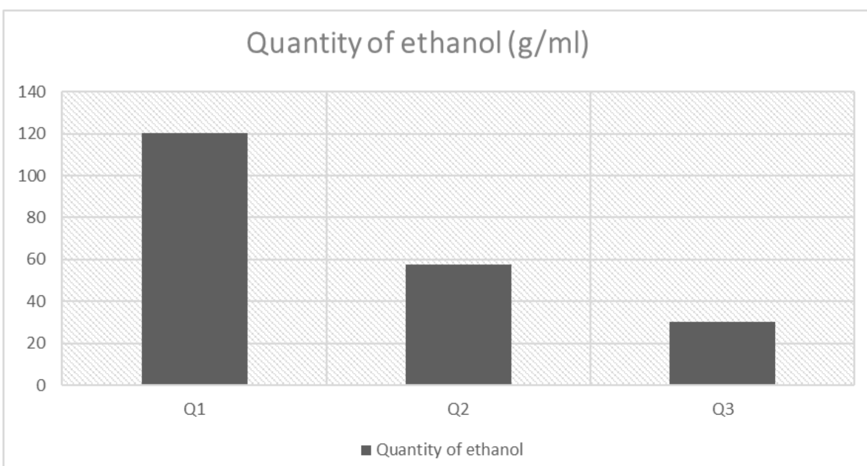


Figure 4.0: Ethanol yielded after distillation at 96h fermentation time.

Discussion

The macroscopic and microscopic identification of the organism was based on colony pigmentation and the structure of the conidial head as described by (Verweji *et al.*, 2007). Also (Verweji *et al.*, 2007) reported that colonies of *A. niger* are carbon black with a dark globular conidial head. *Aspergillus niger* strain was found to have good amylase production potential which is important in the hydrolysis of starch, this is in agreement with the work of (Omemu *et al.*, 2005) who reported that A.*niger* can be used for industrial production of ethanol, citric acid, and gluconic acid because of it hydrolytic capacities in amylase production and its ability to have a high tolerance to acidity thereby enabling it to prevent bacterial contamination. While *Saccharomyces cerevisiae,* on the other hand, is a yeast that is capable of withstanding stressful conditions and has high fermentation efficiency, effective sugar use, tolerance to high ethanol concentration, which are fundamental for industrial use (Andrietta *et al.,* 2007).

The ethanol yield from Figure 4.3; there was an increase in yield and this may be because ethanol yield increases with an increase in concentration but begins to decrease when the organism becomes starved and die thereby leading to a decrease in the metabolic activity and subsequent decrease in ethanol yield. This research is in agreement with the work of (Shilpa *et al.,* 2013) and (Zainal *et al.,* 2014) who carried out similar research using cassava peels and banana peels respectively, where the optimum day of ethanol yield was the fourth day.

The effect of substrate concentration on ethanol yield was carried out using varying substrate concentrations of 2%, 5%, and 10%, of H_2SO_4. From this research, the ethanol yield increased with an increase in substrate concentration which was maximized at 10% (120g/ml) as presented in Figure 4.3. The increase in ethanol yield may be because at low substrate concentrations the yeast tends to starve and productivity decreased. Also, an increase in ethanol yield could be due to the presence of substrates that can readily be hydrolysed to sugar by the amylolytic activity of *A. niger* and subsequent sugar conversion to ethanol by the yeast cells in the medium (Stanberg *et al.*, 2001). This work is in agreement with the work of (Wen *et al.,* 2004) and (Ado *et al.*, 2009) who carried a similar work using cassava starch. This work was also in agreement with the work of (Jimoh *et al.*, 2009) and (Ajay *et al.*, 2014) who reported that ethanol yield increased with an increase in substrate concentration where the optimum concentration for ethanol yield was recorded to be 10% and 12% H_2SO_4 respectively using banana peels.

The effect of various bonding on pretreated samples with acid, when compared with the untreated samples, was carried out using FTIR analysis from figure 4.2; it can be seen that the stretch peak at 3388.08 cm-^{1} represents the stretching of the O-H group. These results represent that partial degradation of cellulose has been done. The C-H stretch at 2851.85 cm-^{1} represents that various ester bonds have also been disrupted. It can be analysed that the peaks became sharper and clear after the pre-treatment with acid at a higher concentration of H_2SO_4 which indicates that the substrate became purer after treatment. This result agrees with the results of (Rawinder Kaur *et al.,* 2017) that performed similar work using rice husk.

Conclusion

From the results obtained from this work the following conclusions can be drawn :
Neem tree leaves can be used in the production of bio-ethanol. The study showed that 10% H_2SO_4 acid hydrolyzed sample has

the highest percentage yield of bioethanol production.

The population of human beings is increasing on average worldwide, hence the demand for energy sources increases. Current fuel bioethanol production from grain-based feedstock is not favourable as it may lead to a food shortage to the teaming world populace. To avoid these foreseen worrisome, lignocelluloses biomass should be utilized in the production of bio-ethanol and biofuels in general.

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OPTIMIZATION OF BIOGAS FROM COW DUNG AND CHICKEN DROPPINGS

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Abstract: In this study, the production of methane gas was enhanced from cow dung and chicken droppings. Two 19 liters capacity rubber prototype biogas digester was constructed at Kaduna State University and it was used to investigate the anaerobic digestion for generating biogas. Furthermore, the anaerobic digestion process was monitored for 21 days. The digester was charged with 1:3 and 1:2 of the waste to water for cow dung and poultry droppings respectively. The result obtained from the gas produced showed that approximately equal amount of gas was produced from both the cow dung and poultry droppings - 0.15kg(150g) of biogas was produced from both. Also, a qualitative analysis was conducted to determine the gases present in the biogas and it was found that methane, ammonia, and carbon dioxide was present in both. However, hydrogen sulfide was present in cow dung but absent in chicken droppings.

Keywords: Methane, Biogas, Chicken droppings, and Cow dung

INTRODUCTION

The need for alternative non-fossil fuel energy sources from locally available resources cannot be over-emphasized. Recently, organic waste treatment has had a lot of attention, due to the possibilities of energy recovery from these wastes as well as to prevent their adverse environmental effects. Energy recovery is possible through the controlled release of chemically bound energy of organic compounds in waste and can be retrieved through chemical and biochemical processes (Gregor, 2012). Appropriate and economically feasible technologies that combine solid waste and wastewater treatment and energy production can simultaneously protect the surrounding water resources and enhance energy availability (Mshandete, 2009). Anaerobic digestion (WRAP 2010) is "a process of controlled decomposition of biodegradable materials under managed conditions where free oxygen is absent, at temperatures suitable for naturally occurring mesophilic or thermophilic anaerobic and facultative bacteria and archaea species, that convert the inputs to biogas and whole digestate ". It is widely used to treat separately collected biodegradable organic wastes and wastewater sludge, because it reduces the volume and mass of the input material with biogas (mostly a mixture of methane and CO_2 with trace gases such as H_2S, NH_3, and H_2) as a by-product. Thus, anaerobic digestion is a renewable energy source in an integrated waste management system. Also, the nutrient-rich solids left after digestion can be used as a fertilizer[8] or Anaerobic manure digestion is a biochemical process by which organic matter is decomposed by bacteria in the absence of oxygen, producing methane and other byproducts. Biodegradable organic waste can be treated with or without air access. The aerobic process is called composting and the anaerobic process is called digestion. Composting is a simple, fast, robust, and relatively cheap process producing compost and CO_2. Digestion is a more sophisticated, slow, and relatively sensitive process, applicable for selected input materials (Polprasert, 2007). In recent years anaerobic digestion has become a prevailing choice for sustainable organic waste treatment all over the world. It is well suited for various wet biodegradable organic wastes of high water content (over 80%), yielding methane-rich biogas for renewable energy production and use. Food industrial waste and animal by-products are suitable for Anaerobic Digestion (AD) giving high gas yields and a nutrient-rich organic fertilizer. Anaerobic methanogenic fermentation is an attractive method for this purpose, as it converts the waste materials into useful products. Due to the increasing regulation on waste disposal and as a result of the global warming effects resulting from the release of greenhouse gases, biological treatments of organic wastes are increasing in importance as an option to reduce water and soil pollution and greenhouse gas emissions (Marchaim, 1992). The complete mixture of this gas is called biogas. Biogas can be used for heating, as fuel for engine generators that produce electricity, or flared into the atmosphere. Biogas consists of a mixture of methane, carbon dioxide, and other trace gases (ex. hydrogen sulfide).

Biogas technology is also potentially useful in the recycling of nutrients back to the soil. Burning non-commercial fuel sources, such as dung and agricultural residues, in countries where they are used as fuel instead of as fertilizer, leads to a severe ecological imbalance, since the nutrients, nitrogen, phosphorus, potassium, and micro-nutrients, are essentially lost from the ecosystem. Biogas production from organic materials not only produces energy but preserves the nutrients, which can, in some cases, be recycled back to the land in the form of slurry. The organic digested material also acts as a soil conditioner by contributing humus. Fertilizing and conditioning soil can be achieved by simply using the raw manure directly back to the land without fermenting it, but anaerobic digestion produces a better material. Chinese workers report that digested biomass increases agricultural productivity by as much as 30% over farmyard manure, on an equivalent basis (Buren, 1983). This is due in part to the biochemical processes occurring during digestion, which cause the nitrogen in the digested slurry to be more accessible for plant utilization, and to the fact that less nitrogen is lost during digestion than in storage or composting. The stability of the digested slurry and its low BOD and COD are also of great importance (Marchaim, 1992). Biogas technology in which biogas is derived through anaerobic digestion of biomass, such as agricultural wastes, municipal and industrial waste, is one such appropriate technology Nigeria, indeed Africa at large should adopt to ease its energy and environmental problems.

Anaerobic Digestion (AD) is a biological process in which microorganisms break down biodegradable material in the absence of Oxygen producing biogas suitable for energy conversion (Fioresea, 2008). Anaerobic digestion consists of several interdependent, complex sequential, and parallel biological actions in the absence of oxygen, during which the products from one group of microorganisms serve as the substrates for the next, resulting in the transformation of organic matter (biomass) mainly into a mixture of methane and carbon dioxide (Aworanti, 2011). Biogas, which is bio-energy produced from biomass has advantages over the other renewable energies. Key by-products of anaerobic digestion include digested solids and liquids, which may be used as soil amendments or liquid fertilizers (Buendia, 2009). The anaerobic fermentation of waste for biogas production does not reduce its value as a fertilizer supplement, as available nitrogen and other substances remain in the treated sludge (Alvarez, 2008). Most of the pathogens are destroyed in the process of anaerobic digestion (Nations, 1996). Shih, in 1993 reported a complete eradication of fecal coliforms and salmonellae in a thermophilic digester ($50^{0}C$), whereas a comparable mesophilic digester ($35^{0}C$) destroyed them only partially (Shih, 1993).

The use of the anaerobic digestion in waste management reduces the volume of waste (Buendia, 2009); with a reduction in odor (Molinuevo, 2009); reduction in greenhouse gas emission by environmental control of Methane, Carbon Dioxide, and Ammonia; with less leakage of nutrient salts to ground and surface water (Elmahgary, 2009). The following is the chemical formula for the anaerobic digestion (Frear, 2004):

$$\text{Organic matter} + H_2O + \text{Bacteria (Acidogenic/methanogenic)} \longrightarrow CH_4 + CO_2 + NH_3 + H_2S$$

Anaerobic co-digestion of animal and organic wastes also provides a sustainable cycle of natural resources. Through the process of photosynthesis, plants manufacture their food. The plant food is used as animal feed and the residue (biomass vegetable) is used in anaerobic digestion. Waste generated on the farm by the animals is also used for anaerobic digestion.

MATERIALS AND METHODOLOGY

Substrates Sources and Characteristics

Two different substrates were used in this research work: Poultry droppings and Cow dung. Dry poultry droppings were collected from Rimi College Quarters, located around Degel one, some few meters away from Kaduna State University, Kaduna; and dry cow dung was collected from around the Railway Station Quarters Kaduna.

Anaerobic Bio-Digester

The main experiment apparatus consists of 18.9 (approx. 19) liters of rubber bio-digester for the experiment and was constructed at Kaduna State University. The biogas digester is divided into three main parts: the inlet chamber, the body, and the outlet chamber. The digester component includes the fermentation chamber (Vf), the gas storage chamber (Vgs), the gas collecting chamber (Vc); the fermentation chamber is the chamber where the slurry is charged in the digester is stored. The gas storage chamber is the upper frustum section of the digester; the gas collecting chamber is the chamber through which the stored gas exits from the digester.

Other materials used for the experiment include: A car tube, hose pipe, weighing balance, measuring cylinder

Experimental set-up

Two 18.9 (approx. 19) liters batch tank reactors were fed with the cow dung and poultry droppings prepared with the same proportion. 5 liters of water was added to 3kg of the poultry droppings (approx. 2:1) before pouring it into the digester and 8 liters of water was also added to 3kg of the cow dung (i.e. approx. 3:1) before pouring it into the digester and incubated at a temperature range of 22°C – 32°C. Biogas production was monitored for 17 days and measured at the end of the production.

Calculating the amount of biogas produced

The amount of biogas that was produced from the animal wastes (i.e. the chicken droppings and the cow dung) was calculated using

Biogas produced = weight of car tube with biogas – the weight of empty car tube

Qualitative Analysis

Qualitative analysis was conducted to determine the various gaseous makeup of the biogas produced:

Test for carbon (IV) oxide (CO_2): A capillary tube was dipped into clear lime-water i.e. Calcium Hydroxide, $Ca(OH)_2$ solution, and inserted into the test tube containing the gas. The lime water turns milky or forms a white precipitate, due to the formation of $CaCO_3$ which is insoluble in water, indicating the presence of carbon (IV) oxides.

$$Ca(OH)_{2(aq)} + CO_2 \longrightarrow CaCO_{3(s)} + H_2O$$

Lime-water white ppt

Test for hydrogen sulfide gas, H_2S: A thin strip of filter paper soaked in lead (II) ethanoate, $Pb(CH_3COO)_2$ or lead (II) trioxonitrate (V), $Pb(NO_3)_2$ solution. The paper turns black due to the formation of lead (II) sulfide, PbS, which indicates the presence of hydrogen sulfide.

$$Pb(CH_3COO)_{2(aq)} + H_2S_{(g)} \longrightarrow PbS_{(s)} + 2CH_3COOH$$

Black

Test for ammonia, NH_3: A stopper of the concentrated hydrochloric acid bottle or a stirrer containing concentrated hydrochloric acid was held in the test tube containing the gas. Dense white fumes of ammonium chloride are produced, indicating the presence of ammonia.

$$NH_{3(g)} + HCl_{(aq)} \longrightarrow NH_4Cl_{(s)}$$

Test for methane: The gas produced was lighted and when it burns indicates the presence of methane.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

RESULTS AND DISCUSSION

Chicken Droppings

Weight chicken droppings used	3kg
Weight of the empty car tube used	0.5kg
Weight of car tube with the biogas	0.65kg
Weight of the biogas produced	0.15kg

Qualitative analysis

Methane, Carbon dioxide, and Ammonia present

Cow Dung

Weight cow dung used	3kg
Weight of the empty car tube used	0.5kg
Weight of car tube with the biogas	0.63kg
Weight of the biogas produced	0.13kg

Qualitative analysis

Methane, Carbon dioxide, Hydrogen Sulphide, and Ammonia are present.

DISCUSSION AND CONCLUSION

The lag phase of the poultry dropping was found to be within the range of 1 - 3 days and that of the cow dung was found to be within the range of 7 – 10 days. Poultry waste has been reported to degrade faster than cow dung (Marchaim, 1992), however, cow dung has been acclaimed to contain bacteria that kick starts anaerobic digestion (Ofoefule, 2010). The cow dung had the highest lag phase, which could be attributed to the composition of the feeds. Several researchers have reported that because cows feed on mainly fibrous material which is rich in lignocelluloses, the decomposition of these fibrous matter takes longer time by micro-organisms since the content and distribution of lignin is responsible for the restricted enzymatic degradation of lignocelluloses, by limiting the accessibility of enzymes (Babatola, 2008). Poultry wastes have the highest biogas yield than cow dung. This agrees well with the Marchaim report in 1992 that poultry waste degrades faster than cow dung (Marchaim, 1992). Wilkie in 2005 reported that cattle manure is established to have low available volatile solids because ruminants extract much of the nutrients from the fodder and the leftover is rich in lignin complexes which were extensively exposed to enzyme action of the four-chamber stomach of ruminants (Wilkie, 2005).

Although there seem to be contradictory reports by various researchers on which of the two wastes has higher biogas potential. Ngozi-Olehi et al., in 2010 researched on biogas potential of cow dung and poultry droppings and domestic waste. The test results indicated that cow dung exceeded poultry dropping in gas production while the domestic waste has the least (Ngozi-Olehi L. C., 2010). Ntengwe, et al., in 2010 research, however, showed a slight increase of cow dung over poultry dropping (Ntengwe, 2010).

In this research work contrary to other researchers' reports, there was equal production of biogas in both the poultry and cow waste. Gas production is related to the volatile solid content of substrates used (Vindis, 2009). Hence this work shows that the volatile solid content of both the poultry and cow waste is approximately the same.

Conclusion

The study of biogas production was conducted for selected animal wastes which include poultry droppings and cow dung using an approximately 19 liters digester. Biogas was successfully produced from the selected animal waste. The result obtained showed that the poultry and cow waste yield approximately the same amount or quantity of biogas.

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THE IMPACTS OF CLIMATE CHANGE ON CROP PRODUCTION IN NIGERIA

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Abstract: Climate change is an environmental challenge that is presently affecting communities, cities, countries, and continents. The impacts of climate change are greatly felt on Nigeria's agricultural sector which profoundly affects crop production. The impacts of climate change on crop production in Nigeria require urgent actions to be taken by farmers, educators, government agencies, and non-governmental organizations to stop global warming too unbearable for mankind and to achieve sustainable economic growth in Nigeria. This study seeks to draw the attention of policymakers in government, private sectors, non-governmental organizations, and farmers who are actively involved in crop production in Nigeria to the impacts of climate change and ways to adapt and mitigate effectively. Through our literature review, It has been discovered that climate change impacts on crop production affect the health, economic and agricultural sectors of the nation in a profound way. This study, therefore, identifies the need for climate change education among farmers both in rural and urban areas in Nigeria to enhance their effectiveness and efficiency in crop production for sustainable economic growth in Nigeria. It also identifies the innovative tools which can be used in educating and equipping the farmers both in rural and urban areas in Nigeria for sustainability locally, nationally, and globally.

Keywords: Adaptation, Climate Change, Crop Production, Mitigation, Sustainable Development.

INTRODUCTION

Climate change according to Kuta (2011) is one of the most critical challenges ever to face humanity. It can cause the worst forms of economic and security problems for humanity. It determines the health of the resources on which the economy depends and this phenomenon is one of the challenges confronting West Africa among other sub-regions of the world. Climate change, however, arises from the release of greenhouse gases, carbon dioxide, water vapours, and nitrous oxide into the atmosphere due to human activities, such as fossil fuel burning, gas flaring, and deforestation (Anabaraonye. B,2017). Climate change according to World Bank (2010) is expected to hit developing countries the hardest. Its effects; higher temperatures, changes in precipitation patterns, rising sea levels, and more frequent weather-related disasters—pose risks for agriculture, food, and water supplies. A common consensus among environmental and agricultural economists is that climate change is a serious threat to ensuring sustainable agricultural growth in Africa. The United Nations Development Programme (UNDP) estimates that Africa will be the continent hardest hit by climate change because it faces more severe climate effects than other regions of the world. Its economies rely on climate-dependent sectors such as agriculture and its capacities to cope and adapt to climate change are generally limited. Nigeria faces numerous challenges as it struggles to achieve the Sustainable Development Goals (SDGs) with flooding which is one of the climate change impacts is one of the most serious natural disasters with wide-reaching impacts. It is a known fact that climate change is altering the weather and climate globally, which invariably affects human life. It is therefore important to remark that anything that affects our lives on earth will be of great concern to us (Okeke. F.N, Okoro. C.E.& Josephine. O.U,2018).

Food and Agricultural Organization 2010, estimates that 30 percent of the world's 925 million undernourished people are in sub-Saharan Africa, with Nigeria accounting for over 9 million of them. Agricultural production in Nigeria is largely dependent on climatic forces. Rain-fed agriculture still accounts for 95 percent of total food production as only about 4 percent of total cultivated area and a mere 2 percent of total agricultural output is irrigated [Eboh 2005]. Thus, agricultural production in the country may be threatened by climate variability. In Nigeria, whilst agricultural gross domestic product (GDP) has maintained a consistent increase in the recent past, available evidence confirms that climate variables have remained unstable. The potential impact of the changing climate conditions poses a further challenge which has implications for the country's ability to meet its current development agenda of attaining food security, employment and income generation, expansion of the export base, and reducing food imports through sustainable agricultural production. Thus, there are indications that the food accessibility and income of the poorest quintiles of society will be severely limited.

Nigeria is now more than ever being confronted with the daunting challenge of ensuring adequate food provision and increasing household income from agriculture for her growing population in the face of changing climatic conditions, on which her agricultural production depends (Chukwunonso, 2015). Flooding which is a result of climate change has been described as an existential threat to human well-being. Globally, it affects the social and environmental determinants of health: clean air, safe drinking water, sufficient food, and secure shelter. The effects of flooding are far-reaching and include severe weather, deteriorated air quality, displacement, and migration of vectors increasing a range of diseases related to water and ecological factors. Increasing incidences of mental health issues are being recorded and identified as a consequence of environmental change (Lu, 2016; PAHO, 2013). Flooding has posed a serious threat to soil fertility in Nigeria which in turn affects crop yield and the health of the populace. Nwadinigwe(2018) attributed flooding as one of the major causes of food insecurity, soil infertility, erosion, and destruction of farmlands in Nigeria. The soil remains the most critical factor in human lives that is essential in food production required for the sustenance of human civilizations and is threatened in recent times by the forces of environmental threats. These threats are climate change and global warming escalated by the forces of diverse erosions and floods disasters. Nwadinigwe (2018) asserted that flooding events can be aggravated by the overflowing of seas and rivers caused by the melting of glaciers as a result of high temperatures of global warming. In Nigeria, just as in many developing countries in the Subtropical region the agricultural sector is more vulnerable to climate change, landless farmers, livestock keepers, people in poor health, those who are under-nourished, people with low economic power, women, and children including women-headed households, those with a low level of education, and those with low technological know-how are more exposed to the risk of climate change (Barber et al, 2003). The overall effect of climate change on agriculture will depend on the balance of these effects and the assessment of the effects of global climate change on agriculture might help to properly anticipate and adapt farming to maximize agricultural production (Fraser, 2008).

Since agriculture in Nigeria is mostly rain-fed, it follows therefore that any climate change is bound to impact its productivity in particular and other socio-economic activities generally, in the country. The issue of climate change has become more threatening not only to the sustainable development of socio-economic and agricultural activities of any nation but also to the totality of human existence (Adejuwon, 2004). As further explained by Adejuwon, the effect of climate change implies that the local climate variability which people have previously experienced and adapted to is changing and this change is observed at a relatively great speed.

The vulnerability of the Nigerian agricultural sector to climate change is of particular interest to policymakers because agriculture is a key sector in the economy accounting for between 60-70% of the labour force and contributing between 30-40% of the nation's GDP. The sector is also the source of raw materials used in several processing industries as well as a source of foreign exchange earnings for the country. The production of major export crops in the country such as groundnut, rubber, coffee, cocoa, and palm produce in the country has declined in magnitude since the drought of 1972/73 which is the first real evidence of climate change in Nigeria. Though there is evidence of an increase in food crop production generally in Nigeria, the nation is not self-sufficient in the production of any food crop except cassava. The question remains therefore as to whether the production level will ever meet the demand level given the rate of population growth in the country. Also, the proportion of change in production due to the impact of climate change will remain an important research focus as well as measures needed to improve the resilience of the farmers to enable them to adapt to climate change.

The actual and potential impacts of climate change in Nigeria are considerable and have far-reaching effects. All sectors of our socio-economic development, including agriculture, are vulnerable to climate change. It presents significant threats to the achievement of the Millennium Development Goals especially those related to eliminating poverty and hunger and promoting environmental sustainability (Enete 2014).

Productive agriculture is essential to feed a growing population and sustain modern civilization. Climate affects agriculture, a fact well known to every farmer. Year-to-year variations in harvest are largely due to variations in temperature and precipitation that can make the difference between bountiful "bumper" crops and economic ruin.[Enete 2014]

CASE STUDY: Production of rice, which is the world's most important crop for ensuring food security and addressing poverty, will be thwarted as temperatures increase in rice-growing areas with continued climate change (Gumm, 2010). Recent research has shown that rice can be used to offset the major impacts of climate change because of its potential and unique properties as a food crop for urban poor and rural rice-growing populations (Manneh et. al. 2007). Rice is a major cereal in Nigeria in terms of its output and land area. The crop is currently grown in more than 70% of the states in the country. Despite the availability of cultivable land area, the current level of demand for rice in Nigeria is about 5 million metric tonnes which is more than twice the quantity produced (2.2 metric tonnes). At present, about 4.9 million hectares are suitable for rice production but just about 1.8 (37%) are currently utilized for cultivation. To amend the problem, the West African Rice Development Association (WARDA), International Institute for Tropical Agriculture (IITA), and ministry of agriculture are frequently improving adaptation measures in rice agriculture in Nigeria. In addition, Nigeria governments have invested more to increase rice production than other cereals. In 2009 for instance, the nation spent more than 10 billion Naira in public-private partnership schemes to improve the irrigation systems and set up about 17 new rice processing mills. The major problems associated with rice production include drought, flooding, salt stress, and extreme temperatures, all of which are expected to worsen with climate change. Drastic changes in rainfall patterns and rise in temperatures will introduce unfavorable growing conditions into the cropping calendars thereby modifying growing seasons which could subsequently reduce crop productivity. So far, there has not been any study to address the economic impacts of climate change on rice farming and farm-level adaptations that rice farmers make to mitigate the potential impact of climate change.

Ramirez (2010) notes that unforeseen changes associated with global warming in temperature, carbon dioxide, and rainfall are expected to impact rice production. Studies have shown that an increase in temperature, due to climate change, adversely affects rice crop physiology ultimately decreasing crop yield and grain quality. Gumm (2010) re-affirms that rising temperature during the past 25 years has already cut rice yield growth rate by 10-20 percent in several locations. He further adds that unless there is a change in the rice production methods or new rice strains that can withstand higher temperatures, are developed, there will be a loss in rice production over the next few decades as days get hotter.

The major causes of climate change in the study area were deforestation, bush burning, gases released from industries, excessive use of chemicals in rice production, application of excess nitrogenous fertilizers, and other natural phenomena. (H.U. Nwalieji and C. O. Uzuegbunam, 2012).

STRATEGIES TO MITIGATE IMPACTS OF CLIMATE CHANGES

(1) Resilient crops and livestock: Because of rising temperatures and increased variability, the development of new crop varieties and livestock breeds that can tolerate these changes will be very important. Due to the frequency of change, it will be important to detect the change and develop genetic material that can adapt to this change relatively fast.

(2) Higher yield and longer shelf life: Crop varieties, as well as livestock, that increase yield per area, tend to reduce agricultural footprint and the effort required to compensate for production loss due to climate change. Longer shelf life would decrease transportation costs, storage costs, and, especially, waste associated with agricultural distribution. Shelf-life enhancement is important in the context of climate change because increased temperatures increase the likelihood of spoilage.

(3) Sustainable Land Management (SLM): Frequently, agricultural practices in developing countries lead to reduced soil quality. Extreme weather associated with climate change may worsen this problem unless improved agronomic practices are introduced. SLM practices aim to increase yield without degrading soil and water resources. In addition, they aim to sequester carbon. There are already several SLM practices such as organic fertilization, minimum soil disturbance, and incorporation of residues, terraces, water harvesting and conservation, and agroforestry (Branca et al. 2013), but there are many opportunities for developing new SLM practices and already existing ones to accommodate spatial and climatic variability. Production level will ever meet the demand level given the rate of population growth in the country. Also, the proportion of change in production due to the impact of climate change will remain an important research focus as well as measures needed to improve the resilience of the farmers to enable them to adapt to climate change.

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RECOMMENDATION

Educating farmers in rural and urban areas in Nigeria on climate change adaptation and mitigation is an urgent task that needs to be undertaken by governmental agencies, NGOs, community leaders, and passionate climate change professionals for our sustainable economic growth and development in Nigeria. Grants and Loan facilities should be readily available for farmers in both rural and urban areas to support them in adaptation and mitigation of the impacts of climate change on crop production in Nigeria. Environmental Leadership summits for farmers on climate change and environmental sustainability, intensive awareness outreach, climate change poems, and blogs, are recommended as important tools which can be used in climate change education in rural and urban areas in Nigeria for sustainability locally, nationally, and globally.

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CLIMATE SCIENCE COMPETENCY GAPS OF TEACHERS IN ENUGU STATE, SOUTH-EASTERN NIGERIA

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Abstract: Consensus on low awareness of climate change in Nigeria is extant. An inquiry was necessary to determine teachers' level of competence in climate science concepts, as a precursor to increased climate change awareness, hence this study. This cross-sectional descriptive survey randomly sampled 410 teachers, spread across 6 local government areas within Enugu state, and utilized the Borich Needs Assessment Model (BNAM) as a framework for eliciting objective responses from teachers on their perceived level of importance, and competency in 13 climate science concepts, with interesting results. All items were held as important, but competency was generally poor as teachers indicated moderate competency in all items listed. Neither age, location, nor academic qualification had any influence on competency. However, academic discipline strongly influenced competency in favor of social science teachers, with years of teaching experience also wielding some influence. These results have implications on climate change education and teacher education and professional development programmes. In-service teachers' competency must be initiated to bridge identified competency gaps.

Keywords**:** Borich Needs Assessment Model (BNAM); capacity building; climate change education; mean weighted discrepancy score (MWDS); teachers' competency; in-service teachers training programme

INTRODUCTION

Teachers' competency in the contents they facilitate for learners, ought not to be in doubt. A subject such as climate change requires high proficiency and competency of teachers in the delivery of its contents, especially the basic concepts that underlie the phenomenon of climate change. Climate itself is the average weather condition of a place, with elements or observable features which include precipitation (rainfall, snow, dew, frost, fogs, hail, and mist), temperature, humidity, pressure, sunlight, cloud, wind, and sunshine, over an extended time, commonly from 35 years and above (Ofuebe, 2017). This implies that climate is a long-term weather condition in a specific place, at a time. However, climate may be forced to change due to factors referred to as climatic forcings. Forcing mechanisms refer to the variation in solar radiation, orbital deviations of the earth, formation of mountains and continental drift; and anthropogenic factors leading to changes in greenhouse gases' denseness in the atmosphere (Moyinoluwa, 2013). Climate forcings, therefore, tend to lead to the deviation of average weather elements from their long-term values over time, or deviation of the climate from the status quo, leading to a notable change called climate change. Climate change is accompanied by consequent impacts on the environment.

Climate change impacts touch on all sectors in Nigeria – environmental, economic, and social. Ikeme (2008) identifies acute electricity supply shortage, as a notable climate change impact. Since hydroelectric power accounts for 36% of the national grid, reduction in runoff contribution to hydroelectric dams due to inconsistent rainfall patterns will in turn affect hydroelectricity generation. Also, the Internal Displacement Monitoring Centre (IDMC) (2017) reports the displacement of 78,000 persons in 2016 due to climate-induced disasters. Such forced migration has its attendant effects socioeconomically. In the work of Agwu and Okimambe (2009), climate-induced health impacts such as increased cases of diarrhea, hypertension, diabetes, malaria, asthma, and ulcer, were identified. Also, various researchers have pinpointed flooding, heatwaves, health-decline, infectious diseases, soil fertility-loss, fishery resource decline, increased gully erosion, deforestation, decreased agricultural yield, coastal/marine erosion, food insecurity, natural disasters, air pollution, reduction in the water availability, and social dislocation as clear evidence of climate change in the South-South and South Eastern part of Nigeria (Etuonovbe 2007; Ozor 2009; Akuegwu, Nwi-Ue & Nwikina 2012; Nnadi, Chikaire, Nnadi, Okafor, Echetema, & Utazi, 2012; Chinweze and Abiola-Oloke 2009).

Notwithstanding the aforementioned impacts of climate change in Nigeria, there are reports of low climate change awareness among the populace (Esiobu, Yewande, & Anoh, 2014; Odjugo, 2013; Nwankwo & Unachukwu, 2012); and misinformation on climate change science (Godfrey, Le Roux-Rutledge, & Burton, 2009; BBC, 2008). Even with the known central roles teachers play in information dissemination at formal and informal education levels, prior studies have failed to take a cursory look at the foundational issue of teachers' competency, which is capable of influencing climate change awareness. From the view of Shobeiri, Meiboudi, and Kamali (2014) that majority of contemporary environmental problems, are due to inadequate awareness and a short mindset on man-nature relationships, it is necessary to consider teachers' competency on basic climate science concepts as a starting point for students' awareness of climate change.

Failure to enhance awareness of students on climate change and coping strategies, to scale down vulnerability and step-up resilience to climate risks will have further consequences. With low awareness, students will likely be exposed to a more deteriorated environment, air pollution, social dislocation, infectious diseases, and other climate change impacts which will impede effective teaching and learning, consequently posing a threat to academic achievement. Teachers therefore ought to be well-grounded in components of CCE, as a way of improving the adaptive capacity of their learners, and minimizing climate change impacts. CCE has been identified by Eze (2020) as the means to the presentation of useful information on climate change. Climate science literacy has been situated in CCE and environmental education (EE) by Nkoana (2019). Thus, the goals of CCE and EE cannot be achieved without formidable climate science literacy. The author strongly opines that climate science literacy is the foundation upon which the building blocks of other components of CCE must be anchored.

Teachers play a vital role in the delivery of CCE content. Ho and Seow (2017) make a connection between teachers' climate change awareness, the proper conceptualization of climate change, and the likely influence of these on CCE. Also, Herman, Feldman, and Vernaza-Hernandez (2017) expect CCE to provide learners with a solid base of knowledge in the science of climate change, to increase their preparation for appropriate evaluation of controversies and arguments on the subject, and to attain the making of reasoned decisions in the face of climate change. Higde, Oztekin, and Sahin (2017) regard pre-service teachers as future key players whose knowledge, beliefs, values, and behaviour have far-reaching educational implications. This then entails that in-service teachers are presently on the frontline in CCE, and their knowledge matters a lot. Explicitly, Ho and Seow (2015) indicate that "teachers' content knowledge can also have a significant impact on their classroom practice". Although students may have other likely sources of information on climate change, it is expected that since they spend most of their days learning within the classroom, they ought to be provided with well-grounded and scientifically-supported information on climate change from their teachers. The burning prevalent question is whether in-service teachers themselves are prepared for CCE.

Previous studies have suggested the likelihood of CCE competency gaps among teachers. Plutzer et al. (2016) report teachers' inadequate grasp of climate change contents, which not only hinders effective teaching but is likely to lead to acceptance of claims that are not scientifically supported. In the reflection of Oversby (2015) on teachers' exposure to CCE, core teacher-related challenges to effective CCE include its absence in degree contents and novelty of the subject. This largely leads to unpreparedness and lack of confidence to integrate such climate change contents in their subjects. Teacher education therefore ought to be modified to include contemporary socio-environmental issues such as climate change. The study of Cheng and So (2015), while evaluating environmental literacy and teaching of teachers found a lack of commitment to EE in addition to content, pedagogic, and resource gaps. The recommendation of Cebesoy (2019) on the inclusion of CCE in pre-service teachers' education, as well as professional training programmes of in-service teachers, is thus germane. The motivation behind this study is the likelihood that teachers' illiteracy and incompetency in climate science is likely to lead to apathy towards EE and CCE, and could metamorphose into climate change denial among the younger generation, with unpleasant consequences.

This study, therefore, undertakes the identification of teachers' competency gaps in climate science concepts. These concepts are considered rudimentary to understanding how climate works, and are *sine qua non* in grasping the climate change phenomena. Five types of learning need (also called gap) have been identified by Ratnapalan and Hilliard (2002), and Grant (2002) – normative, perceived, prescribed, comparative, and expressed learning needs. This study is concerned with normative needs, which represent variances between established standards for teachers, and their present performance/skill in climate science concepts. Teachers' competency in climate science concepts is indispensable in achieving increased climate change awareness of their students and the populace at large. While acknowledging a dearth of literature on the subject of teachers' capacity in climate science concepts, this study which is the first of its kind in Nigeria fills a vital research gap as it presents state-of-the-art teachers' capacity in the chosen area, using a proven needs assessment framework – the BNAM.

Methodological Framework

The Borich Needs Assessment Model (BNAM) is utilized as a framework for this study. Need assessment for Borich (1980), entails "a discrepancy analysis which identifies the bipolar positions of what is and what should be". This methodological model emerged from a quest to devise a suitable instrument for the collection of survey data, which is to be weighed and then placed in order of priority. Responses from such surveys will then provide a decision-making framework for training programs for the concerned professionals. This model (BNAM) has merits above other techniques like the Delphi technique and the Q-sort methodology. Stufflebeam, McCormick, Brinkerhoff & Nelson (1985) posits that BNAM acquires additional information on respondents' knowledge of a topic and the capacity to employ such knowledge. While the Delphi Technique, only presents a group consensus among purposively-selected experts, the Q-sort methodologies simply request respondents' ranking of topics based on personal perception of importance. Thus, the BNAM improves the validation of the process of evaluating respondents' perceptions on in-service education for a homogenous professional group. We, therefore, presume that the additional information which the BNAM avails increases the chances of developing relevant and highly needed in-service teacher training programmes, with regards to CCE.

Thus with the use of BNAM, 13 basic climate science concepts are identified from relevant literature and curriculum in CCE. The listed concepts being very relevant and important for a rounded discourse in other aspects of CCE are used to elicit teachers' current competence to identify the gap, otherwise called competency gap or teachers' need for training. The process followed in identifying competency gaps is here referred to as needs assessment. There are clear steps recommended for adoption, to achieve the aim of needs assessment. The steps given by Bansal and Tripathi (2017) include identification of competencies related to a specific job/role; identification of competencies held by individuals assigned to the identified job/role; comparison of competencies currently held by individuals on a job/role with competencies required (by expected standard) for the job/role; and finally, outlining the training requirements for individuals on the role as deduced from the comparison. These steps given above summarize the method employed in the determination of climate science competency gaps of teachers in this study.

This BNAM was considered fitting for ascertaining the congruence between teachers' perception of the importance, and competency in the listed climate science concepts. Priority concepts to be included in the future anticipated training programme are estimated and ranked using mean weighted discrepancy scores (MWDS). The MWDS has been successfully used for training needs assessment by Umar, et. al. (2017); McKim, and Saucier (2011); Zarafshani and Baygi (2008); Newman and Johnson (1994); Bar-Rick, Ladewig, and Hedges (1983). The BNAM has been seldom used for evaluation of teachers' training needs, even after several studies have proven its efficacy for the determination of training needs among agricultural extension workers, hence a strong justification for use in this study.

Research questions and hypotheses

The core questions this study seeks to answer are: what are teachers' perceived levels of importance, and competence in basic climate science concepts; what is the capacity gap? The null hypotheses are tested in this study include:

$H0_1$: 'There is no statistically significant difference between the mean importance scores of teachers based on gender, location, academic discipline, educational qualification and years of teaching experience.'

$H0_2$: 'There is no statistically significant difference between the mean competency scores of teachers based on gender, location, academic discipline, educational qualification and years of teaching experience.'

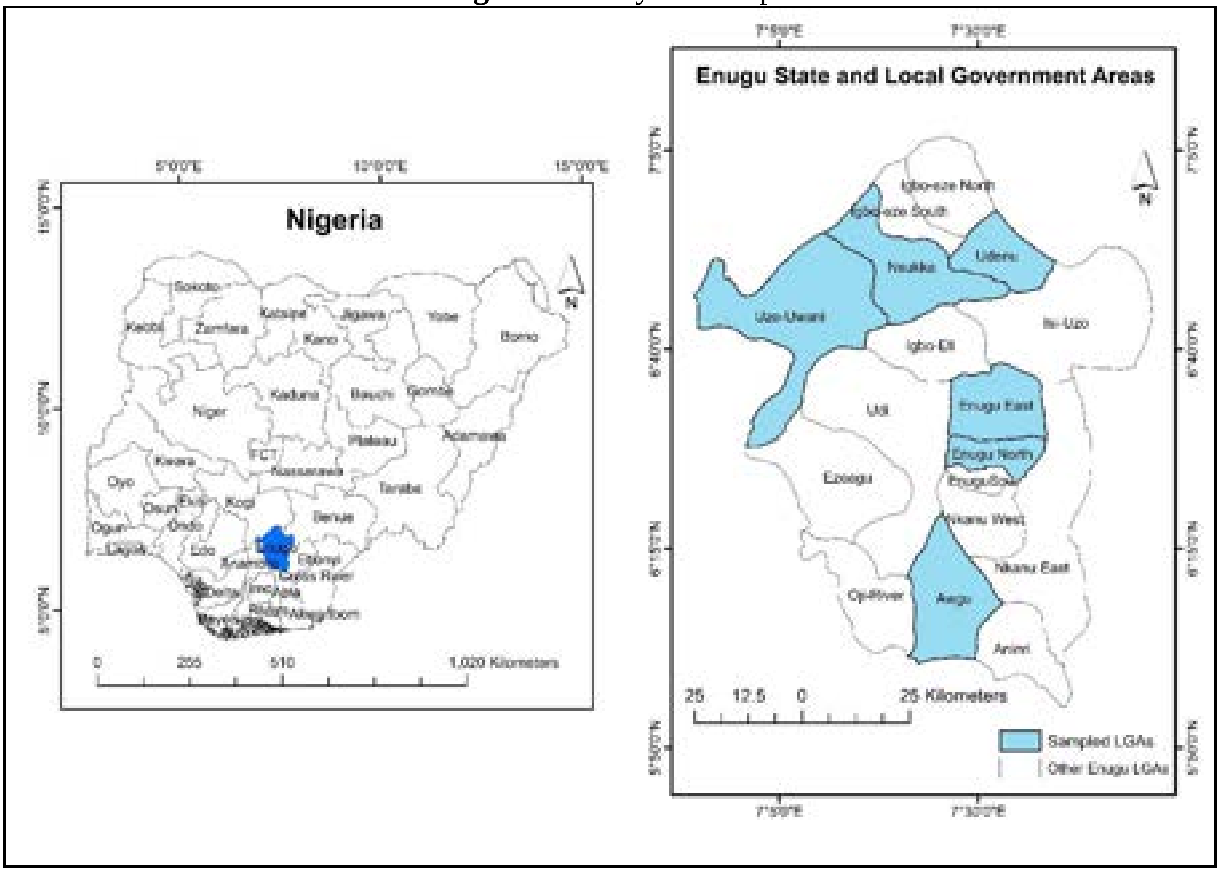
Methods, **Design, area, sample, and instrument used for this study**

A descriptive survey research design is followed by this study. The descriptive survey research design is preoccupied with the description of obtainable characteristics of a particular individual, or of a group of persons, on variables of interest (Kothari, 2004). The design is hence considered suitable for this study, as it entails the assembling of detailed descriptions of existing phenomena with regards to the competence of teachers in climate science concepts for CCE.

The geographical coverage of this study is Enugu state in the southeast geopolitical zone of Nigeria (Figure 1). Four of the six education zones of Enugu State namely Awgu, Enugu, Nsukka, and Obollo-Afor education zones, were used for this study. These areas are purposively selected are most likely to house teachers from different backgrounds, exposures, and experiences due to their strategic locations, thus considered ideal and suitable for this study. All public secondary school teachers in Enugu state constitute the population of this study. The total number of public secondary schools is 291, with a population of 8,338 teachers (Federal Ministry of Education, 2017).

The large population necessitated sampling, hence the use of the Yamane (1967) sample determination formula to obtain a sample size of 400. To avoid shortages due to unreturned and improperly filled instruments, 500 questionnaires were distributed, with 410 retrieved, completed, and providing clean data, considered for use in this study. The sample size for this study is therefore 410 teachers across Enugu State, Nigeria. To represent the four education zones earlier selected, Awgu, Enugu East, Enugu North, Nsukka, Uzo-Uwani, and Udenu Local Government Areas (LGAs) of Enugu state were again selected purposively. These LGAs chosen are known to possess both rural and urban areas, hence are expected to provide a good mix of responses for the study. Every other teacher was randomly chosen to fill out the research instrument.

Figure 1: Study area map



A 13-item researcher-developed instrument named "Teachers' Climate Science Concepts Needs Assessment Questionnaire (TECSCINAQ)", aided data collection for this study. Items of the instrument are basic climate science concepts foundations for CCE. Section 'A' requested relevant personal information of the respondents (teachers); while section 'B' comprises thirteen concepts, requesting teachers to indicate their perceived level of importance, and competence in each concept, in line with BNAM guidelines (Appendix 1). Three experts of Geographical and Environmental Education; and Measurement and Evaluation, face-validated the instrument (TECSCINAQ) to ascertain relevance, suitableness, and clearness of items. The researcher then effected suggested modifications to a large extent, to reflect the views of validators, before producing the final copy that was used for data collection. The reliability of the instrument was determined using Cronbach's alpha as a measure of testing the internal consistency of the instrument. The reliability coefficient of the instrument was given as 0.902 (importance); 0.936 (capacity); and an overall coefficient of 0.896. Thus, the instrument satisfies the validity and reliability criteria for use in this study and is considered suitable.

Borich Needs Assessment Model (BNAM) (Borich, G. D., 1980)

The BNAM as our adopted needs assessment framework has been earlier described. The BNAM was implemented in four stages – identification and listing of climate science concepts; survey of in-service teachers' importance and competence in listed climate science concepts; estimation of competency gaps; and ranking of gaps according to priority.

The first step of the BNAM involves listing competencies. This involves the collection and collation of a list of expected or ideal climate science topics/concepts from relevant curriculum sources, in we expect teachers to possess competency. Following a compilation of a list of expected concepts, a survey is carried out, which is the second step. The survey elicits responses on the importance rating of each concept listed and the respondent's level of competence on each of them. From the survey data, the third step entails the determination of the discrepancy between the importance of a concept and the respondent's competency, using the Mean Weighted Discrepancy Score (MWDS) described in the next section. Finally, a ranking of the concepts is done in descending order. The climate science concept with the highest competency gap/training need is placed at the topmost, with the climate science concept with the least competency gap/training need being at the base. The climate science concepts with the higher ranks are expected to be given priority in future training of in-service teachers.

Data collection, analyses, and interpretation procedure adopted for the study

All ethical procedures were followed in obtaining the data for this study. Approvals were obtained from school principals to access teachers, who are to serve as respondents of the study; and teachers were assured of the confidentiality of their responses. The questionnaires were then allotted directly to the respondents for completion during their free time and retrieved immediately after completion. Some teachers required more time to properly fill the instruments, and in such cases, a return visit was scheduled to retrieve filled instruments. Collected and collated data were analyzed using Microsoft Excel and Statistical Package for the Social Science (SPSS). Mean Weighted Discrepancy Score (MWDS) was utilized to answer the research questions, while statistical tests such as t-test and ANOVA aided the testing of the formulated null hypotheses at a $p<0.05$ level of significance.

For the interpretation and specification of teachers' competency gaps in climate science concepts, the mean scores of the importance of the skills and teachers' capacity in each of the listed competencies were firstly obtained, then an MWDS was calculated to describe the overall rankings for each of the capacities. To determine the MWDS, a discrepancy score was calculated for each respondent on each item/concept by taking the importance rating minus the capacity rating. A weighted discrepancy score was then computed for each respondent on each of the climate science concepts listed, by multiplying the discrepancy score by the mean importance rating. An MWDS for each of the items was then obtained by taking the sum of the weighted discrepancy scores and dividing it by the number of observations.

To minimize likely errors from manually calculating the MWDS, a self-developed Excel-based MWDS Calculator was used. The climate science concepts were ranked using the MWDS to indicate the priority of training needs. Therefore, concepts with higher MWDS are to be given precedence in the design of any teachers' training programme on climate change. This study also follows the benchmark of MDWS >2.0 stipulated by Zarafshani and Baygi (2008), in designating a concept as having competency gaps, requiring teachers' training.

In interpretation of the results obtained from the analyses of TECSCINAQ data, teachers' level of importance in each concept is explained by mean responses (M) as follows: Not Important (M = 1.0-1.49), Of Little Importance (M =1.5-2.49), Somewhat Important (M = 2.5-3.49), Important (M = 3.5-4.49), and Very Important (M = 4.5-5.0); while their level of competence is explained with mean scores as follows: Not competent (M = 1.0-1.49), Slightly competent (M =1.5-2.49), Somewhat competent (M = 2.5-3.49), Competent (M = 3.5-4.49), and Very competent (M = 4.5-5.0). In interpreting the results of the t-test, obtained p-values greater than .05 led to the acceptance of null hypotheses, while p-values less than .05 led to the rejection of null hypotheses. Furthermore, in testing for significance of mean differences using ANOVA, obtained p-value results greater than .05 required no further analysis, whereas p-values less than .05 gave rise to the implementation of multiple comparison (post hoc) tests, to unveil pairwise differences existing between groups. Fisher's least significant difference (LSD) test was adopted for this purpose. The choice of the LSD is in line with the suggestion of Dytham (2011), who stipulates that such a test (LSD) be conducted following a significant ANOVA result, to identify groups that are significantly different from the others.

Distribution of respondents

More female (65.1%) respondents were used in this study. Most teachers had a Bachelor's degree (68%), with more than half of them (69.3%) teaching for the period between one and ten years.

Table 1 contains more details on the frequency of key teacher variables considered in this study.

Table 1: Distribution of respondents by variables

Variable	N	%
Gender		
Male	143	34.9
Female	247	65.1
Location		
Rural	134	32.7
Urban	276	67.3
Discipline		
Science	143	34.9
Social Sciences	132	32.2
Arts	135	32.9
Highest educational qualification		
NCE	87	21.2
B.Sc. and equivalent	279	68.0
M.Sc. and equivalent	41	10.0
Ph.D.	3	0.7
Years of teaching experience		
1 – 5 years	130	31.7
6 – 10 years	154	37.6

11 – 15 years	51	12.4
16 – 20 years	16	3.9
>20 years	59	14.4

RESULTS AND DISCUSSION

The findings of this study are presented in three major headings, in line with the research questions formulated to guide this study. Results of corresponding null hypotheses tested are subsumed in the relevant sections.

Teachers' perceived importance of climate science concepts

The perception of the level of importance of the selected climate science concepts varies. Table 2 shows that teachers perceive as important the following concepts: weather and climatic role of the atmosphere (M=3.81, SD=1.10); atmospheric composition (M=3.92, SD=1.10); altitude (M=3.78, SD=1.17); atmospheric moisture elements (M=3.96, SD=1.15); atmospheric greenhouse gases (M=3.63, SD=1.19); concept of internal climate variability (M=3.51, SD=1.25); wind systems (M=3.67, SD=1.23); difference between weather and climate (M=3.78, SD=1.18); insolation (M=3.63, SD=1.22); inclination of the earth (M=3.60, SD=1.15); and the vertical structure of the atmosphere (M=3.69, SD=1.28). However, elements of weather and climate (M=3.48, SD=1.22); and latitude (M=3.43, SD=1.28) were concepts designated as somewhat important by responding teachers.

Table 2: Ranked teachers' competency gaps on climate science concepts

Rank	Concept	Importance		Capacity		MWDS
		M	SD	M	SD	
1	Elements of weather and climate e.g. precipitation, temperature, humidity, pressure, cloud cover, etc.	3.48	1.22	2.66	1.29	4.22
2	The weather and climatic role of the atmosphere (circulation)	3.81	1.10	2.84	1.33	4.12
3	The composition of the atmosphere	3.92	1.10	2.87	1.37	3.67
4	Altitude	3.78	1.17	2.98	1.39	3.47
5	Atmospheric moisture elements – precipitation and humidity	3.96	1.15	2.89	1.42	3.30
6	Atmospheric greenhouse gases	3.63	1.19	2.78	1.28	3.29
7	Latitude	3.43	1.28	2.59	1.27	3.20
8	The concept of internal climate variability	3.51	1.25	2.69	1.33	3.08
9	Wind systems	3.67	1.23	2.72	1.36	3.06
10	Difference between weather and climate	3.78	1.18	2.91	1.38	3.00
11	Insolation	3.63	1.22	2.74	1.37	2.90
12	Inclination of the earth	3.60	1.15	2.74	1.37	2.90

13	The vertical structure of the atmosphere	3.69	1.28	2.80	1.43	2.82

Further analyses to test the null hypotheses formulated for this study show that the perceived level of importance of the listed climate science concepts did not vary by teachers' gender, location of service, academic discipline, and highest academic qualification (Table 3). However, mean scores of teachers' perceived level of importance of listed climate science concepts vary based on their years of teaching experience. The ANOVA results (p=.014) indicate a significant difference in the mean score across the groups of years of teaching experience, hence requiring further analysis.

Table 3: Results of hypotheses testing statistics based on teacher variables

Variable	**Importance**		**Capacity**		**Remarks (statistics)**
	Mean	**Sig.**	**Mean**	**Sig.**	
Gender					
Male	3.66	.819	2.79	.916	t-test
Female	3.68		2.80		
Location					
Rural	3.70	.552	2.80	.360	t-test
Urban	3.65		2.76		
Discipline					
Science	3.78		2.83		
Social Sciences	3.59	.163	2.93	.022*	One-way ANOVA
Arts	3.67		2.60		
Highest educational qualification					
NCE	3.63		2.84		
B.Sc. and equivalent	3.70	.898	2.76	.736	One-way ANOVA
M.Sc. and equivalent	3.72		2.87		
Ph.D.	3.72		2.33		
Years of teaching experience					
1 – 5 years	3.65		2.76		
6 – 10 years	3.57		2.85		
11 – 15 years	3.70	.014*	2.71	.088	One-way ANOVA
16 – 20 years	3.84		3.33		
>20 years	3.99		2.57		

*. *p* is significant at the 0.05 level.

Table 4: Selected Fisher's LSD multiple comparison results

(I) Teaching experience	(J) Teaching experience	Mean Difference (I-J)	Std. Error	Sig.
>20yrs	**1-5 years**	**.3386822****	**.1248775**	**.007**
	6-10 years	**.4196397****	**.1218020**	**.001**
	11-15 years	*.2884073*[NIS]	*.1521025*	*.059*
	16-20 years	.1530313	.2242310	.495

**. The mean difference is significant at the .01 level.
[NIS]*Italicised figures are nearly significant*

The multiple comparison (post hoc) test results (Table 4) show that teachers who have taught for more than 20 years can identify the climate science concepts as being important, with the highest mean score (M=3.99) among the groups. Their responses are therefore considered statistically significantly different from those with teaching experiences between 1 to 10 years. Interestingly, teachers with 11 to 15 years of experience have nearly differing significant mean scores (M=3.84; p=.059) but passed the benchmark of the probability level (p=.05) set for this study.

Teachers' competence in climate science concepts

The level of competence of teachers on the selected climate science concepts used in this study also differs. The results of analyzed data indicate that teachers are somewhat competent in all listed concepts (Table 2). Somewhat/moderate competence in climate science concepts listed, presupposes a foundational difficulty in the delivery of CCE contents, as teachers ought to be very competent in the contents they are expected to facilitate.

Again, further statistical analyses were implemented to unravel variables that could have influenced teachers' competency in proficient delivery of the listed climate science concepts. Teachers' competency seems not to differ based on their gender, location of service, academic qualification, and years of teaching experience (Table 3). Academic discipline was identified as the sole influencer of teachers' competency in the listed climate science concepts, from the ANOVA value (p=.022). Social science teachers had the highest competency (M=2.93), followed by science teachers (M=2.83) and art teachers (M=2.60). The multiple comparison results (Table 5) indicate that art teachers' mean competency scores differ significantly from that of social sciences (p=.007), and are nearly significant from science teachers (p=.057).

Table 5: Selected Fisher's LSD multiple comparison results

(I) Academic discipline	(J) Academic discipline	Mean Difference (I-J)	Std. Error	Sig.
Arts	*Sciences*	*-.231235* NLS	*.1212561*	*.057*
	Social sciences	**-.3334413****	**.1236852**	**.007**

**. The mean difference is significant at the .01 level.
NLS *Italicized figures are nearly significant*

Even though social science teachers are the least number of respondents, they had the highest mean competency scores. This could be attributed to Geography teachers being grouped in the social science discipline. Most of the listed concepts are included in the Geography curriculum as lesson contents. A brief discussion on the contents of some science and social science school subjects with contents related to climate science has been captured in Eze (2020). Additionally, a curious inquiry was made into the nearly significant ANOVA value (p=.088) of years of teaching experience as influencing teachers' competency (Table 6). The results show that the mean competency score of teachers with 16 to 20 years of experience (M=3.33) differs significantly from that of teachers with 1 to 5 years (M=2.76), and 20+ years of experience (M=2.57).

Although the findings of this study agree with Okeowo (2015) that years of experience minimizes the need for training, the two studies differ on an educational level as a factor that reduces competency gaps. While Okeowo (2015) also opine that higher educational qualification erodes competency gaps and the need for training, this study posits differently, as all respondents irrespective of academic qualification, had more or less the same mean score on competency, as there was no significant difference in their mean competency scores. In the light of these results, the view of Osuji (2014) on 'dire need for capacity building of teachers in Nigeria to bring the desired transformation of the Nigerian educational system' is worth consideration, notably because climate change apathy is not a path to thread.

Table 6: Selected Fisher's LSD multiple comparison results

(I) Teaching experience	(J) Teaching experience	Mean Difference (I-J)	Std. Error	Sig.
16-20 years	**1-5 years**	**.5773176***	**.2681924**	**.032**
	6-10 years	.4858891	.2658923	.068
	11-15 years	**.6216063***	**.2900641**	**.033**
	20+ years	**.7576597****	**.2853293**	**.008**

**. The mean difference is significant at the .01 level.
*. The mean difference is significant at the .05 level.

Competency gaps requiring teachers' professional development

From the application of the BNAM framework and calculation of the MWDS, teachers' competency gaps in climate science concepts have been identified. The authors find the use of the BNAM fascinating. Although each respondent is left to objectively assess and assign their perceived level of importance and competence on each concept, competency gaps representing the entire population were identified. Furthermore, the MDWS was calculated for each climate science concept and subsequently ranked in descending order (Table 2) in such a way that concepts with large competency gaps in which teachers would require more training are placed atop. Generally, with the least ranked climate science concept having an MWDS=2.82 and the benchmark (MWDS=2.0) of Zarafshani and Baygi (2008), for determination of competency gap requiring training, the results indicate that teachers would require training on all the concepts listed, without exception, although at varying degrees. In filling these identified competency gaps, in-service training, workshops, refresher courses, electronic training, study leave, and provision of teaching materials have been advocated by Okenjom, Ogar, Bake, and Eze-Anyim (2016) as training avenues must be considered.

Adopting any of the aforementioned approaches will bring teachers to the same level of exposure to these climate science concepts, thus closing up any competency gaps ascribable to either academic discipline or years of teaching experience. Davis and Yi (2004) found that training programmes, both for in-service and pre-service teachers, could serve as a means to update teachers' knowledge, interaction, and improve their knowledge structure. Hence, in-service teachers can enhance their competency in climate science concepts through training programmes. The need and benefits of in-service programmes have been discussed elsewhere in Ibiang, Ashuar, and Ogar (2016), with Osuji (2014) providing a list of institutions responsible for teachers' professional in-service training.

Such training should focus on teachers' acquisition of scientifically-supported evidence and information for easy recognition of unscientific claims, as advocated by Plutzer et al. (2016). Also, it is not out of place to consider the thoughts of Cheng and So (2015) on reconsideration of teacher education programmes to concentrate on improvement of both content knowledge and commitment to EE, and by extension CCE. If teachers who have recently joined the profession are not possessing the highest competence in climate science concepts, it reveals a defect in teacher-preparation programmes. Such defects ought to be presently addressed through relevant curriculum innovations and interventions.

Conclusion

This study has provided an evidence-based illustration of the application of the Borich needs assessment model, to determine the competency gaps of teachers in basic climate science concepts in Enugu state, Nigeria. Teachers perceive all listed climate science concepts as important. However, their level of proficiency in the delivery of the same concepts is unacceptable, being only somewhat/moderately competent in all the listed concepts. Perception of the level of importance is influenced strongly by years of teaching experience, as teachers who have tough for more than 20 years rightly ascribed high importance to each listed concept. Teachers' competency is chiefly influenced by academic discipline, in favor of social science teachers, and partly influenced by years of teaching experience. Overall, teachers' in-service training programmes for improved CCE must commence at all basic climate science concepts considered in this study, with elements of weather and climate; weather and climatic role of the atmosphere, being the topmost. There is an urgent need for the design and implementation of training programmes to upgrade teachers' competency in climate science concepts to stem the tide of low awareness of climate change among students.

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Declaration of competing interests

The authors hereby declare that they have no competing interests.

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Appendix: Data Collection Instrument

TEACHERS' CLIMATE SCIENCE CONCEPTS NEEDS ASSESSMENT QUESTIONNAIRE (TECSCINAQ)

SECTION A: Personal Information

Gender: Male Female **Location of service:** Rural Urban

Academic Field: Sciences Social Sciences Arts

Highest Educational Qualification:

NCE B.Sc./B.Ed./B.A. M.Sc./M.Ed/M.A Ph.D

Years of Teaching Experience:

1-5years 6-10years 11-15years 16-20years >20years

Section B: Capacity Building Needs

Circle appropriate responses as follows

KEY ***(Please read the scoring below before responding to Items 1 – 13)***

Importance of climate science concept: 1=Not Important; **2**=Of Little Importance; **3**=Somewhat Important; **4**=Important; **5**=Very Important

Level of teachers' competence on climate science concept: 1=Not Competent; **2**=Slightly Competent; **3**=Somewhat Competent; **4**=Competent; **5**=Very Competent

	Kindly indicate the level of importance you attach to each of these climate science concepts and rate your level of competence in knowledge (and proficiency of delivery) of each of the concepts?	**Rate the importance of this concept**						**Rate your level of capacity on this concept**				
1	The vertical structure of the atmosphere	1	2	3	4	5		1	2	3	4	5
2	The composition of the atmosphere	1	2	3	4	5		1	2	3	4	5
3	The weather and climatic role of the atmosphere (circulation)	1	2	3	4	5		1	2	3	4	5
4	Difference between weather and climate	1	2	3	4	5		1	2	3	4	5
5	Elements of weather and climate e.g. precipitation, temperature, humidity, pressure, cloud cover, etc	1	2	3	4	5		1	2	3	4	5
6	Wind systems	1	2	3	4	5		1	2	3	4	5
7	Insolation	1	2	3	4	5		1	2	3	4	5

8	Inclination of the earth	1	2	3	4	5		1	2	3	4	5
9	Altitude	1	2	3	4	5		1	2	3	4	5
10	Atmospheric moisture elements – precipitation and humidity	1	2	3	4	5		1	2	3	4	5
11	Latitude	1	2	3	4	5		1	2	3	4	5
12	The concept of internal climate variability	1	2	3	4	5		1	2	3	4	5
13	Atmospheric greenhouse gases	1	2	3	4	5		1	2	3	4	5

EFFECTS OF CHROMIUM (III) ON SOIL BACTERIAL NUMBERS AND PHYTOREMEDIATION POTENTIALS OF *Arachis hypogea* and *Vigna unguiculata*.

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Abstract:This study was undertaken to evaluate the effect of chromium (III) nitrate on soil bacterial numbers, growth performance, and phytoremediation potentials of two staple leguminous crops, namely cowpea (*Vigna unguiculata*) and groundnut (*Arachis hypogea*). Pristine sandy loam soil samples were polluted with chromium (III) nitrate salt at four different levels (50mg/kg, 100mg/kg, 200mg/kg, and 400mg/kg) in triplicates. Bacterial enumeration was done by plate count procedures using nutrient agar while phytoaccumulation of chromium in both legumes was determined using Atomic Absorption Spectrophotometer after pulverization and digestion of the plants with HCl/HNO_3 (3:1 v/v). There was a significant ($P < 0.05$) retarding effect of this metal on the study parameters. A consistent decrease in the total bacterial count in response to an increase in dosage of the metal salt was observed. The mean counts showing its effect on soil bacterial numbers at the fourth week are: 1.83×10^{10}cfu/g, 1.23×10^{10}cfu/g, 8.00×10^{9}cfu/g and 5.00×10^{9}cfu/g for 50mg, 100mg, 200mg and 400mg respectively unlike the control which was 1.57×10^{11}cfu/g. Chromium at 400mg increased germination times for groundnut and cowpea by 5 days and 3 days respectively. Preferentially, the roots were found accumulating more of the pollutant than the shoots and the accumulation was metal-dose-dependent. Cowpea demonstrated a higher clean up potential (bioconcentration factor=3.99mg/kg) than groundnut (bioconcentration factor = 0.8mg/kg), making it a better candidate for the phytoremediation of chromium-contaminated soils.

***Keywords*:** Chromium (III) nitrate, bacteria, cowpea, groundnut, phytoremediation.

INTRODUCTION

Chromium (Cr) is one of the naturally occurring elements found in rocks, soils, and volcanic dust. Its presence in the environment occurs in two main forms, namely, chromium (III) and chromium (VI). It causes a severe and deleterious effect on human health by altering body metabolism, while in plants it reduces productivity by the causation of chronic diseases, loss of chlorophyll, and protein contents.

High levels of pollutants in the soil also negatively impact microbial growth and metabolism.

Shanker et al. (2005) observed that chromium's impact on the physiological development of plants depends on the metal speciation, which is responsible for its mobilization, uptake, and subsequent toxicity in the plant system. Heavy metal species commonly found in the soils as a result of human activities include copper (Cu), zinc (Zn), nickel (Ni), lead (Pb), cadmium (Cd), cobalt (Co), mercury (Hg), chromium (Cr) and arsenic (As), etc). Some of them act as micronutrients in small concentrations for the development of living organisms, but when bioaccumulated over time they become toxic to life.

The risk associated with polluted soils is the contamination of the food chain. When plants grow on polluted soils, they become potential threats to human and animal health. Plants may also have their growth sharply reduced by high levels of toxic elements in their tissues, causing a decrease in crop yields and further economic loss. This creates the need for remediation of polluted soils and one of the techniques currently advocated is phytoremediation which is the use of plants to remove, transfer, stabilize and/or destroy contaminants in the soil or groundwater. In phytoremediation, a plant can be classified as an accumulator, excluder, or indicator according to the concentration of metals found in its tissue.

Microorganisms in the rhizosphere of plants growing on trace metal contaminated soils play an important role in phytoremediation. These microorganisms can survive and serve as effective metal sequestering and growth-promoting bioinoculants for plants in metal stressed soils (Rajkumar and Freitas 2008). They mitigate the toxic effects of these heavy metals on plants through the secretion of acids, proteins, phytoantibiotics, and other chemicals (Denton, 2007). Because of these and other beneficial roles of soil microbes their safety is of paramount concern to agriculturists and environmentalists.

Owing to the growing increase in heavy metals pollution of the soil, occasioned by industrialization, there is also a concomitant concern for plants and microbial safety, considering their significant roles in the ecosystem. This research was therefore carried out to evaluate the impact of chromium on soil microbial activities, growth performance, and phytoremediation potentials of *Arachis hypogea* (groundnut) and *Vigna unguiculata* (cowpea).

MATERIALS AND METHODS

Sample Collection

Soil samples were collected from the Plant Science and Biotechnology Garden, University of Nigeria, Nsukka at a depth of 0 - 15cm. viable seeds of both cowpea and groundnut were purchased from Ogige market in Nsukka metropolis and stored at room temperature for 24h. Analytical grade nitrate salt of chromium, $Cr(NO_3)_2 \cdot 9H_2O$, was purchased from Nsukka Market.

Determination of the Effects of Chromium on Soil Bacterial Population

Pristine sandy loam soil was air-dried, sieved, and dispensed in 100g weights into twelve 250ml conical flasks. The soil samples were contaminated with four different levels of Cr with each level in three replicates. A control experiment made up of three unpolluted soil samples was also set up. The conical flasks were watered periodically to sustain the microorganisms. Bacterial analysis was done using 1.0g of soil collected from each flask at one weekly interval over four weeks. The population of viable bacterial cells in each soil sample was determined by the spread plating technique as described by Wistreich (1997).

Planting Experiments

After the soil samples have been air-dried and homogenized they were sieved and dispensed in 3kg weights into 24 (20 cm deep × 18 cm diameter) plastic pots, each perforated at the bottom. Each of the four different levels of $Cr(NO_3)_2 \cdot 9H_2O$ (50mg/kg, 100mg/kg, 200mg/kg, and 400mg/kg) was used in triplicates to treat the soil in the pots. Soil samples that received no metal treatments were prepared and kept as control. Seven days after soil treatments, four viable seeds each of groundnut and cowpea were planted in each plastic pot. This was done in triplicate along with the control. The pots were watered with 200ml of water every four days for eight weeks. The growth rates, germination percentage, and metal uptake potentials of the plants were recorded.

RESULTS

Effects of Chromium the Germination, Growth Performance and Phytoremediation Potentials of *Vigna unguiculata*.

Tables 1and 2 show the effects of chromium on germination time, germination percentage, nodulation, weight and root length, metal uptake along with BCF and TF potentials of *Vigna unguiculata* and *Arachis hypogea*. Germination time in both plant seeds increased with an increase in chromium dosage. In both control and 50mg/kg treated soil, all the seeds sown in each pot germinated whereas, in the other levels, there was a concomitant reduction in the number of germinated seeds as the dose increased. The uptake of chromium by cowpea was also found to be concentration-dependent. The root was seen to be a better site for chromium accumulation than the shoot, though at 400mg/kg treated soil only. However, chromium accumulation was not observed in both the shoot and root parts of the groundnut.

Table 1: Effects of chromium on germination, general vegetative growth, metal uptake and translocation potentials of *Vigna unguiculata*

Parameters	50mg	100mg	200mg	400mg	Control
Germination time (days)	4.5±1.29	6.5±1.29	7±1	9±1	4±1
Germination percentage (%)	100	92	83.33	41.67	100
Shoot metal uptake (mg/kg)	No	No	No	No	No
Root metal uptake (mg/kg)	No	No	No	0578±0.004	No
Bioconcentration factor (mg/kg)	No	No	No	6.31	No
Translocation factor (mg/kg)	No	No	No	No	No

Nodulation	31.67±1.53	24.00±1.00	13.33±1.53	6.33±1.53	41.06±0.42
Wet weight (mg)	3.16±0.06	1.93±0.15	1.7±0.26	1.33±0.15	2.9±0.10
Dry weight (mg)	1.73±0.15	1.48±0.07	0.96±0.15	0.88±0.15	2.05±0.05
Root length (cm)	14.8±0.31	12.8±0.3	11.4±0.21	10.5±0.61	13.0±0.75

*No = Not observed

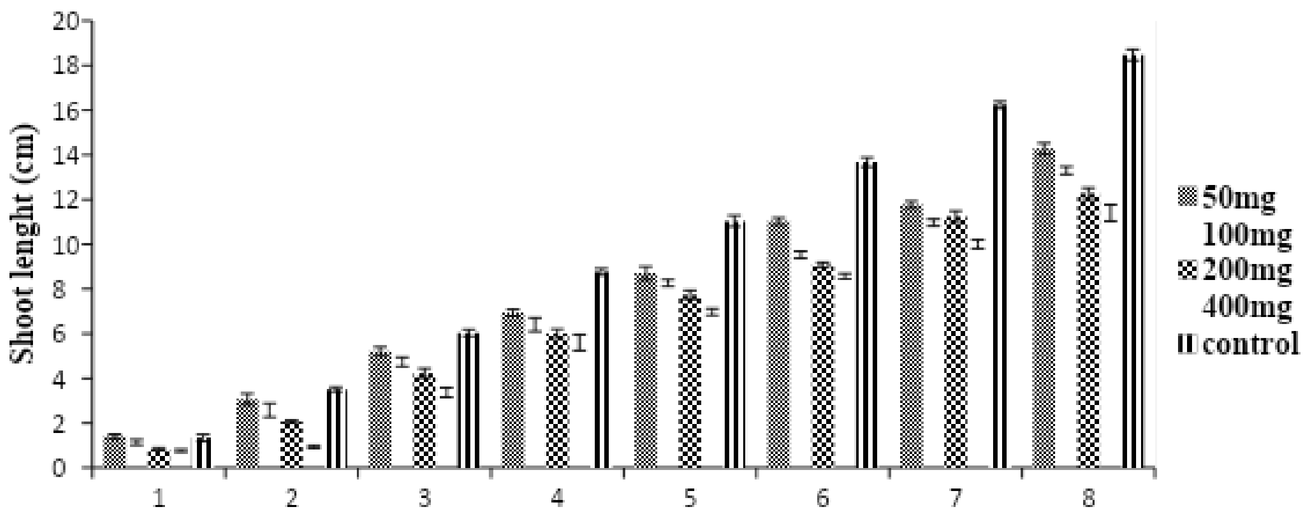
Table 2. Effect of chromium on germination, general vegetative growth, metal uptake along with BCF and TF potentials of *Arachis hypogea*

Parameters	50mg	100mg	200mg	400mg	Control
Germination time (days)	4.5±1.29	5.5±1.29	7±1	8.75±1.7	4±1
Germination percentage (%)	100	91.76	66.76	41.47	100
Shoot metal uptake (mg/kg)	-	-	-	-	-
Root metal uptake (mg/kg)	-	-	-	-	0.005±0.002
Bioconcentration factor (BCF)	-	-	-	0.005	-
Translocation factor (TF)	-	-	-	-	-
Nodulation	50.33±1.53	41.33±0.57	30.33±1.53	20.33±1.53	65.33±1.53

Wet weight (mg)	5.433±0.25	4.46±0.15	3.36±0.25	2.93±0.12	6.33±0.15
Dry weight (mg)	3.27±0.15	2.86±0.15	2.13±0.15	1.76±0.15	4.56±0.12
Root length (cm)	13.33±1.15	12.33±1.26	9.53±0.75	8.73±0.862	13.1±1.21

Effects of Chromium on the Shoot Growths of Cowpea and Groundnut as well as on Bacterial Numbers.

Figures 1 and 2 depict the effects of different levels of chromium on the shoot lengths of cowpea and groundnut respectively. Chromium exhibited a dose-dependent retardation effect on the shoot growth of the legumes. This dose-dependent retardation effect of chromium was also observed on bacterial growth (Figure 3).



1 2 3 4 5

Figure 1: Effects of Different Levels of Chromium on the Shoot Length of Cowpea Grown in Sandy Loam Soil.

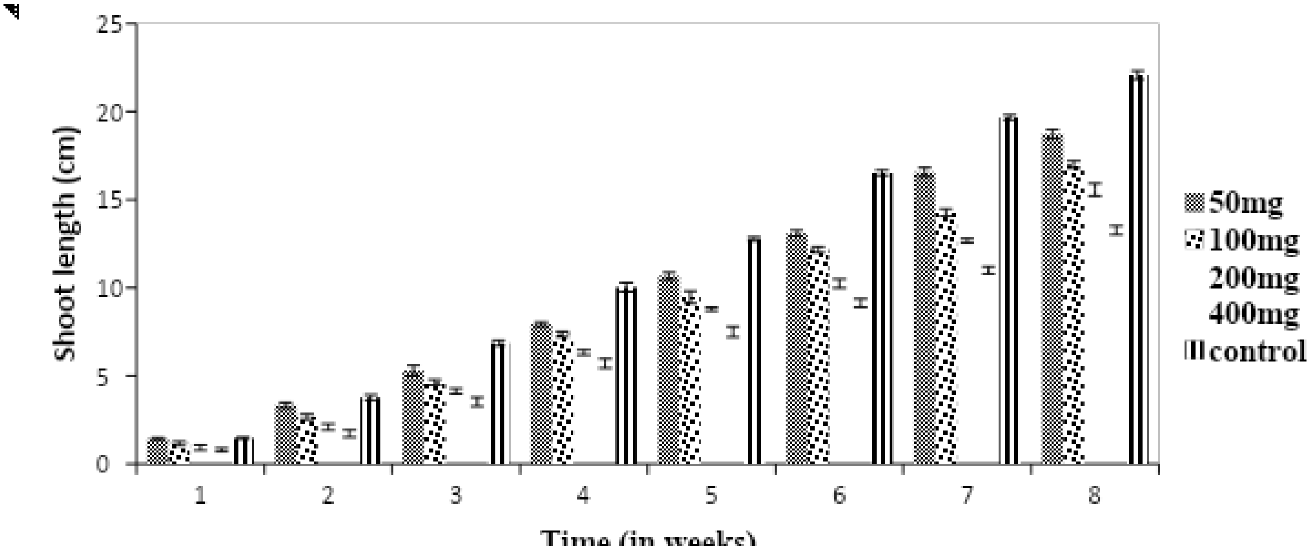


Figure 2: Effect of Different Levels of Chromium on the Shoot Length of Groundnut Grown in Sandy Loam Soil.

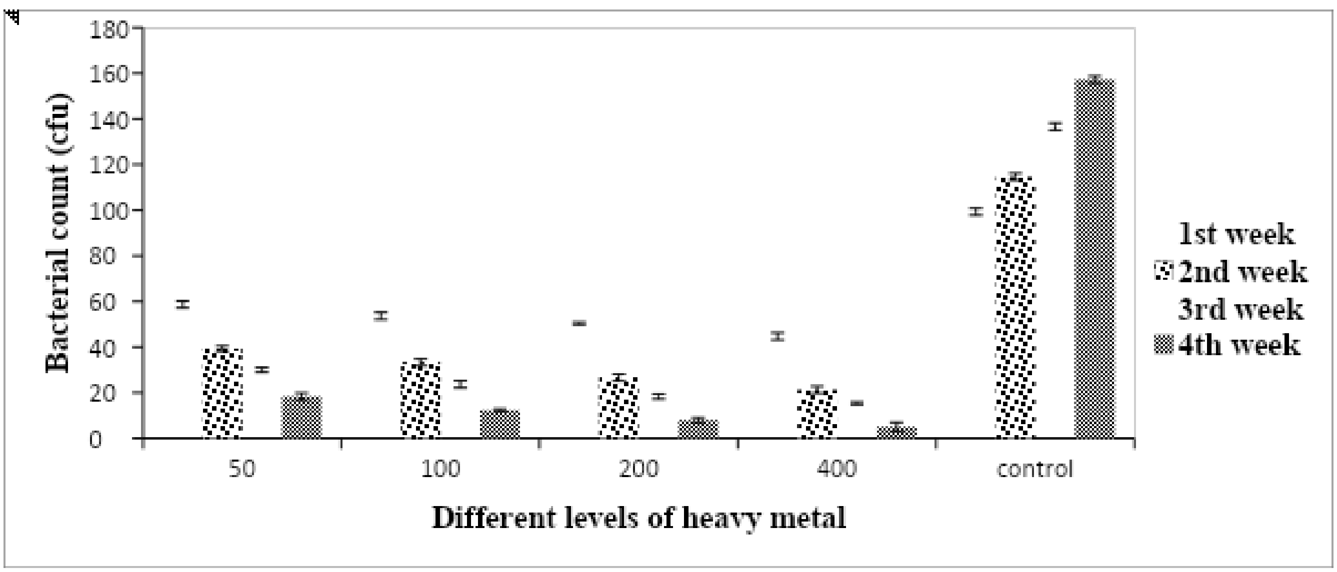


Figure 3: Effect of Different Levels of Chromium on Bacterial Population

DISCUSSION

The deleterious effect of chromium on soil bacterial population was found to increase with the increase in levels of contamination. The higher the metal dose, the more significant ($P < 0.05$) the retardation effects chromium had on the total bacterial population count. Ghorbani et al. (2002) in their study, identified a change in bacterial community structure (microbial biomass) as a result of heavy metal toxicity in the soil environment. Once a rise in soil metal concentration occurs, it becomes uninhabitable for microbial communities and unsuitable for crop production.

The first sign of plant growth is seed germination and it is regulated by several physical and physiological factors. The report has shown that the growth and physiology of plants are indirectly affected by soil metal contents (Luilo and Othman 2006). The reduced germination (germination time and percentage) in both plants (cowpea and groundnut) as observed in our study could be attributed to metal toxicity. Shafiq et al. (2008) attributed it to the accelerated breakdown of stored nutrients in seeds and alteration of selective permeability properties of cell membranes. From the results, it was observed that chromium had a more adverse effect on the germination and growth of groundnut than cowpea. This shows that cowpea probably has a higher intrinsic resistance to chromium than groundnut. Hu et al. (2015) suggested that damage of chloroplasts and possibly reduction in photosynthesis could lead to a significant reduction in shoot lengths of plants grown in chromium polluted soil.

The observed decrease in the biomass of cowpea and groundnut is also an index of chromium phytotoxicity. Results from the present research show that the two plants used in the study were not able to facilitate the mobility of chromium to the shoot region at all levels of treatment. However, trace amounts were observed to be domiciled within the root region, indicating a low mobility potential of chromium in *Vigna unguiculata* and *Arachis hypogea*. It could be that the two plants have barriers against chromium transport or lack mechanisms for chromium transport from root to their shoot part.

CONCLUSION

Findings from this work show:

- That chromium retards the soil bacterial population.
- That chromium inhibits germination and growth in groundnut and cowpea.
- That cowpea however has better phytoremediation capacity than groundnut for soil heavily polluted with chromium.

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DECARBONIZATION AND SUSTAINABLE DEVELOPMENT GOAL 13: A REFLECTION OF THE MARITIME SECTOR.

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Abstract: Fossil fuels as the beacon of industrialization emit carbon dioxide more than any other source of energy. Carbon dioxide emission among other Green House Gases is the dominant gas responsible for global warming and the damaging impact of climate change. Given the enormity of the impact of climate change, United Nations General Assembly in 2015 adopted 17 Sustainable Development Goals (SDGs) of which goal 13 was a call for climate action to mitigate the drastic effect of climate change by reducing global warming to 2˚C above pre-industrial levels or 1.5˚C by 2030. Shipping in the maritime sector accounts for over 80% of the global trade and is hugely dependent on Heavy Fuel Oil (HFO) and emits about 2.7% of the global carbon dioxide. Against this backdrop, the concern of this study is, therefore, to ascertain the level of progress in global decarbonization for sustainable development focusing on shipping in the maritime sector. The documentary method of research was adopted for the study while Win-Win Solution served as the conceptual framework. The analyzed the efforts to decarbonize the shipping industry and determine if the maritime sector will likely achieve the green shipping target by 2030. The study revealed that progress in shipping industry decarbonization is dependent on the alignment of alternative fuels with new technologies. The study recommended that government intervention in funding maritime sector decarbonization is a prerequisite to realizing the 2030 – 2050 green shipping targets.

***Keywords*: Decarbonization, Global warming, Carbon dioxide, Shipping, Maritime.**

1.1 Introduction

One of the biggest global challenges facing the world before and after the COVID-19 pandemic is climate change caused by Green House Gases' emission chiefly carbon dioxide, giving rise to increasing earth temperature, global warming, and causing rising sea levels and extreme weather events. Taala (2020a) maintained that "2016 was the warmest year and 2019 was the second warmest while 2010 – 2019 was the warmest decade on record". However, Fountain, Migliozzi & Popovich (2021) assert that "2020 was effectively tied with2016 for the hottest year on record, as global warming linked to greenhouse gas emissions showed no signs of letting up". According to Guterres (2020), "as the new year approaches, the challenges are clear: the #COVID-19 response will consume 2021 and the climate crisis will drive the decade". For United Nations, "2021 can be a year of a quantum leap towards carbon neutrality". As reiterated by United Nations, "making peace with nature is the defining task of the 21st century. It must be the top priority for everyone everywhere"

Given the preceding realities, the global community under different fora such as the United Nations Framework Convention on Climate Change, Kyoto Protocol, Sustainable Development Climate Action, Paris Agreement, Green New Deal, etc have sought ways to reduce global carbon dioxide emission and global warming below two degree Celsius (2°C) or below one and half-degree Celsius (1.5°C), if possible. The highest annual decline in carbon dioxide emission since after Second World War was recorded in 2020 due to the short down of the global economy as a result of the COVID-19 pandemic. According to McSweeney & Tandon (2020), "Global carbon dioxide (CO2) emissions from fossil fuel and industry are expected to drop by 7% in 2020, as a result of the effects of Covid-19 lockdowns". Experts have argued that this improvement is only temporary because climate change is not on pause and once the global economy begins to recover from the pandemic, emissions are expected to return to higher levels.

According to Global Carbon Project-GCP (2020) estimate, "carbon dioxide emission clocked in at 34 billion tones i.e a fall of 2.4GtCO2 compared to 2019. It further indicated that Fossil CO2 emissions had fallen in all the world's biggest emitters – 12% in the US, 11% in the EU, 9% in India, and 1.7% in China (McSweeney & Tandon, 2020)". These biggest emitters are equally the biggest industrialized nations. Carbon dioxide "remains in the atmosphere and Oceans for centuries. This means that the world is committed to continued climate change regardless of any temporary fall in emissions due to the Coronavirus epidemic (Taala, 2020b)".

Shipping had been described as the most internationalized industry and assuming it is a country, it would be the 6th biggest Green House Gas emitter. International vessels with an "intricate web of multi-state ownership transverse the global commons of the high seas carrying goods that have been produced or extracted in piecemeal all over the world for delivery to national and international markets. There is virtually nothing about the industry that is not international (Cowing, 2017)". According to Schlanger (2018), "roughly 90% of all internationally traded goods get to where they're going by sea. The ships that transport these goods are a massive source of greenhouse gases, in part because they use "bunker fuel", the dregs of the fossil-fuel refining process. It's extremely cheap, one reason you can get international goods all over the planet. But it's also one the world's dirtiest diesel fuels, with a much higher carbon content than the diesel fuel used in cars". In the view of Green (2018), "Ships are very fuel-efficient in terms of transporting cargo, but the Heavy Fuel Oil (HFO) used by 80% of the world's shipping fleet is nasty stuff. It's more carbon-intensive than other fuels and produces other Green House Gases as well as air pollutants such as sulfur dioxide, which causes acid rain". According to International Council on Clean Transportation (ICCT) study, "HFO use increased by 75% between 2015 – 2019 (Gerretsen, 2020)". Gallucci (2017), stressed

that "the industry's reliance on high-carbon fuel poses a major stumbling block for global efforts to rein in pollution and curb global warming. If left unchecked, its carbon footprint is expected to soar in coming decades, just as emissions from cars and power plants decline that of shipping could cancel out progress in other sectors".
International Maritime Organization (IMO) remarked that "carbon emission from shipping could rise to as much as 250% by 2050 as the world economies grow and expand due to increasing in global trade. According to International Transport Forum (2017), "what drives the growth of global shipping emissions is the rise of international trade, projected to almost double by 2035 and growing at a rate of approximately 3% per year until 2050". Cames et.al (2015), "in their study of mitigation targets for international aviation and maritime transport, forecasted that the shipping industry could be responsible for 17% of global CO2 emissions in 2050 if left unregulated".

Given the internationalization and complex nature of the shipping industry which makes it difficult for its emission estimation and control to be captured by national governments, it came under the regulation of the International Maritime Organization (IMO), a United Nations specialized agency that "continually contribute to the global fight against climate change, in support of the UN Sustainable Development Goal 13, to take urgent action to combat climate change and its impacts (IMO, 2019)". As a way of combating Green House Gases (GHGs) emission particularly CO2, the IMO in 2008 came up with the first-ever initial strategy of reducing GHGs emission in the shipping industry with "the ambition of reducing the shipping industry's greenhouse gas emissions by at least 50% by 2050 and reducing the carbon intensity of emissions by 40% by 2030, and 70% by 2050 compared to 2008 levels (Hellenic Shipping News, 2020)". The concern of this study is, therefore, to ascertain the level of progress in decarbonizing the shipping industry, analyze the efforts towards decarbonizing the industry, identify barriers and determine if the maritime sector will likely achieve green shipping target by the year 2030.

2.1 Conceptual Framework

The concept upon which this study is premised is a win/win solution. It is an approach in which parties collaborate or contribute towards a common plan of action to achieve a common goal for their common benefit. Decarbonization of the shipping industry is an "all hands on deck affair" to reduce global warming; achieve green shipping and safety of the planet. It requires the genuine commitment and collaboration of all stakeholders in the industry for the advantage of the human community and vice versa.

3.1 Level of progress in decarbonizing the shipping industry

Progress is incremental; however, experts argue that "incremental progress, past, and present, is unsatisfactory — in part because of the outsize influence of the shipping industry in the IMO rulemaking process. Indeed, it is common practice to have private shipping registry companies represent nation-states at the IMO (Green, 2018)". These private interests influence regulations to fit into their business interest and program. In doing this, they slow progress in the decarbonizing shipping industry in favor of their business interest. This is more so when carbon dioxide emissions from international shipping cannot be attributed to any specific nation. There is nothing much wrong with the incremental approach, "Ships are long-term capital investments, as such taking older models out of commission before the end of their natural life is a costly proposition (Green, 2018)'.

The shipping industry is complex because of complex interest and huge capital involvement representing governments, NGOs, and private interests. Its part of the reason the shipping industry lacks a central body that enforces regulations and IMO as the regulating body can not be forceful in rule implementation for decarbonization. For instance; it takes a huge cost to build or own a ship, "the economical life span of an average ship is 20-30 years which means that ships built now and in recent past will be the ships sailing by 2050 and retrofitting an existing ship to a new propulsion system is, if possible, a very costly affair. So every ship built from now on, ought to be emission-free, or at least almost emission-free (Langelaan, 2019)". This is creating a crisis in the shipping industry as there is a fall in demand for ships by ship-owners due to uncertainties about which of the renewable alternative energy will be commercially viable and technically suitable for new shipping technologies. In addition to that; is the acceptability by the industry to achieve carbon intensity emissions reduction of 40% by 2030, and 70% by 2050 compared to 2008 levels. According to the forecast of the Organization for Economic Cooperation and Development (OECD) in (Green, 2018) "the new technologies, alternative fuels and renewable energy could almost fully decarbonize the shipping industry by 2035. That would eliminate the equivalent of the annual emissions of 185 coal plants. Though these ambitious goals are technically feasible, politics are the main constraint".

At any realm, "cost and benefit" is central to the level of progress in the decarbonization of the shipping industry or in terms of IMO enforcing emission reduction, much less when IMO has no enforcement mechanism. IMO will have to implement what is generally acceptable to all parties due to cost and is usually dependent on member states for enforcement of regulations. According to Majuro (2017), "IMO treaties only come into force on the basis when a certain proportion of the world fleet has backed them". Some environmental experts have equally argued that of the major carbon-emitting industries shipping is the least. Therefore, the decarbonization of the industry ought to be gradual and within the scope and interest of parties involved due to its capital intensity.

3.2. EFFORTS TOWARD DECARBONIZATION OF THE SHIPPING INDUSTRY

The efforts to decarbonize 'International Shipping' can best be described by International Maritime Organization (IMO) the United Nation's agency saddled with the responsibility of regulating international shipping as it is beyond the purview of national governments. According to IMO (2019), "it fell to scientists to draw international attention to the threats posed by global warming. Evidence shows that in the 1960s and 70s concentrations of carbon dioxide (CO2) in the atmosphere were increasing and that led climatologists and others to press for action". However, the record shows that it took years before the international community could respond.

Even at that, the responses have always been dotted by unharmonious and divergent views from stakeholders within and outside the shipping industry.

In response, by the international community, an Intergovernmental Panel on Climate Change (IPCC) was created in 1988 by the World Metrological Organization and the United Nations Environment Programme (UNEP), which issued the first assessment report in 1990 and stated that global warming is real. The report spurred the government to create the United Nations Framework Convention on Climate Change (UNFCCC) endorsed around 1992 followed by the Kyoto Protocol adopted in 1997 in Kyoto, Japan, an international agreement linked to (UNFCCC) of which the major feature is binding targets for '37' industrialized countries and the European community for reducing Green House Gas (GHG) emissions. Another touted global response is the 2015 Paris Agreement:

> *"The Paris Agreement on climate change was made in 2015 by Parties to the United Nations Framework Convention on Climate Change (UNFCCC) and entered into force in 2016. The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. The Paris Agreement does not include international shipping, but IMO, as the regulatory body for the industry, is committed to reducing greenhouse gas emissions from international shipping (IMO, 2018)".*

The IMO laid out its "initial climate strategy" in April 2018, with a final revised version set to come out in 2023 (Timperley, 2017). Levels of ambition directing the initial strategy are as follows:

1. **Carbon intensity of the ship to decline through implementation of phases of the Energy Efficiency Design Index (EEDI) for new ships:** to review to strengthen the energy efficiency design requirements for ships with the percentage improvement for each phase to be determined for each ship type, as appropriate;
2. **Carbon intensity of international shipping to decline:** to reduce CO_2emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70%by 2050, compared to 2008; and
3. **GHG emissions from international shipping to peak and decline:** to peak GHG emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 whilst pursuing efforts towards phasing them out as called for in the Vision as a point on a pathway of CO_2emissions reduction consistent with the Paris Agreement temperature goals.

Deducing from Talanoa Dialogue (2018), "in 2011, IMO adopted mandatory measures to improve the energy efficiency of international shipping representing the first-ever mandatory global energy efficiency standard for an international industry sector, the first legally binding instrument to be adopted since the Kyoto Protocol that addresses GHG emissions and the first global mandatory GHG-reduction regime for an international industry sector". The Dialogue further stated that "the technical and operational requirements that apply to ships of 400 GT and above, are known as the Energy Efficiency Design Index (EEDI), applicable to new ships, which sets a minimum energy efficiency level for the work undertaken (e.g. CO2 emissions per tonne-mile) for different ship types and sizes, and the Ship Energy Efficiency Management Plan (SEEMP), applicable to all ships". These mandatory requirements according to the Talanoa Dialogue, entered into force on 1 January 2013 and the Energy Efficiency Operational Indicator (EEOI) for monitoring the operational energy efficiency of the ships also remains available for voluntary application.

3.2.1 IMO Energy Efficiency Partnership Projects Towards GHG Reduction in Shipping Industry.

IMO's energy-efficiency measures implemented through global partnership projects include:

Global Maritime Energy Efficiency Partnerships (GloMEEP) project supports the uptake and implementation of energy-efficiency measures for shipping, thereby reducing greenhouse gas emissions from shipping. GloMEEP was launched in 2015 in collaboration with the Global Environment Facility and the United Nations Development Programme.

Global Industry Alliance (GIA) to Support Low Carbon Shipping was launched in 2017 under the auspices of the GloMEEP Project, is identifying and developing solutions that can help overcome barriers to the uptake of energy-efficiency technologies and operational measures in the shipping sector.

The Global Maritime Technology Cooperation Centres Network (GMN) project, funded by the European Union, has established a network of five Maritime Technology Cooperation Centres (MTCCs) in Africa, Asia, the Caribbean, Latin America, and the Pacific. Through collaboration and outreach activities at the regional level, the MTCCs have been focusing their efforts since 2018 to help countries develop national maritime energy-efficiency policies and measures, promote the uptake of low-carbon technologies and operations in maritime transport and establish voluntary pilot data collection and reporting systems.

GreenVoyage2050 project, a collaboration between IMO and the Government of Norway. The project was launched in 2019 and will initiate and promote global efforts to demonstrate and test technical solutions for reducing GHG emissions, as well as enhancing knowledge and information sharing to support the IMO GHG reduction strategy.

In October 2020, a working group within IMO (Intersessional Working Group on Reduction of GHG Emissions from Ships (ISWG-GHG 7), during their seventh session, came up with a draft amendment in line with the implementation of the initial IMO GHG reduction strategy which requires ships to combine a technical and an operational approach to reduce their carbon intensity. New short-term measures were developed and forwarded to the "Marine Environment Protection Committee (MEPC 75) in November 2020, as a decision making body in IMO which if approved by the committee would then be forwarded for adoption at the MEPC 76 session, in 2021 (IMO, 2020)". According to IMO, "the draft amendment proposed that short-term measures should be those measures finalized and agreed by the Committee between 2018 and 2023".

3. Barriers to Decarbonization

According to Hellenic Shipping News (2020), "Shipping emissions are expected to continue to grow thereby increasing the importance of addressing barriers to decarbonization". There are so many barriers to international shipping decarbonization ranging from institutional, financial, and technical aspects; however, a few of the fundamental barriers will be identified.

- ***Lack of alternative fuel/renewable energy that has commercial viability for international shipping:*** *According to Parker (2020), "*discussions of fuels cannot be limited simply to arguments about whether ammonia is better than hydrogen, or whether methanol might be more viable than biofuels rather needed conversations should encompass "big picture" like encouraging decarbonization actions through levies or financial mechanisms" that will finance the development of commercially viable biofuels/renewable energy. Today, "we have neither clarity nor consensus on the sustainability issues surrounding the fuels being explored for shipping's decarbonization, and the criteria to assess their sustainability remain undefined (Atkinson, 2020)".
- **Politics**: It seems the urgency of addressing carbon dioxide and other GHG emissions does not appeal to all governments/political leaders. This is more of a concern when industrialized and big emitting nations/leaders are involved. For instance, Donald Trump (American President) announced in 2017 that America was exiting the laudable 'Paris Agreement' and he did. However, on the contrary (Joe Biden) US President-elect "pledged to lead the world to lock in enforceable international agreements to reduce emissions in global shipping and aviation (Gerretsen, 2020)". According to Edmund Hughes, the IMO's head of air pollution and energy efficiency, "while the IMO has received proposals from some countries that it should align itself with the Paris Agreement's 1.5˚C goal, not all governments necessarily agree with this (Timperley, 2017)". According to Green (2018), "a coalition of highly ambitious nations, led by small island states in the Pacific, pushed for deeper cuts by calling for full shipping decarbonization by 2050 but Brazil and Panama among the largest shipping registries in the world resisted it citing concerns about detrimental effects on trade. Likewise, neither the United States nor China signed the voluntary declaration in which states affirmed their commitment to a shipping agreement that is consistent with the Paris agreement".

- **Transparency of data:** Marine Environmental Protection

Committee- MEPC during their 70th session in October 2016, mandated ships to record and report their fuel oil consumption.

"Ships of 5,000 GT and above (representing approximately 85% of the total CO2 emissions from international shipping) will be required to collect consumption data for each type of fuel oil they use, as well as, other specified data, including proxies for "transport work". The aggregated data will be reported to the flag State after the end of each calendar year and the flag State, having determined that the data have been reported in accordance with the requirements, will issue a Statement of Compliance to the ship. Flag States will be required to subsequently transfer this data to an IMO Ship Fuel Oil Consumption Database. The Secretariat is required to produce an annual report to the MEPC, summarizing the data collected (Talanoa Dialogue, 2018)".

The challenge to this data collection practice is transparency because no shipping line will report against itself. Such report should not come from shippers themselves, for no one sets exam for him/her self and fail. However, both shipping industries and National Governments have to be transparent and sincere in their data collection and transmission knowing full well that the impact of global warming affects us all. For the safety of the planet, integrity should be premium over profit and safety over cost.

- **Capital:** The major challenge to the introduction of Zero Emission Vessels (ZEVs) that will guarantee green shipping by 2030 is capital. Ships as well known are long-term capital investment and taking older models out of commission before the end of their life span is a costly adventure. In addition, is the fact that banks are reluctant to fund technology that is yet to be developed. According to Gallucci (2017), "most brands and shipping companies alike remain reluctant in doing anything that would raise the cost of transporting goods or the final price tag".
- **Emission ownership dilemma:** This dilemma emanates from the fact that carbon dioxide emissions from international shipping cannot be attributed to any specific nation because of the international and complex nature of shipping and vessels ownership. Estimation can hardly be near accurate. For instance: "a state cannot include shipping emissions in their reduction targets if the international community cannot figure out how these emissions should be allocated to states. Christiana Figueres, the former Executive Secretary of the UNFCCC, stated that emissions from international vessels are not even covered under the legalities of the convention simply because they are not national emissions (personal communication 2016) in Cowing (2017)".
- **The challenge of the flag of convenience:** Open registry in disguise offers shipowners the

opportunity to cut corners or breach international shipping regulations for profitable interests without being held responsible, such as pollution of the ocean environment. In some scenarios, both flagging states and IMO are incapable of enforcing compliance from such erring ship owners. A good example is provided by Cowing (2017) & DeSombre (2006), thus:

"the limited enforcement capacity of flagging countries and the inability of the IMO to compel enforcement is seen with the 'oil tanker Prestige'. This particular vessel flew a Bahamian flag, had a Greek captain, a Filipino and Romanian crew, was registered in Liberia, owned by a Swiss company that was itself owned by Russian nationals, was carrying oil from Latvia to Singapore, classified by the U.S., and insured by the United Kingdom (DeSombre, 2006). When the ship sank in 2002, causing the largest oil spill in both Spain and Portugal's histories, the 11 countries that had stakes in this one vessel pointed fingers at each other with no one party taking responsibility. As this exemplifies, the flag state is not always willing or able to take responsibility and the IMO did not step in to force the Bahamian hand. The Prestige also exemplifies the great need to be able to say with certainty who and what is responsible for all matters pertaining to ships so that catastrophes of all sorts may be mitigated. If that party is to be the flagging state, then mechanisms need to be put into place to ensure responsibility is carried through and to either provide support to countries that may need assistance in enforcement or preventing countries from offering open registries".

4.1 Findings

What is expressed here is the likelihood of achieving the green shipping target between now and 2030. For now, no study or organization has given assurance that fully decarbonizing the shipping industry is feasible by 2030 neither is there clarity nor consensus on the sustainability issues surrounding the fuels being explored for shipping's decarbonization, and the criteria to assess their sustainability remain undefined as Atkinson observed. It, therefore, implies that most of the strategy on decarbonization in the shipping industry is a work in progress. Concrete progress in a global or commercial sense is yet to be achieved in terms of renewable energy and compliant technology. As a result of cost, it is still business as usual for some shipping outfits. However, Organization for Economic Cooperation and Development (OECD) forecasted that with the new technologies, alternative fuels, and renewable energy, the shipping industry will almost fully be decarbonized by 2035.

The subsisting fact remains that the new technologies, alternative fuels, and renewable energies are still at the experimental and developmental stages without any indication yet about any of them being globally or commercially viable before 2035 or 2050. Even China as the second-largest global economy and the world's largest emitter of fossil-fuel CO_2 – 10.06 billion metric tonnes (Blokhim, 2020) is projecting 2060 as the target year to halve emissions by 50%. These ambitious emission reduction goals were usually perceived to be technically feasible but politics is seen as the main obstacle. Politics is the main obstacle because it can only be achieved with the collaboration, sponsorship, and commitment of every national government without seeking specific national interests against the common global climatic agenda. The politics of global trade and capital accumulation has always posed an obstacle towards transparent and collaborative decarbonization of the shipping industry and the global economy. It is for this reason that the efforts towards decarbonization of the international shipping industry have always been dotted by divergent views from stakeholders within and outside the shipping industry.

Another important note to the un-likeliness of decarbonizing the international shipping industry before 2030 is the fact that, if IMO as the sole agency that is regulating the shipping industry sets 2023 as the year for final revision of its 2018 laid out 'Initial Climate Strategy' what is the possibility of eliciting compliance from parties before 2030 without an adequate enforcement capacity? The possibility is doubtable.

5.1 Conclusion

The global community is not yet on the same page as to the urgency of decarbonizing the shipping sector as some national governments have failed to align themselves with the Paris Agreement's 1.5˚C goal. Even when achieving 2030 green shipping does not appear feasible; there is already dissension between major and minor players in international shipping like Small Island states in the pacific on one hand and Brazil, Panama, US, and China on the other over full decarbonization by 2050 citing concerns about detriment effects on trade. If this type of disagreement persists longer than expected, it means that 2050 green shipping is not realizable much less than 2030. The implication is increased carbon intensity from shipping *vis a vis* increase in international trade, global warming, and earth temperature.

In the case of the COVID-19 pandemic, preventive, protectionist, and hedging approaches appear to have helped but in the case of the climate crisis that may not help because the sky is all over the earth.

Deducing from the findings and data from the study, we recommend thus:

1. Realizing the objectives of alternative fuels at a commercial level and matching technology should be prioritized first before setting a CO2 reduction target for the shipping industry or global economy. Such targets are not realizable without sustainable alternative fuels and counterpart technology.

2. Government intervention in funding the research and development of alternative fuels that will be commercially viable and the shipping technology to match. The capital demand requires that government should take the lead in this adventure.

3. Market forces: In the absence of a central body to enforce international shipping regulations, the force of the market dynamics – competition guided by government commitment will bring the expected decarbonization result through technology innovation in alignment with low carbon alternative fuel.

4. Win/Win approach: International Maritime Organization (IMO) parties must imbibe win/win disposition for the

decarbonization of the shipping industry and the global economy at large because we are all together in it for good or bad. Collaboration, commitment, and transparency remain the approaches with which the shipping industry and the global community need to successfully apply to reduce carbon emission and global warming when it is still within control.

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A REVIEW OF THE IMPACT OF CLIMATE CHANGE ON CROP PRODUCTION IN THE SOUTHEASTERN PART OF NIGERIA

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Abstract: A review on the impact of climate change on crop production in the South Eastern part of Nigeria was carried out to ascertain the level of damage already caused by the effect of climate change induced by global warming in this region. Without a doubt, climate change has posed tremendous negative effects on agricultural production in the Southeast of Nigeria. Several studies have been carried out by different researchers and agencies on the impact of climate change in Nigeria and the Southeast in particular. Thus, several research works on climate change in Southeast Nigeria were examined and used to evaluate its effects so far on crop production to assess the vulnerability of the natural environment and the possibility of solutions. The climate conditions considered included precipitation, temperature, and rising sea level. The results from the review indicate significant negative impacts of climate change on crop production in the region.

INTRODUCTION

Climate change without doubt has profound effects on agricultural production in South Eastern Nigeria. The general climate outlook for Africa is characterized by rising temperatures and an increased frequency and severity of extreme weather (IPCC, 2013). Available evidence has also shown that climate change is global, likewise, its impacts but the most adverse effects will be felt more by developing countries especially those in Africa due to their practice of weather-dependent agriculture and their low level of coping strategies (Ohajianya and Osuji, 2012). Climate change will cause yield declines for the most important crops (Ellen and Barry, 2005).

The cause of climate change is the greenhouse gases that are already warming the planet (IPCC, 2007). If nothing is done to curb emission, the stock of greenhouse gases is expected to grow substantially over the next century largely from burning fossil fuels but also from land-use change (IPCC, 2007). This will result in future climates to warm and will likely cause changes in precipitation patterns (Mendelson, 2008). There are many impacts expected from climate change, but the most impacts will be on agriculture. Quantifying these impacts of climate change will provide important insights into how much to spend on mitigation (Mendelson, 2008). Farmers in developing countries have been warned that farms are often sensitive to warming (Resenzweig and Parry, 1994) this is because; developing countries are more dependent on farming, many of the farms are located in places that are already too hot or dry and poor farmers are less able to adapt. Results of research also showed that farms in the southern warmer regions were more vulnerable than farms in the northern regions (Mendelson et al., 1994).

However, there is a need for sustainable agriculture to meet the increasing demand for food for the growing population in Nigeria. To ensure food security, we need to understand the climate changes around us and how it affects agricultural productivity and rural livelihood (Agbola and Fayiga, 2016). Nigeria is still practicing rain-fed agriculture which renders her vulnerable to adverse effects of climate change. Extreme climate events such as flooding, extreme heat, and drought have led to soil degradation which results in low crop yield (Agetunmobi and Abiodun, 2010). The decline in agricultural productivity discourages the farmers and may lead to change in livelihood especially in the rural areas (Agbola and Fayiga, 2016).

The impact of climate change has seriously been felt with regards to food insecurity in the Southeastern part of Nigeria resulting in the low productivity of food crops. As a result, early assessments of vulnerability are crucial for adaptation strategy to avoid the worst possible consequences of climate change on agriculture. The assessments are also needed to detect areas that needed urgent attention by the government as well as the agriculturists for maximum returns.

Some studies have provided qualitative evaluations of vulnerability to climate change (Agbola and Fayiga, 2016; Alabi, 1999). Some of the concepts used in the study of climate change include Vulnerability which according to (IPCC, 2007) is composed of three factors: exposure, sensitivity, and adaptive capacity. Although this concept is useful, its full application is not straightforward. Exposure means a qualitative change in climate parameters such as temperature, precipitation, and sea level that a system is exposed to in a changing climate. While sensitivity means the potential impact of these climate parameters, adaptive capacity relates to all factors that contribute to the ability of communities to make adaptive adjustments to the processes, practices, and structures of their environment (Akpodiogaga and Odjugo, 2010). Such adjustments are normally assumed to be conscious decisions to respond to environmental change. Adaptive capacity must arise from the configuration of components that are present in the system.

Consequently, the objective of this study was to review past studies on the effect of climate change on agriculture in South Eastern Nigeria for effective and efficient approaches to adaptive adjustments to the processes, practices, and structures of the environment.

Observed Effects of Climate Change in South Eastern Nigeria

Climate change in Nigeria is evident from temperature increase, rainfall variability; increasing rainfall in the south and decreased rainfall in the North, drought, desertification, rising sea levels, erosions, floods, thunderstorms, lightings, landslides, land degradation, and loss of biodiversity (FAO, 2003). All of these will continue to negatively affect human life and ecosystems in Nigeria.

Although depending on location, regions experience climate change with significantly higher temperatures during the dry seasons while rainfalls during rainy seasons help keep the temperature at milder levels (Onyeneke, et al., 2021). As agriculture is one of the sectors affected by climate change in Nigeria, there are a few comprehensive reports and papers that provide useful evidence and discussion of the various impact of climate change throughout Nigeria. The vast majority of the literature that provides evidence of climate change impacts and responses, however, focuses on individual farming communities in a particular region of the country. The experiencing challenges of climate change are not the same across the country because of the two precipitation regimes; high precipitation in parts of the southeast and southwest and low precipitation in the North. The areas around the coast in Nigeria such as the southern regions are at the risk of rising sea levels. For example, the Niger Delta area is extremely vulnerable to flooding at risk of rising sea levels. Climate change was the reason behind the flood that took place in southern Nigeria in 2012. The flood was responsible for the loss of houses, farms, farm produces, and so on.

Ajiere and Nwagbara (2018) examined the impact of climate change on maize and cassava yields in southeastern Nigeria. The Ex-post-factor research method in the contest of quasi-experimental research design was adopted for the study. Data for rainfall and temperature were obtained from Nigeria Meteorological Agency (NIMET) and those for crop yields came from the Federal Ministry of Agriculture of Nigeria and the Agricultural Development Programme (ADP) of selected states. The data were analyzed using descriptive statistics, multiple linear regressions, and analysis of variance. Results showed that there is evidence of climate change in southeastern Nigeria, with notable fluctuations in the identified trends. Employing the trend analysis represented by the least square line, Abia State rainfall is increasing at 0.12mm per annum, while Imo State is decreasing at -1.1255mm per annum. Al the states recorded positive slopes in mean temperature which shows an increase in their trend.

Also, Chinwoke and Togun (2018) studied the effects of climate change on cocoyam farming in southeast Nigeria. Data was collected from three hundred and eighty-four cocoyam farmers selected with the aid of a multi-stage sampling technique using a structured questionnaire and interview schedule. Data obtained was analyzed using mean, frequency counts, and percentages. Findings showed that almost all the farmers had noticed the change in climate for mostly about 11-20 years with their level of knowledge mainly moderate, personal experience, Radio messages, fellow villagers, and extension workers were the major sources of climate change information. A majority believed that cocoyam diseases were induced by climate change. The major effects of climate change on cocoyam farming in the zone according to the farmers, were increased loss during storage as a result of increased temperature, a reduced yield of cocoyam, decay of corms stored in the soil as a result of the prolonged dry season, increased disease incident and uncertainty in planting date.

Munonye (2017) studied climate change and sustainable agriculture in southeast Nigeria. The objective of the work was to study the impact of climate change on yam (*Dioscorea rotundata*). Some climate parameters such as sunshine, relative humidity, and rainfall have a negative relationship with yam production and are significant at 10% probability. Crop production was predicted to decline by 25% per hectare by 2060. The assessment of climate change and appropriate mitigation and adaptation strategies in southeast Nigeria (Nwaiwu, et al., 2014) showed that temperature and rainfall which are the two most significant climate elements that affect food crop production in Nigeria exhibited an increasing trend. The study also found that adaptation strategies that were more appropriate to farmers in the southeast zone were late commencement of planting, use of fertilizers, choice of cropping systems, breakage of the daily schedule, and planting of cover crops and among others.

Coster and Adeoti (2015) studied the effects of climate change on maize production and farmers' adaptation strategies in Nigeria using a Ricardian Approach. A multistage sampling technique was employed for the study. Data were collected on 346 maize-based farming households in three different agro-ecological zones of Nigeria. The empirical results showed that maize net revenue is sensitive to climate change. The predicted results using a range of climate scenarios confirmed that climate change will have a negative impact on maize net revenue in the future. The farmers have taken adaptive measures against climate change which are changing the planting dates, changed land-use practices, mixed cropping, and mixed farming. Previous research strongly suggests that crops growing regions of sub-Sahara Africa will encounter increased growing season temperature and frequency of droughts (IPCC, 2007). This would result in some agricultural land becoming unsuitable for cropping and some tropical grassland becoming increasingly arid (Ajetumobi and Abiodun, 2010).

CONCLUSION

Evidence from past studies revealed that global warming has influenced agricultural productivity through climate change, leading to low food production. The impact of climate change is related to increased temperature and rainfall, water resources scarcity, and increased frequency of storms. Climate change has been identified as one of the greatest challenges to the persistent low agricultural productivity in southeast Nigeria. Twenty percent of the papers studied presented the negative impact of climate change on agriculture in the region. Although the impacts are not the same for every region in Nigeria, it depends on the current local climate, how climate locally changes, and other conditions such as soil conditions among others. However, the main hurdle to measuring the impacts of climate change in communities is the absence of existing data on farm performance. Existing data are often available at the federal level or in selected places. It is important when addressing programs to assist regions in the country with climate change to take note of what specific problems they are having and what actions would provide the greatest long-term relief.

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THE CASHEW PLANTATION: GREEN GROWTH FOR ENVIRONMENTAL MANAGEMENT AND SUSTAINABLE LIVELIHOOD IN DEKINA, KOGI STATE.

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Abstract:The last century has suffered significant changes associated with global warming and biodiversity loss; these environmental problems are triggered by man's anthropogenic activities in the form of land use land cover change and emission of Green House Gases. This causes the environment and inhabitants to be more vulnerable to the impacts of climate change such as heatwaves, flood events, biodiversity loss, and losses in livelihood as agricultural activities are being threatened by unstable climate conditions. However, embracing a strategy that will promote a green economy through reduction of the effects of climate change and as well enhance food security may secure and boost the livelihood of the inhabitants. This study examined the cashew plantation as a panacea to extreme poverty; a tool for environmental management and sustainable development. To achieve this, the variation in cashew areal extent between the period of 2002 and 2018 was determined using ArcGIS; a structured questionnaire was designed to identify the various ways in which cashew farming has contributed to the food supply, household income, and environmental sustainability among others. A total of 712 cashew farmers were sampled in the Dekina LGA of Kogi State. It was revealed that there has been an increase in the areal extent of cashew plantation from 261.9261sq/km in 2002 to 301.7943sq/km in 2018 indicating an annual increase of about 2.5 sq/km. An average of 25bags of cashew nuts are harvested in the season and sold out at an average cost of N24,100.00 per bag. Therefore, within a farming season, the sum of N602,500.00 is earned by a cashew farmer. The Nagelkerke R Square result further revealed that 7.1% (0.071) of the variability in livelihood sustainability was explained by cashew farming. The economic viability of cashew farming in Dekina LGA is attracting more investments in the expansion of cashew farmland. Consequently, cashew farming is increasing the vegetal covers of the study area, where it also enhances the ecosystem services and livelihood of the inhabitants. The government is encouraged to invest more in cashew farming as it has proven to be a green strategy in protecting the environment as well as enhancing local livelihood.

***Keywords*:** Climate change, Sustainable Livelihood, The cashew plantation.

INTRODUCTION

The last century has suffered significant changes associated with global warming and biodiversity loss. These environmental problems are triggered by man's anthropogenic activities in the form of land use land cover changes. The conversion of natural, agricultural, and other low-population-density lands to cities or urban areas has brought unprecedented changes to the environment. This lack of respect for the environment has resulted in the increasing effect of climate change coupled with the countless environmental problems experienced today such as flooding, urban heat island effect, soil erosion, and biodiversity loss among others (Celik, 2013). Consequently, the livelihood of millions of people in 3rd world countries is being threatened by the effects of climate change because of its direct impact on agriculture (Chambwera and Stage 2010; Aid 2014), jeopardizing the security of household income and food supply (Selvaraju, Subbiah, Baas, and Juergens, 2006).

Conceptually, “livelihoods” include all the assets, rights, means, and activities undertaken by people to earn a living (Elasha, Elhassan, Ahmed, and Sumaya, 2005). For a livelihood to be sustainable, it should have the capability to cope with stress and shocks as well as recover from them; it should also be able to improve its assets and capabilities in a manner that does not undermine the natural resource base (Department For International Development DFID, 2001). In contrast, a climatic change which is evident in the reduction as well as variations in the pattern of rainfall, coupled with high temperatures and even drought affects farming activities which serve as the major source of livelihood in developing countries, thus, threatening the natural, social, economic and even cultural conditions of both individuals and communities and at the same time robbing several livelihood assets of their value (Selvaraju et. al. 2006). This trend has made it necessary for farmers to adopt other alternatives to supplement their regular farming activities. As a result, attention has been shifted to cashew cultivation because of its ability to thrive in harsh climatic and environmental conditions.

Cashew (*Anacardium occidentale* L) is a forest tree crop grown widely due to its environmental-friendly nature. It is cultivated in several parts of Nigeria because of its wide array of environmental benefits. Because cashew requires annual rainfall as low as 600ml, it can be grown in the north of the country and the semi-arid regions to ameliorate desert encroachment which greatly threatens the area. It can also be cultivated in the southern part of Nigeria to check the effect of gully erosion. From an ecological perspective, the cashew tree possesses great potential to restore rigorously degraded lands (Dick, Garnett, Jones, Karim, Sundufu, Wadsworth, and Okoni-Williams 2015). The conversion of land for the cultivation of cashew provides enormous benefits to farmers as it enables them to take part in commercial crop production that assures profit with little capital (Gilleo, Jassey, and Sallah, 2011). The cashew tree which is tolerant to drought and also thrives on poor sandy soil is often intercropped with other food crops like cassava, thus providing a buffer against the failure of rain-fed annual crops in a context of climatic uncertainty (Mitchell 2004).

In Nigeria like in other parts of the world, cashew farming is a form of plantation forestry used for forest conservation (Aweto, 1990; Oriola, 2009) and has been in practice as far back as the 15th century when it was adopted as a strategy to for afforestation and erosion control (Asogwa, Hammed and Ndubuaku, 2008). In Kogi State, cashew farming has been in practice over the years; and as a result of its high demand and economic value, several hectares of land have been planted with cashew. Cashew plantation or cultivation helps in wealth creation (livelihood diversification and sustainability) and ensuring environmental protection. Cultivated fruit trees have long provided smallholders with food and in more recent times, with income. Planting high-value tree species like cashew to produce marketable forest products is one way of strengthening this source of income and of improving the nutritional value for rural poor households as well as helping to restore biodiversity.

In recent years, cashew has gained prominence among other cash crops in Dekina LGA; many smallholders have embraced cashew farming as a means of supporting their livelihood. This is because of the high economic value of cashew nuts both in local and international markets. However, little empirical evidence exists to ascertain the contribution of cashew farming to sustainable livelihood as well as its viability as an environmental management strategy in the study area. No literature defines the areal extent of cashew in the study area and how it has affected environmental management efforts. It is against this background that the present study is carried out to examine the contributions of cashew farming on environmental management, livelihood sustainability, and local empowerment in Dekina LGA of Kogi State, Nigeria.

Research hypothesis

1. There is no significant change in cashew areal extent in Dekina LGA between 2002 and 2018
2. Cashew production does not have a significant impact on livelihood sustainability in Dekina LGA.

Materials and Method

Study Area

Dekina LGA of Kogi State was created in 1979 with Dekina town as the headquarters, it is located between latitude $7^{0}18^{1}0^{11}$ N to latitude $7^{0}51^{1}$ 0^{11} N of the equator and longitude $6^{0}45^{1}$ 12^{11} E to longitude $7^{0}28^{1}0^{11}$ of the Greenwich meridian (Figure 1). Dekina covers a landmass of 2,337.5km^{2} (Ocholi, 2007). To the North-East, Dekina is flanked by Omala, Bassa to the northwest, Ankpa to the east, and Ofu Local Government Area to the south. The area is inhabited by indigenous Igala speaking people with other immigrants like the Ibara, Igbos, Yorubas, Ebiras, and the Hausas.

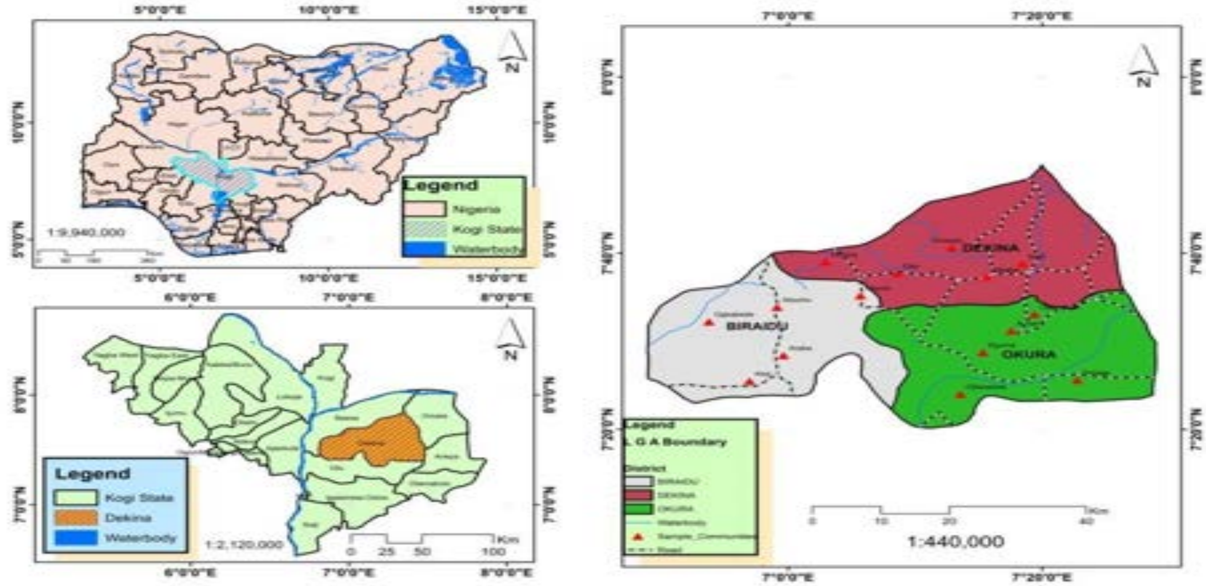

Figure 1: Nigeria showing Kogi State, showing Dekina LGA and the sampled communities
Source: *GIS Lab, Department of Geography & Environmental Studies, KSU (2019)*

Data required and source

Data were gathered from both primary and secondary data sources. Primary data were gathered through the administration of a well-structured questionnaire to cashew farmers across selected communities in Dekina LGA of Kogi state. **Satellite Imageries** of Dekina LGA were also acquired for two study years; 2002 and 2018. The Landsat imageries were downloaded from the official website of the United States Geological Survey (USGS); the coordinates of sampled cashew farms were also collected to ascertain the spectral signature of those sampled locations to differentiate cashew plantation from other vegetation on the satellite imageries.

Sampling and Method of Data Analysis

Multistage sampling was used to carry out the study. Stratified, random, and purposive sampling techniques were employed in data collection. First, a stratified sampling technique was employed to sample cashew farmers into the three already existing districts in Dekina local government area, namely: Dekina, Okura, and Biraidu districts. From each of these districts, a random sampling technique was employed to select five Cashew producing communities using a Table of Random numbers. In all, a total of 15 cashew-producing communities across the three existing Districts that make up Dekina LGA were used for data collection and a total of 6478 cashew farmers were identified in the fifteen (15) selected communities (Dekina cashew farmer's association. 2019). A total of 712 cashew farmers were sampled in accordance with Taro Yamane's formula of 1969 and questionnaires were administered using purposive sampling.

Descriptive and inferential statistical tools were employed. Data obtained from the questionnaire administration were analyzed using simple percentage, frequency tables, Principal Component Analysis (PCA), and the research hypothesis that *there is no significant change in cashew areal extent in Dekina LGA between 2002 and 2018* was tested using Chi square test while the hypothesis that *cashew farming does not have a significant impact on livelihood sustainability in Dekina LGA* was tested using Logistic Regression Analysis.

Image Classification

Firstly, all the data were pre-processed so that they are of good quality – this processing includes atmospheric correction of TM data. Next, the features of cashew plantation are analyzed and key distinguishing features are defined and new composites are then generated. Finally, supervised classification and accuracy assessment are carried out to analyze the improvement in classification accuracy obtained. Bare surface/farmland, Built-up Area, Cashew plantation, Light vegetation, Thick Vegetation, and Waterbody were identified as the final six class types in this study. Training samples for Bare land/farmland, Built-up areas, and Waterbodies were selected according to Landsat TM images using visual interpretation.

RESULTS AND DISCUSSIONS

Temporal Variation in Cashew Areal Extent in Dekina LGA between 2002 and 2018

To understand the changes that occur in cashew areal extent over the study period of 2002 to 2018, it is imperative to, first of all, understand the land use/land cover distribution of each study year (i.e. land use/land cover distribution of 2002, and 2018). To this effect, the land use/land cover distribution of Dekina LGA for the year 2002, and 2018 is displayed in Figure 2. Image “A” and “B” indicate land use/land cover classification for the years 2002 and 2018 respectively.

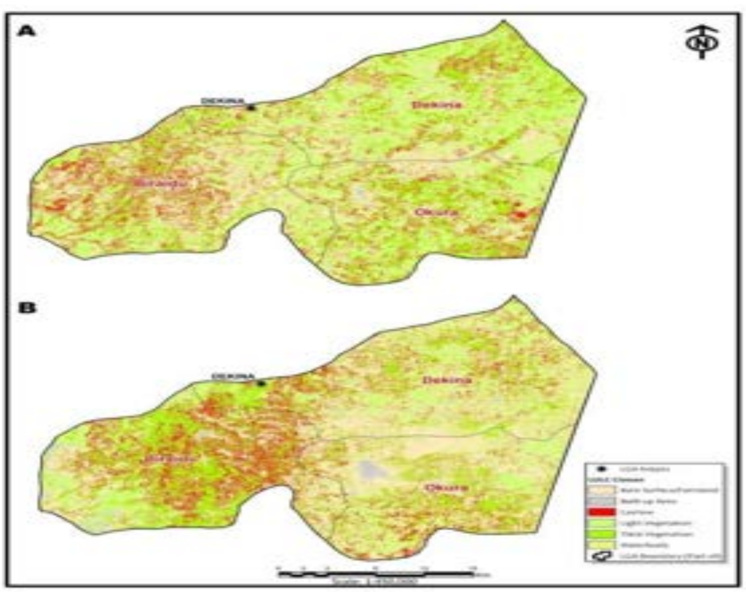

Fig. 2: Land use/land cover map of Dekina LGA for 2002 and 2018
Source: *GIS Lab, Department of Geography & Environmental Studies, KSU (2019)*

Table 1: Land use/land cover classification of Dekina LGA for 2002 and 2018

	2002		2018	
Features	**Area (sq/km)**	**Percentage**	**Area (sq/km)**	**Percentage (%)**
Bare surface/Minor Settlement/Farmland	2298.5568	59.4839	2524.608	65.3338
Built Up	7.1334	0.1846	39.8655	1.0317
Cashew	261.9261	6.7783	301.7943	7.8101
Light Vegetation	6.3045	0.1632	422.5905	10.9361
Thick Vegetation	901.5309	23.3305	40.7934	1.0557
Water body	388.7163	10.0595	534.5163	13.8326
Total	**3864.168**	**100**	**3864.168**	**100**

Source: *GIS Lab, Department of Geography & Environmental Studies, KSU (2019)*

Details of the analysis displayed in Table 1 indicate that there has been an increase in cashew to a real extent throughout the study. The result shows that in the year 2002, 6.78% (261.9261 sq/km) of the total landmass of Dekina Local government area was occupied by purely uninterrupted cashew plantation as little patches of Cashew farms mixed with other vegetation are most likely to be overshadowed by other vegetation, this value increased to in 2018 to about 301.7943 sq/km (7.81%) indicating an increase of Cashew plantation in the study area by 39.8682 sq/km in 2018 and an annual increase of 2.5 sq/km between 2002 and 2018. By visual observation of the classified image displayed in Figure 2, it is evident that Cashew plantation increased greatly in the Biraidu district of Dekina LGA. A slight increase can also be observed in the Dekina district of the Local government. However, this is not the case in the Okura district of Dekina LGA as cashew plantation appears to have declined between the period of 2002 and 2018. This can be attributed to the increase in the rate of urbanization in Okura district as Anyigba which is the seat of Kogi State University is located in the Okura district of Dekina LGA thereby resulting in high demand for land for residential, educational as well as commercial purposes. This is also portrayed in the increase in Baresurface/Minor settlement/farmland and Built-up areas between 2002 and 2018 as displayed in Figure 2 and Table 1. The category of Baresurface/Minor settlement/Farmland occupied the majority of the landmass occupying about 59.48% (2298.5568 sq/km) and increased by 65.33% (2524.608 sq/km) in 2018. This can also be attributed to the increase in population in the study area mainly as a result of the immigration of people due to the establishment of Kogi State University Anyigba in 1999; a significant increase in built-up areas can be noticed in Anyigba part of the Local Government (Figure 2). Table 1 also showed that during the year 2002, Light Vegetation occupied the least amount of land covering just 0.16% (6.3045 sq/km) as most parts of the study area were heavily vegetated at this time. However, in 2018, there was a high increase in Light vegetation up to 422.5905 sq/km representing 10.94% of the study area. This is due to the deforestation of heavily forested areas for agricultural purposes as well cashew cultivation as young cashew plantations are captured under the category of light vegetation contributing to the sharp rise in Light vegetation between 2002 and 2018. This is because cashew has gained prominence among other tree crops over the last five years in Dekina LGA of Kogi State. Similarly, heavy forest vegetation was also deforested to cater to the residential needs of the populace as a result of urbanization activities in the study area. The water body also appears to have increased over the study period of 2002 and 2018. This can be attributed to the fact that during the year 2002, most water bodies were overshadowed by vegetation making it less visible in land use/land cover classification but as a result of deforestation activities, hidden water bodies are now exposed well enough to be captured by satellite imageries.

Assessment of the change in cashew areal extent between 2002 and 2018

The first hypothesis that *there is no significant change in cashew areal extent between 2002 and 2018* is statistically tested using Chi square analysis and the result obtained is shown in Table 3. The result showed that there is a significant difference in the areal extent of cashew plantation between the years 2002 and 2018. Chi-square analysis was performed on the areal extent of cashew for the years 2002 and 2028 (261.9261 sq/km and 301.7943 sq/km respectively) as obtained from satellite image classification as explained in Chapter three. The Chi-square distribution is significant at $p<0.05$. Therefore, predictor variable(s) that has a p-value less than 0.05 is significant and as such, the change in cashew areal extent between 2002 and 2018 in Dekina LGA of Kogi State is significant and the null hypothesis is rejected.

Table 3: Summary of Chi-square result showing a change in cashew areal extent between 2002 and 2018

	Chi-square	DF	Sig.
Pearson	562.000	1	0.000
Likelihood ratio	776.248	1	0.000

*Significant at 5% confidence level

Cashew Marketing Channel and Source of Income

Cashew farming and business is a lucrative profession that has attracted several people and has sustained the livelihood of households for decades. The marketing of cashew products is an essential part of the cashew business. The result in Table 4 showed that cashew products- mostly nuts- are marketed through different marketing chains available to cashew farmers. From the result, a good number of the cashew farmers (50.4%) do the marketing on their own. This means that they make arrangements on how their cashew products are transported to the market or customers and for those who have been in the business for years, they have customers or buyers that come around to buy the nuts directly from them. This lends support to the work of Salau, Popoola, and Nofiu (2017) when they reported that the majority of the cashew farmers sell their nuts directly to processors and exporters. Another prominent marketing channel in the study area is the use of middlemen. 34.7% of the cashew farmers indicate that they market their cashew nuts through middlemen who take the nuts directly to the buyers and any complaint is transmitted to the farmers. The result, therefore, shows that cashew farmers in the area make use of different marketing chains or channels in selling nuts. In a related study, Onyenobi, Ewuziem, and Wazza (2011) and Salau et al. (2017) stated that the marketing of cashew nut produce involves several players and channels. The study shows that for the cashew farmers, the sales of cashew nuts are alleged by 99.7% of the respondents as their main source of income. This is expected considering the fact that nuts are used as raw materials for the production of cashew nut shell liquid (CNSL) oil. Taiwo (2017) stated that both the CNSL and CNS (cashew nutshell) are used as biomass fuels for clean power generation. CNSL is in high demand due to its other multiple uses for the production of paints, laminating resins, and intermediates for the chemical industry. The information in Table 4 further shows that the sales of cashew nuts are done in bags. The result obtained showed that a good number of the cashew farmers (85.5%) sell their nuts at the rate of ₦21,000-₦30,000 per bag, this was closely followed by those who sell theirs at ₦10,000-₦20,000 (13.8%); an inconsequential number sell theirs more than ₦30,000. The information further shows that the average selling price per bag of cashew nuts in the area of study is ₦24,100. Indeed, the price of cashew nuts per bag is dependent on the time of harvest which could be affected by the demand and supply variables of the period of harvest. Information on the bags of cashew harvested revealed that a good number of the cashew farmers (33.8%) harvested 21 – 30 bags, while another 33% harvested over 30 bags, with only 2.9% harvesting less than 10 bags bringing the average harvested cashew nuts to 25 bags per season. The bags of cashew harvested is affected by several factors among which are farm size and pest and disease. A step further was taken to estimate the annual income of individuals from cashew farming. Results obtained and displayed in Table 4 indicated that the average income earned by a cashew farmer per season is put at ₦602,500.

Table 4: Cashew marketing channel and source of income

Variables	**Category**	**Freq**	**%**
Marketing channel	Via cashew cooperative	60	8.4
	Via cashew association	45	6.3
	Personally	359	50.4
	Via cashew research institute of Nigeria	1	0.1
	Middlemen	247	34.7
		712	**100**
Source of income	Sales of Nuts	710	99.7
	Others	2	0.3
		712	**100**
Cashew selling price per bag	₦10,000-₦20,000	98	13.8
	₦21,000-₦30,000	609	85.5
	>₦30,000	5	0.7

		712	**100**
Average selling bag/bag	₦24100	712	100
Harvested bags of cashew	<10	21	2.9
	10-20	215	30.2
	21-30	241	33.8
	>30	235	33.0
		712	**100**
Average harvested bags/season	25	712	100
Average income/season	₦602,500	**712**	**100**

Source: Researcher's fieldwork, 2019

Benefits of Cashew farming on Sustainable Livelihood

Ten sustainable livelihood indicators are used to understand the impact of cashew farming on sustainable livelihood (Table 5). Results of principal components analysis (PCA) revealed that out of the 10 variables used, only two (2) components accounting for 79.4% of the variation in the data set were extracted. Using component loadings of $\pm\geq 0.9$ as criteria for selecting variables, PC_1 had strong and positive loadings on three variables; the variables were- cashew farming have helped in the supply of raw materials (0.914), cashew farming helps families to be self-dependent (0.910) and cashew farming has increased food supply (0.901). PC_1 was responsible for 50.8% of the total variance in the data set and the positive loadings indicated an increase in raw materials, self-dependence, and food supply with the increase in cashew farming. Based on the variables loaded on PC_1, it, therefore, represented an increase in access to raw materials and self-dependence. In addition, PC_2 was responsible for 28.6% of the total variance in the variable set and had two variables with positive loadings; the variables where cashew farming helps generate government revenue (0.914) and cashew farming increases foreign exchange (0.904). The positive loadings suggest an increase in government revenue with the increase in cashew farming. The result presented in Table 5 based on the extracted components identifies an increase in raw materials/ self-dependence and an increase in government revenue as the principal level of cashew farming to a sustainable livelihood. These two factors represent the apparent gains of cashew farming to a sustainable livelihood. The first extracted component depicts an increase in raw materials/ self-dependence. This is expected as the increase in cashew farming in the study area will foster household sources of livelihood by increasing cashew production which will make raw material available to our local industries and foreign companies.

The availability of raw materials from cashew farming in the form of cashew nuts increases farmers' source of income and gives farmers the confidence and courage to continue in the line of business. Also, the result shows that increase in cashew farming results in household self-dependence. This is apparent as sustainable cashew farming increases household income. This can make many cashew farmers self-dependent and able to meet the needs of their families. The increase in cashew farming will result in the increase in revenue that accrues to the household; the availability of money enables the household to make food available and also meet other needs. The cashew farmer will be able to solve his or her problems without assistance from anybody. Being self-dependent enables cashew farmers to acquire farm inputs and other things to enhance cashew productivity. Also, the second identified principle shows that an increase in cashew farming increases government revenue. This is because sustainable cashew farming will conserve soil fertility and increase cashew production. The taxes obtained from the sales of cashew nuts in our local markets and from those to be exported help to increase government internally generated revenue. Such revenue enables the government to carry out capital projects for the communities and the general functionality of the state. This goes to show that government needs to support cashew farming in the state to encourage more households into cashew farming. This will help to increase its source of revenue as well as enable households to become self-reliant. The result in Table 5, therefore, recognizes an increase in raw materials/self-dependence and an increase in government revenue as the principal gains of cashew farming to sustainable livelihood in the study area.

Table 5: Level of Cashew farming to sustainable livelihood

Variables	Principal components	
	PC_1	**PC_2**
Cashew farming has helped in the supply of Raw Materials	0.914	0.255
Cashew farming has helped families to be Self-dependent	0.910	0.283
Cashew farming has helped in Food Supply	0.901	0.249
Cashew farming helps in Environmental Sustainability	0.898	0.248
Cashew farming has increased Employment Opportunities	0.865	0.177
Cashew farming Increases household income	0.749	0.003
Cashew farming helps generate Govt Revenue	0.142	0.914
Cashew farming has helped in Foreign Exchange Savings	-0.052	0.904
Cashew farming has led to Infrastructural Development	0.347	0.814
Cashew farming has helped improve Social Interaction	0.588	0.591
Eigenvalues	**5.08**	**2.86**
% variance	**50.8**	**28.56**
Cumulative exp.	**50.8**	**79.36**

[a]the underlined with coefficients $\pm \geq 0.9$ are considered significant
Source: Researcher's fieldwork, 2019

Assessment of Cashew farming and livelihood sustainability

In this section, the research hypothesis that *cashew farming does not have a significant influence on livelihood sustainability* is statistically tested using binomial logistic regression analysis. Livelihood sustainability was measured using the item that says *cashew farming helps in the food supply*; this item was used because it had the highest mean value. The result displayed in Table 6 revealed that the binomial logistic regression was significant (X^2 = 23.458, $p<0.05$). This implies that cashew farming in the study area can predict livelihood sustainability. The strength of regression result represented by Nagelkerke R Square result revealed that 7.1% (0.071) of the variability in livelihood sustainability was explained by cashew farming. The result in the model summary showed that the predictor used in the model can predict livelihood sustainability. Wald statistics have a chi-square distribution which is significant at $p<0.05$. Therefore, predictor variable(s) that has a p-value less than 0.05 is significant and the null hypothesis is rejected. Looking at the result in Table 6, cashew farming significantly predicted livelihood sustainability ($p<0.05$). It further shows that cashew farming with an OR (Odd Ratio) of 5.38 which is greater than 1 suggests that it is more than 5 times likely to predict livelihood sustainability. The result obtained, therefore, shows that livelihood sustainability is significantly predicted by cashew farming. The continuous productivity of cashew trees cum yield enables farmers to make money out of the product and from the money earned, improved seedlings of cashew can be purchased to replace dead ones as well as make use of the money realized to meet up with household demands.

Table 6: Summary of binomial logistic regression result showing the influence of cashew farming on livelihood sustainability

Variables	B	S.E.	Wald	Df	Sig.	Odd ratio
Knowledge	1.68	0.32	27.83*	1	0.000	5.38
Constant	0.87	0.28	9.62	1	0.002	2.39

Overall model estimation

	Chi-square	Df	Sig.
Step	23.458*	1	0.000
Block	23.458*	1	0.000
Model	23.458*	1	0.000

Nagelkerke R Square = 0.071; Overall model classification = 90.9%
*Significant at 5% confidence level

Cashew farming and Ecosystem services

The population means and Chi-Square test of independence were used to determine the impact of cashew farming on ecosystem services. This was achieved using farmers' responses measured using the Likert Scale with responses ranging from strongly agree to strongly disagree on 3 items. The results obtained are shown in Table 7. The first ranked item showed that 79.1% of the cashew farmers stated that cashew farming has helped in forest conservation. They believe that cashew farming or plantation is a forest crop that serves as artificial forest. And that cashew farming helps in forest regeneration over time. In a related study, Sousa, Luz, Sousa, Cassama, Dabo, Dafa, and Bivar, (2015) stated that cashew plantation has the potential for forest recovery. This means that through the planting of forest crops or trees like cashew, forest regeneration is enhanced. This is also consistent with the report of USGS 2016 which states that the expansion of the Cashew plantation has helped to mitigate the loss of woody cover and biomass, somewhat offsetting the loss of trees from deforestation. The second-ranked item showed that 82.4% of the cashew farmers stated that cashew farming has helped in environmental conservation. This is such as it helps to conserve the environmental condition by improving air quality as cashew trees help to mitigate the effect of the anthropogenic emission of carbon dioxide (CO_2). When soil is properly conserved through the adoption of best management practices that do not expose soil under the canopy to soil erosion, soil fertility is maintained which will favour cashew yield. In addition, the third-ranked item revealed that 84.5% of the cashew farmers believed that cashew farming has helped in soil conservation. This is expected as cashew farming helps to protect the soil from the erosive force of rainwater. The presence of herbaceous species found under the canopy of cashew trees also helps to add nutrients to the soil through litter dropping which decays to increase the organic matter content and also serves as a physical barrier to soil erosion. The presence of vegetation helps to dissolve the erosive force of stormwater thereby reducing the rate of nutrient loss from the topsoil. This is consistent with the findings of Iwara (2018) that found soil under the tree canopy to have higher nutrients compared to soil outside the tree canopy. In a related study, Tola and Mazengia (2019) stated that cashew (*Anacardium occidentale L.*) is a forest tree that is used for afforestation and soil conservation

Table 7: Impact of Cashew farming on the ecosystem

Items	Total % response		Chi-square	Mean	Rank
	A	D			
Knowledge about CBNRM has helped in forest conservation.	79.1	20.9	694.05*	3.16	1
Knowledge about CBNRM has helped in environmental conservation.	82.4	17.6	579.79*	3.06	2
Knowledge about CBNRM has helped in soil conservation.	84.5	84.5	527.99*	3.02	3

*Significant at 5% alpha level; p-Value is 0.000; df = 3; 8.4% for those who are not aware of CBNRM

CONCLUSION AND RECOMMENDATIONS

The significant increase in cashew areal over the study period indicates the reversal of deforestation and its attendant effects on the environment. This indicates an approach towards environmental stability where ecosystems services and their functions are enhanced annually. The rising economic proceeds from cashew farming are also an indication of the sustainability of the livelihood of the farmers. Therefore, there is the need for the government and other supporting bodies to provide a mechanism that will encourage the improvement of the value chain of the crop as it has proven to be a strategy to achieving both environmental and livelihood sustainability in Dekina LGA.

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HEAVY METAL ADSORPTION USING SUGARCANE BAGASSE – A COMPREHENSIVE REVIEW

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Graphical Abstract

1. Introduction

Environmental pollution and contamination are some of the ruinous effects of technology and innovation that humanity has enjoyed in recent decades. Quality water and waste management are two of the most integral constitutions of modern society [1, 2]. In the search for a pollution-free environment, various remediation techniques have been explored to either stabilize, immobilize, transform, degrade, or detoxify environmental pollutants and contaminants. While micro-organisms are largely utilized in the treatment of organic pollutants, the use of plants is famous for their remediation of the heavy metal polluted environment(s) [3]. One of the classes of pollutants in the environment that have been extensively researched in recent years is heavy metals. Rapid population growth, urbanization, and industrialization are some of the culprits that are responsible for the increase in heavy metals in the environment [4]. In the environment, heavy metals cannot be degraded because of their stability, so they pile up until their concentration goes above the threshold which subsequently impacts the environment negatively [4]. Activities that introduce heavy metals into the environment include but are not limited to smoking of cigarettes, burning of wastes, combustion of metal ores, the use of fossil fuels, etc. [5] and their negative effects in plants include decreased absorption and movement of major elements to the leaves from the plants' roots, decrease in the development of the roots and shoots in the seedling stage, disruption of the physiological and biochemical processes in the plant such as photosynthesis which could lead to the death of the plant [4]. In humans, the effect could be as mild or severe leading to diseases such as cancer, cardiovascular or renal disorder, osteotoxicity, damage of the DNA, and even death depending on the concentration and the heavy metal that has been absorbed into the bloodstream [6].

Cadmium (Cd) is one of the naturally occurring elements with an atomic number of 48 in the periodic table [7]. It is used in industries producing alloys, coatings and pigments, batteries, and as PVC stabilizers [8]. Activities that may introduce cadmium (as cadmium is popularly used as a corrosive agent) into the environment include burning of wastes, production of cement, production of steel and iron, the usage of fossil fuels, and cigarette smoking [7, 8]. Tobacco cigarettes are good sources of cadmium as they are made up of about $1.2\text{-}3 \times 10^{-6}$ g/g of Cd [9]. Inhalation and Ingestion are the two major pathways by which cadmium goes into the body [9, 10]. In comparison with other heavy metals, cadmium is absorbed more by plants [9]. Much awareness of the toxicity of cadmium took place in 1912 when a zinc mine in the Toyama Prefecture area of Japan released effluents contaminated with cadmium into the Jinzu River Basin. Water from the river was used as an irrigation source for the cultivation of rice which consequently affected rice growth. People that ingested the rice were plagued with the Itai-Itai disease which affected the bones and lead to other complications like kidney disorder, anaemia, and even death [7]. In minute quantity, the presence of cadmium in the kidney may give rise to proteinuria [8]. Other effects of long-term exposures and high concentrations of cadmium include hearing and sight problems, male infertility, cardiovascular abnormalities, carcinogenesis, osteotoxicity, renal disorder, blood diseases, death, etc. [8, 10]. In plants, cadmium is also known to affect the processes of respiration and photosynthesis [11].

Having an atomic number of twenty-four and being the seventh most abundant metal in the earth's crust, Chromium (Cr) is a very important element not just to humans but also to chemical industries [12, 13]. It is important for glucose metabolism in living organisms [14], and also involved in minute quantity for the metabolism of proteins and lipids in humans [13]. It has applications in various chemical and industrial settings like in mining, cleaning of metals, electroplating and plating, leather, photography, electrical and also galvanometric procedures, etc. [14]. Due to its ability to form a protective coating on alloys in an oxidizing environment, it is utilized in the fabrication of dental as well as medical tools [13]. Despite the beneficial role it plays, it is still one of the most toxic heavy metals. Volcanic eruption, burning of coal and oil are a few of the activities that introduce chromium into the environment [15, 16]. Unlike cadmium where exposure is not by skin contact, chromium exposure can occur either through skin contact, inhalation, or ingestion [13]. Chromium has variable oxidation states, but the hexavalent and trivalent oxidation is the most stable which also adversely affects different organisms in high concentrations [12, 14]. The Cr (II) oxidation state is not also stable and is easily oxidized into Cr (III) in the presence of air [15]. Chromium accumulation in plants could lead to changes in enzymatic function, decreased amount of pigments, induction of chlorosis in immature leaves, reduction of growth, reduction of germination of seeds, damage in root cells [12]. Accumulation of chromium in humans could cause respiratory challenges such as chronic bronchitis and asthma, skin irritation, cancer, mutation, or even DNA damage [13]. Heightened concentrations of cadmium in drinking water could give rise to stomach tumors [16]. It increases the Reactive Oxygen Species' concentration and antibodies' production, while it decreases glycogen content in the liver, proteins and lipids content in the liver, gills, and muscles, rate of the blood clot, etc. in aquatic organisms [16].

Paints used on buildings built before 1978 were known to contain lead (Pb) due to its ease of coverage [17] but with knowledge of the lead toxicity, the use of lead in chemical and processing industries was discouraged. Unfortunately, lead is still being used in various countries [18]. It is utilized in various processes like the manufacture and recycling of batteries, manufacture of arms, pipes, and pigments, refining, etc. [18]. Lead poisoning occurs through ingesting contaminated water (which is the primary source), having contact with lead-based pigments and airborne particulates containing lead, cigarette smoking [19]. Its ability to accumulate in the skin, brain, liver, kidney, bones, and blood makes lead very toxic [20]. Apart from occupational sources, other sources of lead are children's toys, metal costumes, jewelry, soils, medicines and cosmetics, dust, tableware, and paints [17, 21, 22]. Children are affected more by high concentrations of lead than adults. It not only affects the neuropsychology of children, but it may also contribute towards stunted physical growth, difficulties in learning, and mental retardation [19]. It can cause kidney damage, miscarriage for pregnant women, male infertility, blood disorders in adults [17, 18]. At high concentrations, seizures, neurological disorders, cancer, brain damage, and even death could arise [19].

Copper, with atomic number twenty-nine, is an important element to both plants and animals. It is a micronutrient that can both be toxic and beneficial which is regulated by the concentration ingested [23]. In animals, copper plays important functions in the immune, cardiovascular, nervous, reproduction, and hematological systems [24] while in plants, it is needed for proper development and growth as it plays the role of a catalyst in biological processes of respiration and photosynthesis and lignin formation in the cell wall [25]. Sources of copper pollution include mining, the application of bactericides, pesticides, and fungicides to plants [25]. In addition, another important source of copper exposure is through the drinking of water from water connected with copper pipes [26]. Copper toxicity in animals could lead to liver disorders and damage, anorexia, ulcerations, hemolysis, anaemia, depression, and genetic defects like Wilson's disease [24, 26] while at heightened levels in plants, it could cause the discoloration of leaves, improper root development, stunting, necrosis, and chlorosis. It supports the excessive production of ROS which affects biological processes like photosynthesis negatively [25, 27].

As the twenty-fourth most abundant metal in the earth's crust, Nickel is contained in large amounts in the environment [28]. It is a key requirement for the growth and development of various plants and microbes [29]. It is found in the hair, saliva, breast milk, and liver in humans [30]. Natural sources of nickel in the environment include; dust, emissions from volcanoes, and forest fires [28], while occupational sources that release nickel into the environment include manufacturing of cement and disinfectants, pigment making, catalysts, magnets, and ceramics production, smelting, electroplating, jewelry, and mining industries [28, 29]. In plants, nickel toxicity has been associated with necrosis, poor root development, and chlorosis [28]. Recently in Andhra Pradesh's Eluru town, India, the presence of nickel in milk for consumption has led to the hospitalization of over six hundred people suffering from various complications and at least one death [31]. Some of the nickel's toxic effects stem from its role in the replacement of other metals in the formation or binding of proteins such as albumin and histidine, enzymes, or other cellular compounds [28, 30]. The primary route of nickel exposure in animals generally is through the ingestion of nickel-containing food. Secondary routes include the skin, and inhalation/respiration (which is the most hazardous route) [28, 29]. It is also one of the most common agents responsible for allergic contact dermatitis and was even named the "Allergen of the Year" in 2008 [29, 30]. Apart from dermatitis, the toxicity of nickel causes cancer of the respiratory tract, renal and cardiovascular disorders, lung fibrosis, and neurological disorders [30, 32, 33]. Nickel is a carcinogen as stated by the International Agency for Research on Cancer that placed them under Group 1, meaning that they are carcinogenic to humans [29].

Various techniques have been employed in the cleanup of heavy metals from the environment. Some of these techniques include chemical precipitation, electrodialysis, coagulation/flocculation, ultrafiltration, reverse osmosis, oxidation, ion exchange, ozonation, irradiation, electrokinetic coagulation, biological treatment, and adsorption [1, 34, 35]. Of these techniques, adsorption is most utilized especially in the removal of heavy metals from industrial effluents because of their simplicity and low cost of set-up as well as maintenance [34, 36]. The process of adsorption is also recommended for the adsorption of heavy metals in little concentrations from wastewater [37]. Biosorption is the process by which non-living things such as agricultural wastes and by-products attract metal ions to themselves and permit their accumulation from an aqueous solution [38]. A good adsorbent for the adsorption process should be relatively cheap, present in large quantities, and with high regeneration capacity [37]. It is to this effect that biosorption using low-cost agricultural wastes or product(s) has been and is still encouraged [37]. Some of the reasons why biosorption is utilized above other conventional methods in the removal of heavy metals include high efficiency, cost-effectiveness, little or no use of chemicals (less sludge as waste), biosorbent regeneration, and the possibility of recovering the metal [37].

A lot of research has been centered on the utilization of agricultural materials especially *agricultural wastes* in the removal of heavy metals from aqueous solutions to obtain a more sustainable environment in line with the 2030 SDGs. However, a comprehensive review that studied the use of a specific *waste* – sugarcane bagasse to remediate wastewater by adsorbing heavy metals from the wastewater has not been conducted to the best of knowledge of the researchers. Therefore, through this paper, the researchers seek to investigate the progress that has been made over the years especially with the various methods of modification of the adsorbent (sugarcane bagasse). This paper also seeks to reveal the knowledge gaps on the subject matter as well as make suggestions for future research directions.

2. Sugarcane Bagasse

Sugarcane (*Saccharum* spp.) is a giant, thick perennial grass from the family *Poaceae* [39]. The abundance of this plant is unquestionable as about 647 million metric tons of sugarcane were produced in Brazil; the current world's largest producer of sugarcane in the 2019/20 sugarcane crushing season which saw most of them being utilized in the ethanol and/or sugar industry [40]. The remnant from the synthesis for either sugar or ethanol is the sugarcane bagasse [41] used as a raw material for bioethanol production, animal feeds, and concrete as a replacement for sand [42]. More than one-fourth of the sugarcane produced is converted into bagasse [43].

Industrially, bagasse is the residue left after sugarcane has been crushed in mills and the juice extracted to produce sugar. This fibrous material with reduced moisture and sugar content is sent to the boiler house from the mills where it is burnt in the furnace to form bagasse ash to generate electricity to power the sugar factory. This material high in cellulose is also used in the production of bioethanol. Domestically, bagasse obtained from the chewing of sugarcane are not properly utilized like the bagasse in the industry as they try to minimize waste in the sugar industry, they are dumped by the roadside, in water bodies and therefore constitute some quantity of undecomposed wastes in our environment.

The functional groups such as carbonyl, hydroxyl, and carboxyl present in agricultural wastes especially lignocellulosic materials are binding sites for heavy metals in the adsorption process. The groups act as Lewis bases by donating a pair of electrons to the heavy metals to form complexes [44]. Modification of these wastes or by-products especially through the chemical method increases the quantity of these functional groups present in these wastes or by-products [37] and aids in the removal of soluble organic compounds [45], which increases the number of binding sites and invariably, increases the adsorption capacity of these adsorbents as evident in their maximum adsorption capacity [37]. A similar effect is achieved by the activation using physical methods such as pyrolysis as it increases the surface area for the attachment of these metals.

The FTIR of sugarcane bagasse shows that it contains polar functional groups such as the carbonyl group, aryl-alkyl ether, hydroxyl group [43] which are known to attract heavy metals in aqueous solution. Sugarcane bagasse is made up of about 35-40 % Cellulose, 21-25 % Hemicellulose, 22.2-26.5 % Lignin and 1.4-21 % Ash content [46, 47]. Typically, about 40-50 percent of bagasse is made up of cellulose [43] and this shows that bagasse is rich in cellulose which is converted into bioethanol for fuel. Cellulose [48], as well as Hemicellulose [49], has even been extracted from sugarcane bagasse. Cellulose, lignin, and pectin are the major components responsible for the adsorption of heavy metals [50]. Of these, the major component responsible is the cellulose present in it. Research has shown that the modification of the bagasse with either acid or base increases the cellulose content of the material in the direction of the concentration of the modifying agent [46]. The objective of this review is to provide insights into the suitability of the usage of sugarcane bagasse in the adsorption or removal of heavy metals from an aqueous solution.

3. Heavy Metal Adsorption Capacities of Sugarcane Bagasse

The adsorption of metal ions from aqueous media is contingent upon several factors which include contact time, initial concentration of metal ions, temperature, pH of the solution, among other parameters [51-54]. However, several studies have shown that adsorbent dosage, temperature, and pH particularly play a key role as regards the adsorbent capacity to adsorb heavy metals [55]. Over the years, the adsorbent dosage has been posited to be a subjective parameter that significantly differs across several studies [56], and in some instances, researchers have failed to report the adsorbent dosage in their studies. In this regard, the temperature and the pH at which the adsorption of the metal ions took place were stated and discussed in this section.

At higher temperatures, there is an enhanced movement of metal ions towards the adsorbent's active site. This may be attributed to the weakening and breaking of the internal bonds that enhance the sugarcane bagasse to adsorb metal ions from the solution [57, 58]. Also, at this temperature, ions diffuse faster from the solution and effectively bind to the adsorbent's active site. This consequently leads to a heightened adsorption capacity [51, 54, 57]. However, some studies have shown that at a higher temperature, in some instances, the adsorption capacity may be significantly reduced [59-62]. A plausible reason for this is the breakdown of the complex formed between the metal and the adsorbent which causes a change in the sorbent's surface structure.

The pH of a solution also determines the adsorbent's adsorption capacity in that it affects the charge of the binding sites and the metal ion speciation [54, 59, 63-67]. Studies have shown that at acidic pH, the adsorption capacity is significantly reduced in contrast to that at higher pH [53, 54, 64, 65, 67]. A plausible reason for this may be the reduced competition between hydrogen and metal ions from the sorbent's sorption site [60, 63, 65, 67]. As there is no noticeable trend in the adsorption capacity of the sugarcane bagasse with respect to the pH and temperature of maximum adsorption, it is quite arduous to describe the interrelationship between these factors and how they affect the adsorption capacity of the sugarcane bagasse.

While it is evident that there is no particular trend based on the effect of pH and temperature on the adsorption capacity, it is worthy to note that for studies that utilize modified and unmodified sugarcane bagasse for adsorption of metal ions, the modified sugarcane bagasse often have higher adsorption capacity. This may be attributed to the increase in functional properties and binding sites of the adsorbent by the modifying agent and therefore, higher sorption affinity [56, 68-72]. However, in some instances, the adsorption capacity of the unmodified sugarcane bagasse in some studies seems to be significantly higher than that of the unmodified sugarcane bagasse in other studies. This observation reflects those of [73] who maintained that different preparation methods of the adsorbent often result in those with varied adsorption capacity.

Previous studies have reported that metals, in form of leachates, may permeate soils supporting vegetation [74,75]. Consequently, these plants may take up these metals from the contaminated soil [74,76], coupled with those that are organically bound to the fibres of the biomass [77]. In research by [78], the metal uptake capacity of sugarcane bagasse from metal tailings was investigated. Although this research puts sugarcane bagasse forward as a plant tolerant to harsh conditions and as a potential stabilizing agent to metal tailings owing to its metal uptake ability, it was reported that significant concentration of metals, particularly zinc and lead, which varied across different parts of the sugarcane bagasse were detected ($p < 0.001$). In a later year, [79] in their research further showed that for different species of plants, the amount of metal taken up differs.

While research by [78] revealed a heightened concentration of metals in the roots of sugarcane plantlets, another research by [80] showed that it is not restricted to roots only, as even in parts of sugarcane that are edible, the concentration of Cadmium and Lead were significantly high. This is consistent with the observation of [79] that reported the presence of metals in rhizomes, stems, leaves, and roots of plants. This observation particularly supports the translocating ability of metals in plants. As different researchers may employ different preparation methods in their studies that utilize sugarcane bagasse as an adsorbent, a probe into literature has shown that some only utilize simple physical methods which most times are incapable of fully releasing the active binding sites of the prepared sugarcane bagasse of the initial metal ions from the contaminated site. This may therefore explain the observed heightened adsorption capacity of unmodified sugarcane bagasse in some studies relative to modified sugarcane bagasse in other studies.

Another plausible explanation for the observed higher adsorption capacity of the unmodified sugarcane bagasse in some studies compared to the modified form in other studies may be attributed to adsorbent dosage. With increasing adsorbent dosage, there is an observed increment in the percentage of metal ions from the aqueous media [73,81]. Conversely, there is a decreased adsorption capacity of adsorbent observed with increasing dosage [73]. A plausible reason for this is the unsaturation of the increased active sites introduced as a result of increased dosage which provides more active sites for adsorption [82,83]. The decreasing adsorption capacity may be also attributed to the aggregation of particles of sugarcane bagasse which leads to a reduction in the adsorbent surface area [73,82,83]. It may therefore be safe to assume that for studies that utilized unmodified sugarcane bagasse and reported higher adsorption capacity, the adsorbent dosage was significantly lower than studies that utilized modified sugarcane bagasse which therefore explains the reason for the observed higher adsorption capacity. Table 1 below summarizes the adsorption capacity of the modified and unmodified sugarcane bagasse in no particular order.

Table 1: Heavy Metal Adsorption Capacities of Unmodified and Modified Sugarcane Bagasse

Copper II (Cu)							
S/N	**Modifying agent**	**Dosage (g/L) g***	**T (°C)**	**pH**	**Max. Capacity (mg/g)**	**Qmax Determination method**	**References**
1	Unmodified	0.1*	50	5	0.523	Langmuir	[84]
2	Unmodified	-	-	-	6.87	Langmuir	[85]
3	Unmodified	0.5	20	6.48	10.64	Redlich-Peterson	[86]
4	NaOH	0.1*	50	5	0.938	Langmuir	[84]
5	HCl	0.1*	50	5	2.006	Langmuir	[84]
6	Zinc Chloride	5.1	-	4	13.31	Theoretical	[87]
7	Citric acid	-	-	-	31.53	Langmuir	[85]
8	Mercerizing agent + succinic anhydride + 1,3-diisopropyl carbodiimide	-	-	-	59.5	Langmuir	[88]
9	Mercerizing agent + succinic anhydride + acetic anhydride	-	-	-	69.4	Langmuir	[88]
10	NaOH, Pyrolysis, Nano	-	-	4	113.63	Langmuir	[89]

	Magnetic synthesis						
11	Succinic anhydride $+NaHCO_3$	-	-	-	114	Langmuir	[90]
12	Succinic anhydride + polyamine in anhydrous DMF	-	-	-	133	Langmuir	[90]
13	Succinic anhydride + 1,3-diisopropyl carbodiimide	-	-	-	139	Langmuir	[90]
14	Succinic anhydride + Na_2CO_3	-	-	5.4	185.2	Langmuir	[91]
15	NaOH + Succinic anhydride + Na_2CO_3	-	-	5.6	185.2	Langmuir	[91]
16	H_2SO_4 + NaOH + CS_2	-	-	-	200	Experiment	[92]
17	Acrylic acid and acrylamide	-	25	6	268	Langmuir	[93]
Cadmium II (Cd)							
S/N	**Modifying agent**	**Dosage (g/L)**	**T (°C)**	**pH**	**Max. Capacity (mg/g)**	**Qmax Determination method**	**References**
1	Unmodified	10	-	5	19.45	Langmuir	[94]
2	Unmodified	-	-	-	69.06	Langmuir	[95]
3	Sugarcane bagasse-derived Activated Carbon	-	30	4	2.0137	Freundlich	[96]

4	Sodium hydroxide	-	-	6.5	80.3	Langmuir	[97]
5	Peroxide hydroxide	-	-	6.5	90.9	Langmuir	[97]
6	Citric acid	-	-	6.5	90.9	Langmuir	[97]
7	Mercerizing agent + succinic anhydride + 1,3-diisopropyl carbodiimide	-	-	-	106.4	Langmuir	[88]
8	Magnet	-	-	-	123.65	Langmuir	[45]
9	Mercerizing agent + succinic anhydride + acetic anhydride	-	-	-	158.7	Langmuir	[88]
10	Succinic anhydride + 1,3-diisopropyl	-	-	-	164	Langmuir	[90]
11	Succinic anhydride +$NaHCO_3$	-	-	-	196	Langmuir	[90]
12	Succinic anhydride + Na_2CO_3	-	-	6.1	212.8	Langmuir	[91]
13	H_2SO_4 + NaOH + CS_2	-	-	-	250	Experiments	[92]
14	NaOH + Succinic anhydride + Na_2CO_3	-	-	6.1	256.4	Langmuir	[91]
15	Succinic anhydride + polyamine in anhydrous DMF	-	-	-	313	Freundlich	[90]

16	Acrylic acid and acrylamide	-	25	6	320	Langmuir	[93]
Chromium (Cr)							
S/N	**Modifying agent**	**Dosage (g/L)**	**T (°C)**	**pH**	**Max. Capacity (mg/g)**	**Qmax Determination method**	**References**
1	Unmodified [Cr (VI)]	-	30	6	3.9557	Freundlich	[98]
2	Unmodified [Cr (III)]	-	25	5	20.34	Langmuir	[99]
3	Unmodified [Cr (III)]	-	-	-	21.87	Langmuir	[85]
4	EDTA + Pyrolysis [Cr (VI)]	-	30	6	0.2040	Freundlich	[98]
5	EDTA [Cr (VI)]	-	30	6	1.5480	Freundlich	[98]
6	Sodium hydroxide [Cr (III)]	-	25	5	21.40	Langmuir	[99]
7	Citric acid [Cr (III)]	-	-	-	22.08	Langmuir	[85]
8	Citric acid [Cr (III)]	-	25	5	26.20	Langmuir	[99]
9	Sodium hydroxide + Citric acid [Cr (III)]	-	25	5	58.00	Langmuir	[99]
10	HBP-NH_2-Grafted Bagasse Cellulose [Cr (III)]	-	35	3	82.99	Langmuir	[100]
Nickel II (Ni)							

S/N	Modifying agent	Dosage (g/L)	T (°C)	pH	Max. Capacity (mg/g)	Qmax Determination method	References
1	Unmodified	10	25	5	2	Langmuir	[101]
2	Zinc Chloride	5.0	-	4	2.99	Experiments	[87]
3	Sugarcane bagasse pith – Activated carbon	2	-	6.5	140.85	Langmuir	[102]
4	H_2SO_4 + NaOH + CS_2	-	-	-	167	Experiments	[92]
Lead II (Pb)							
S/N	**Modifying agent**	**Dosage (g/L) g***	**T (°C)**	**pH**	**Max. Capacity (mg/g)**	**Qmax Determination method**	**References**
1	Unmodified	-	25	5	6.366	Langmuir	[45]
2	Unmodified	-	28	4.5	23.8	Langmuir	[103]
3	Unmodified	10	-	7	31.5	Langmuir	[94]
4	Unmodified	-	-	5	37.883	Langmuir	[104]
5	Unmodified	2.5	25	6.3	53.475	Freundlich	[105]
6	Pyrolysis + H_3PO_4	0.2*	-	-	3.7705	Freundlich	[106]
7	Sulphuric acid	-	25	5	7.297	Langmuir	[45]
8	Unmodified	-	-	-	11.63	Langmuir	[85]
9	Zinc Chloride	3.4	-	4	19.30	Experiments	[87]
10	Pyrolysis, H_2SO_4	-	-	5	23.4	Langmuir	[107]
11	Citric acid	-	-	-	52.63	Langmuir	[85]
12	Pyrolysis	2.5	25	6.3	57.803	Freundlich	[105]
13	Pyrolysis + H_3PO_4	2.5	25	6.3	66.225	Freundlich	[105]

14	Mercerizing agent + succinic anhydride + 1,3-diisopropyl carbodiimide	-	-	-	158.7	Langmuir	[101]
15	Carbodiimide	-	-	-	189	Langmuir	[90]
16	Succinic anhydride $+NaHCO_3$	-	-	-	189	Langmuir	[90]
17	Mercerizing agent + succinic anhydride + acetic anhydride	-	-	-	222.2	Langmuir	[101]
18	Magnet	-	-	-	248.64	Langmuir	[102]
19	Succinic anhydride + polyamine in anhydrous DMF	-	-	-	313	Langmuir	[90]
20	H_2SO_4 + sodium dithionite + Pyridine + NH_3 + nitration	-	30	4	323	Langmuir	[108]
21	H_2SO_4 + NaOH + CS_2	-	-	-	333	Experiments	[92]
22	NaOH + Succinic anhydride + Na_2CO_3	-	-	5.5	500.00	Langmuir	[91]
23	Acrylic acid and acrylamide	-	25	6	700	Langmuir	[93]
Zinc II (Zn)							
S/N	**Modifying agent**	**Dosage (g/L)**	**T (°C)**	**pH**	**Max. Capacity (mg/g)**	**Qmax Determination method**	**References**

1	Unmodified	0.5	20	6.48	4.05	Redlich-Peterson	[86]
2	Unmodified	-	30	6	4.5893	Freundlich	[98]
3	EDTA + Pyrolysis	-	30	6	0.3762	Freundlich	[98]
4	EDTA	-	30	6	2.0400	Freundlich	[98]
5	Ethylene diamine tetraacetic dianhydride	-	-	6.2	105.26	Langmuir	[109]
6	H_2SO_4 + NaOH + CS_2	-	-	-	200	Experiments	[92]

4. Adsorption Isotherms and Kinetic Models for Heavy Metal Adsorption

In this section, the applicability of adsorption isotherms and kinetic models to assess the adsorbent activity of sugarcane bagasse in the removal of heavy metals from aqueous solution are discussed citing relevant literature in Table 2. Traditionally, models (adsorption isotherms) are used to explain the bio-sorption usage that occurs during the distribution of adsorbate species between the liquid and an adsorbent. This is usually based on a set of assumptions related mainly to the adsorbents' homogeneity or heterogeneity, coverage type, and the prospect of interaction between the adsorbate species.

Heavy metals adsorption using the modified and unmodified sugarcane bagasse were mostly predicted by the Langmuir Isotherm followed by the Freundlich Isotherm which denotes that the adsorption of the heavy metals occurred on either heterogeneous or homogenous surfaces of the bagasse. Apart from the Langmuir and Freundlich Isotherm, other isotherms were fitted for the adsorption of heavy metals. Some of the other isotherms are; Temkin [98,106], Redlich-Peterson [86] and Radke-Prausnitz [99]. Therefore, to have a better understanding of the adsorption process, the two most occurring isotherms are explained below.

The Langmuir adsorption isotherm model expresses the quantitative formation of a monolayer adsorbate on the outer surface of the adsorbent, after which no further adsorption takes place. The equilibrium distribution of metal ions between the solid and liquid phases is described by this equilibrium model [111]. The Langmuir isotherm holds true for monolayer adsorption onto a surface with a defined number of identical sites. In this model, it is assumed that there is no transmigration of the adsorbate in the surface plane. Thereby there is uniform energy of adsorption on the surface. Based upon these assumptions, the Langmuir isotherm is represented by the following equation:

qe = xm= qmaxbC$_e$1+bC$_e$………… (1)

While the linearized form of the isotherm equation is:

1qe = 1qmax + (1qmaxb × 1Ce) …… (2)

C_e is the equilibrium concentration of adsorbate (gdm^{-3});
q_e is the amount of metal adsorbed per 1 g of the adsorbent at equilibrium (mgg^{-1});
q_{max} – the maximum sorbate uptake (mgg^{-1}); and
b – The Langmuir isotherm constant (dm^3 mg^{-1}).

The Freundlich isotherm is based on the heterogeneous surface properties and it gives the relationship between equilibrium liquid and solid phase capacities based on the multilayer adsorption. This isotherm assumes that adsorption sites are distributed exponentially relative to the heat of adsorption. The model is described by the following equation:

qe= KfCe1/n ………… (3)

The logarithmic form of the Freundlich model yields a linear relation by plotting log q_e versus log C_e:

log qe=log Kf+ 1nlog Ce ………… (4)

The constant K_f (the Freundlich capacity factor) is an approximate indicator of adsorption capacity, while 1/n is the Freundlich intensity parameter. For adsorption where the best-fit isotherm is the Langmuir and Freundlich isotherm, it is assumed that the adsorption occurred on monolayer and multilayer of the modified or unmodified sugarcane bagasse respectively.

Kinetic studies help to specify the adsorption rates which are very important in determining the adsorption efficiency [112]. From table 2, the best-fit kinetic model for most of the bagasse adsorbent used for removing various heavy metals is the pseudo-second-order kinetic model followed by the pseudo-first-order kinetic model. Other kinetic models used to describe the adsorption of various heavy metals by the bagasse are; the second-order kinetic model [117], and the first-order kinetic model [118]. The implication of the pseudo-first and second-order kinetic models are explained below.

In the pseudo-first-order model, straight-line plots of log (q_e–q) against time are made to determine the rate constants and equilibrium metal uptake, at different initial metal concentrations. The general formula for the pseudo-first-order equation model [113] is as follows:

The integrated linear form of the pseudo-first-order model as [114] reports is given in the following equation;

$\ln (q_e - q_t) = \ln q_e - K_1 .\ t$ ………… (5)

q_t is the metal ion adsorbed (mgg^{-1}) at time t (min),
q_e is the metal ion adsorbed (mgg^{-1}) at equilibrium time and
K_1 is the pseudo-first-order adsorption rate constant (Lmin^{-1}).

The pseudo-second-order kinetic model is useful in predicting the adsorption rate for a given system. This is useful in determining the adsorbate residence time and the reactor dimensions of the system's kinetics [115]. The pseudo-second-order chemisorption kinetic rate equation is expressed in the formula below.

tqt= 1K2qe2+ tqe ………… (6)

Where K_2 is the pseudo-second-order adsorption rate constant (g mg^{-1} min^{-1}). Since most of the best-fit kinetic models of both the unmodified and modified sugarcane bagasse are the pseudo-second-order kinetic model, it assumes that the adsorption is not just a chemical process but is also heavily dependent on the number of active sites on the bagasse and the number of heavy metals present in the solution.

Table 2: Adsorption Isotherm and Kinetic Models of Unmodified and Modified Sugarcane Bagasse for Heavy Metal Adsorption

Metal	Adsorbent	Best-fit Isotherm	R2	Best-fit Kinetics	R2	References
Zn(II)	Ethylene diamine tetraacetic dianhydride	Langmuir	0.9995	-	-	[109]
	H_2SO_4 + NaOH + CS_2	Langmuir	0.993	Pseudo-second Order	0.99	[92]
	EDTA + Pyrolysis	Temkin	0.9683	-	-	[98]
	EDTA	Freundlich	0.9953	-	-	[98]
	Unmodified	Freundlich	0.9989	-	-	[98]
	Unmodified	Redlich-Peterson	0.9999	Pseudo-second Order	0.998	[86]
	Charred xanthated sugarcane bagasse (CXSB)	Langmuir	0.99	Pseudo second order	0.99	[116]
Cd(II)	Unmodified	Langmuir	0.9990	-	-	[95]
	NaOH + Succinic anhydride + Na_2CO_3	Langmuir	0.9998	-	-	[91]

	Succinic anhydride + Na_2CO_3	Langmuir	0.9972	-	-	[91]
	H_2SO_4 + NaOH + CS_2	Langmuir	0.997	Pseudo-second Order	0.99	[92]
	Acrylic acid and acrylamide	Langmuir	0.995	Pseudo-second order	0.996	[93]
	Succinic anhydride +$NaHCO_3$	Langmuir	0.9934	-	-	[90]
	Succinic anhydride + 1,3-diisopropyl carbodiimide	Langmuir	0.9957	-	-	[90]
	Succinic anhydride + polyamine in anhydrous DMF	Freundlich	0.9856	-	-	[90]
	Charred xanthated sugarcane bagasse (CXSB)	Langmuir	0.99	Pseudo second order	0.99	[116]
Cu(II)	Succinic anhydride + Na_2CO_3	Langmuir	0.9999	-	-	[91]
	NaOH + Succinic anhydride + Na_2CO_3	Langmuir	0.9994	-	-	[91]
	H_2SO_4 + NaOH + CS_2	Langmuir	0.991	Pseudo-second Order	0.99	[92]
	NaOH, Pyrolysis, Nano Magnetic synthesis	Langmuir	0.996	Pseudo-second Order	0.9826	[89]
	Succinic anhydride +$NaHCO_3$	Langmuir	1	-	-	[90]

	Succinic anhydride + 1,3-diisopropyl carbodiimide	Langmuir	0.9998	-	-	[90]
	Succinic anhydride + polyamine in anhydrous DMF	Langmuir	0.9927	-	-	[90]
	Unmodified	Langmuir	0.8720	Pseudo-second order	0.9992	[85]
	Citric acid	Langmuir	0.9980	Pseudo-second order	0.9970	[85]
	Acrylic acid and acrylamide	Langmuir	0.9989	Pseudo-second order	0.975	[93]
	Charred xanthated sugarcane bagasse (CXSB)	Langmuir	0.99	Pseudo second order	0.99	[116]
Pb(II)	Succinic anhydride + Na_2CO_3	Langmuir	0.9997	-	-	[91]
	Pyrolysis, H_2SO_4	Langmuir	0.9508	Pseudo-second Order	0.9994	[107]
	Unmodified	Freundlich	0.999	-	-	[105]
	NaOH + Succinic anhydride + Na_2CO_3	Langmuir	0.9999	-	-	[91]
	Unmodified	Redlich-Peterson	0.9997	Pseudo-second Order	0.999	[86]
	H_2SO_4 + NaOH + CS_2	Langmuir	0.995	Pseudo-second Order	0.99	[92]
	Pyrolysis	Freundlich	0.999	-	-	[105]

	Pyrolysis + H_3PO_4	Freundlich	0.999	-	-	[105]
	Pyrolysis + H_3PO_4	Temkin	0.9940	Pseudo-second Order	1.0000	[106]
	Unmodified	-	-	Second order	0.9925	[117]
	Succinic anhydride +$NaHCO_3$	Langmuir	0.9945	-	-	[90]
	Succinic anhydride + 1,3-diisopropyl carbodiimide	Langmuir	0.9999	-	-	[90]
	Succinic anhydride + polyamine in anhydrous DMF	Langmuir	0.9994	-	-	[90]
	Unmodified	Langmuir	0.974	Pseudo-first order	0.9993	[104]
	Unmodified	Langmuir	0.9320	Pseudo-second order	0.9960	[85]
	Citric acid	Langmuir	0.9900	Pseudo-second order	0.9960	[85]
	Acrylic acid and acrylamide	Langmuir	0.992	Pseudo-second order	0.997	[93]
	H_2SO_4 + sodium dithionite + Pyridine + NH_3 + nitration	Langmuir	0.990	Pseudo-second Order	0.99	[108]
	Charred xanthated sugarcane bagasse (CXSB)	Langmuir	0.99	Pseudo second order	0.99	[116]

Ni(II)	H_2SO_4 + NaOH + CS_2	Langmuir	0.996	Pseudo-second Order	0.99	[92]
	Unmodified	-	-	First order	0.9339	[118]
	Charred xanthated sugarcane bagasse (CXSB)	Langmuir	0.99	Pseudo second order	0.99	[116]
Cr(VI)	EDTA + Pyrolysis	Langmuir	0.9120	-	-	[98]
	EDTA	Freundlich	0.9894	-	-	[98]
	Unmodified	Freundlich	0.9979	-	-	[98]
	HBP-NH_2-Grafted Bagasse Cellulose	Freundlich	0.9946	Pseudo-second order	0.9999	[100]
	Pyrolysis	Freundlich	0.956	-	-	[119]
Cr(III)	Unmodified	Two-site Langmuir	0.788	Pseudo-second order	0.999	[99]
	Sodium hydroxide	Two-site Langmuir	0.788	Pseudo-second order	0.999	[99]
	Citric acid	Radke-Prausnitz	0.922	Pseudo-second order	0.999	[99]
	Sodium hydroxide and Citric acid	Radke-Prausnitz and Freundlich	0.949	Pseudo-second order	0.999	[99]
	Unmodified	Freundlich	0.9941	Pseudo-second order	0.9890	[85]
	Citric acid	Langmuir	0.9940	Pseudo-second order	0.9990	[85]

Cr(II)	Sodium hydroxide	Langmuir	0.991	-	-	[97]
	Peroxide hydroxide	Langmuir	0.99	-	-	[97]
	Citric acid	Langmuir	0.99	-	-	[97]

5. Mechanism of Heavy Metal Uptake from aqueous media and Optimum pH

Bio-sorption encompasses the use of dead biological materials (modified or unmodified) for the sorption of substances (inorganic and organic) existing as soluble or insoluble forms in an aqueous media. The incorporation of these bio-adsorbents for the removal of pollutants has been met with significant success. Many researchers have investigated these "green technologies" which include but are not restricted to wheat bran [120,121], rice husk [122], corn cob [123], eggshells [94], orange peel [124], chicken feathers [125], coconut, palm kernel and groundnut shell, [126,127] and sugarcane bagasse [94,128]. The use of sugarcane bagasse in the treatment of wastewater has shown great potential to be considered a practical renewable sorbent [129]. It is also regarded as a low-cost and eco-friendly bio-sorbent with the ability to remove toxic chemicals including heavy metals [130]. It is, therefore, necessary to explore the mechanisms that govern these processes which are valuable for the future development of the system [131].

Complex mechanisms are followed by metal sequestration in the biosorption process, which mainly involve ion interactions and the formation of complexes between metal cations and ligands [132]. The primary adsorption mechanisms carried out by sugarcane bagasse on heavy metals are shown in Figure 1. Although these mechanisms (ion exchange, complexation, surface adsorption, and intraparticle diffusion) vary, they can be predicted when the nature of the sorbent surface structure and its associated functional groups are understood. As a general rule, an increase in surface area corresponds to an increase in adsorption efficiency by the exposure of more active sites that bind pollutant ions [116]. With respect to functional groups, the binding mechanism of heavy metal ions onto sugarcane bagasse stems from its abundance of the hydroxyl group. Ion exchange takes place because of the electrostatic interaction between positive ions and the negatively charged groups in the bio-sorbent. This functional group can also react with chemicals resulting in the surface modification favoring ion exchange or complexation.

In this study, several examples of sugarcane bagasse-based bio-sorbent as shown in Table 3, reveal the uptake mechanisms of metallic ions. Ion exchange and electrostatic interaction were reported to be the predominant mechanism for the bio-sorption of zinc by EDTA-modified sugarcane bagasse [109]. They suggested that carboxylic and amine functional groups could be responsible for forming stable complexes. An ion-exchange mechanism was also proposed by [116] for xanthate modification. The main sequestration mechanism for cadmium ions was ion exchange and intraparticle diffusion [116]. The main sequestration mechanism was electrostatic interaction and Electron/ion exchange for copper [89, 92] and nickel [87], while the predominant mechanisms for lead biosorption involve ion exchange [87, 92], chemisorption [107], physisorption, intra-particle diffusion and external mass transfer [106].

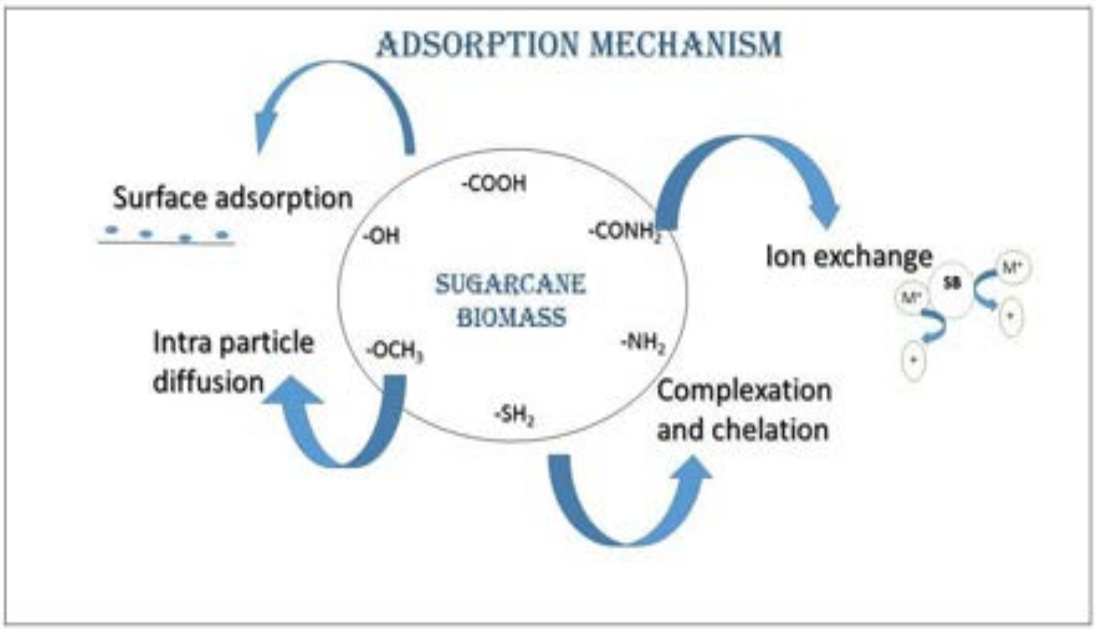

Figure 1: Adsorption mechanism for Sugarcane bagasse biomass

The solution's pH is a very important factor in the adsorption process as it controls the magnitude of electrostatic charges imparted by the pollutant ions [133]. The influence of the optimum pH of the solution can be explained based on pHpzc. The point of zero charges (pHpzc) is said to occur when the surface of the adsorbent material is neutral (i.e. the net charge of the functional group is zero). When pH < pHpzc the surface charge becomes positive which makes adsorption of positively charged metal ions rather difficult. However, the surface charge becomes negative for pH > pHpzc. When the pH increases, the surface affinity with the metal also increases (due to a smaller number of H^+ and a larger number of negative surface ligands) which improves adsorption. The optimum pH values for biosorption of the heavy metals as shown in Table 3 ranged from 2 to 8.5. The optimum pH varies from one study to another probably due to different surface modifications performed for improved surface area and adsorption sites. Batch studies [95] using unmodified sugarcane bagasse as sorbent for removal of Cd showed the maximum adsorption at pH 6. The dependence of Cd uptake on pH was linked to both the surface functional groups and the metal ion species that populated the aqueous solution. The species Cd^{2+} and $Cd(OH)^{+}$ are predominant at pH lower than 6, while the groups on the surface are protonated and cannot bind to metal ions in solution. In contrast, a study carried out by [92] showed maximum adsorption occurs at lower pH values (< 4) for Cr(VI). The dependence of Cr(VI) ion on pH was linked to the surface protonation of the chitosan-based biosorbent. Moreover, under acidic conditions, Cr(VI) mainly exists in the solution in the forms of $HCrO_4^-$ and CrO_4^{2-} allowing for strong electrostatic attraction between positively charged adsorbent surface and negatively charged Cr(VI) ions. The suggested mechanism was physisorption. Generally, the pH of the adsorption medium affects the presence and form of metal ions greatly and also has a strong influence on the adsorbents, especially the ones containing functional groups [134-135].

Table 3: Optimum pH and Adsorption Mechanism of Unmodified and Modified Sugarcane Bagasse for Heavy Metal Adsorption

Metal	Adsorbent	Optimum pH	pHzc	Adsorption Mechanism	References
Zn(II)	Ethylene diamine tetraacetic dianhydride	7	-	Ion Exchange	[109]
	H_2SO_4 + NaOH + CS_2	6	4	Electrostatic Interaction, Ion exchange	[92]
	H_3PO_4 + Pyrolysis	5	-	-	[136]
	Unmodified	4	-	-	[137]
Cd(II)	Unmodified	6	-	Intra-particle Diffusion	[95]
	Succinic anhydride + Na_2CO_3	6.1	-	-	[91]
	H_2SO_4 + NaOH + CS_2	5	4	Electrostatic Interaction, Ion exchange	[92]
	NaOH + Succinic anhydride + Na_2CO_3	6.1	-	-	[91]
	Acrylic acid and acrylamide	6	-	-	[93]
	NH_4Cl + Pyrolysis	4	-	-	[138]

	Unmodified	9	-	-	[139]
	Ion Exchange Resin	7	-	-	[140]
	Unmodified	5	-	Ion-exchange, complexation	[94]
Pb(II)	Ion Exchange Resin	7	-	-	[140]
	Succinic anhydride + Na_2CO_3	5.4	-	-	[91]
	Acrylic acid and acrylamide	6	-	-	[93]
	H_2SO_4 + sodium dithionite + Pyridine + NH_3 + nitration	4	-	-	[108]
	NaOH + Succinic anhydride + Na_2CO_3	5.5	-	-	[91]
	H_2SO_4 + NaOH + CS_2	4	4	Electrostatic Interaction, Ion exchange	[92]
	Zinc Chloride	6.5	6.6	Electrostatic Interaction, Ion exchange	[87]
	Sugarcane Bagasse Activated Carbon Coated with Magnetic Nanoparticles	7	-	-	[141]
	Pyrolysis, H_2SO_4	5	-	Electron exchange, Chemisorption	[107]
	Pyrolysis + H_3PO_4	4	-	Physisorption, ion exchange, intra-particle diffusion, external mass transfer	[106]
	Unmodified	7	-	Ion-exchange, complexation	[94]

Cu(II)	Succinic anhydride + Na_2CO_3	5.4	-	-	[91]
	NaOH + Succinic anhydride + Na_2CO_3	5.6	-	-	[91]
	H_2SO_4 + NaOH + CS_2	5	4	Electrostatic Interaction, Ion exchange	[92]
	NaOH, Pyrolysis, Nano Magnetic synthesis	4	-	Electron exchange, Chemisorption	[89]
	Zinc Chloride	6.8	6.6	Electrostatic Interaction, Ion exchange	[87]
	Unmodified	5	-	Ion exchange, Chemisorption	[101]
	Acrylic acid and acrylamide	6	-	-	[93]
	Sulphuric acid	5	-	-	[142]
Cr(VI)	Pyrolysis	6	-	-	[119]
	Bio-polymeric gel beads	4	-	-	[143]
	Unmodified	4	-	-	[137]
	HBP-NH_2-Grafted Bagasse Cellulose	2	-	Physisorption	[100]
Hg	H_3PO_4 + Pyrolysis	8	-	-	[144]
Fe(II)	H_3PO_4 + Pyrolysis	6	-	-	[136]

6. Thermodynamic Studies

Thermodynamic studies give more information on the uptake in the adsorption of heavy metals by sugarcane bagasse and also go a long way in telling and revealing the strength and the energy of interaction between the heavy metals and sugarcane bagasse. This energy is in form of heat, showing the effect of temperature on the adsorption processes. The effect of temperature on heavy metals adsorption by sugarcane bagasse has been studied at different temperatures by different researchers. Adsorption generally increases with an increase in temperature because this increases the force that propels the ions towards the adsorbent active sites [145]. However, adsorption may decrease with an increase in temperature in cases where ions are weakly held as a result of the breakdown of metal adsorbent complexes and changes in the structure of sorbent surface sites [146, 147]. Thermodynamic parameters such as equilibrium constant Kd, entropy change (□Sº), enthalpy change (□Hº), and change in Gibbs free energy(□Gº) as to be calculated to know the energy of the reaction.

□G = −R ln K_d(T) ………… (7)

ln K_d = SR – HRT ………… (8)

□G = □H – T□S ………… (9)

where K_d is the Langmuir equilibrium constant (L/mol). R and T represent the universal gas constant (8.314 J/mol K) and the system temperature (K). ΔS° (J/mol K) and ΔH° (KJ/mol) are determined from the intercept and slope of the van Hoff plots of ln K_d *versus* $1/T$. T is the temperature in Kelvin and Kd is a constant obtained from the product of the Langmuir constants qm and b in dm3 mol1 which was corrected to be dimensionless [148]. The negative values of (⊗Gº) indicate the feasible and spontaneous nature of the adsorption of metal ions onto sugarcane bagasse. The negative value of ΔH° for sugarcane bagasse indicates the exothermic nature of the adsorption process, whereas the positive value obtained for the composite indicates the endothermic nature with that adsorbent. The positive value of (ΔS°) reveals a rise in randomness at the solid/solution interface within the adsorption process

In Table 4, the thermodynamic parameters are tabulated for the adsorption of heavy metals by sugarcane bagasse adsorbents

Table 4: Thermodynamic Studies of Unmodified and Modified Sugarcane Bagasse for Heavy Metal Adsorption

Metal	**Adsorbent**	**Temp (K)**	**ΔG° (KJ/mol)**	**ΔH° (KJ/mol)**	**ΔS° (J/mol/K)**	**References**
Pb(II)	Unmodified	-	-6.48	-17.370	-37.000	[85]
	Citric acid	-	-11.08	-39.530	-95.000	[85]
	Pyrolysis + H_3PO_4	303	-11.546	39.988	0.0205	[106]
	Unmodified	303	-17.76	-5.080	0.0149	[94]
	Sugarcane Bagasse-derived Activated Carbon	303	-11.46	39.988	0.0205	[103]

	Unmodified	295	-22.1	-34.6	-42.5	[103]
		301	-21.7			
		310	-21.7			
		318	-21			
	Double mercerized + succinic anhydride + 1,3-diisopropyl carbodiimide	-	-29.59	-	-	[101]
	Double mercerized + succinic anhydride + acetic anhydride	-	-23.62	-	-	[101]
Cu(II)	Unmodified	-	-3.47	-20.020	-55.540	[85]
		298	-1.729	26.42	0.094	[149]
		303	-2.323			
		308	-2.68			
		313	-3.157			
		318	3.677			
	Citric acid	-	-6.34	11.820	60.940	[85]
	Mercerizing agent + succinic anhydride + 1,3-diisopropyl carbodiimide	-	-28.22	-	-	[101]
	Mercerizing agent + succinic anhydride + acetic anhydride	-	-24.25	-	-	[101]
	Oxalic Acid	298	-4.122	17.45	0.072	[149]
		303	-4.376			
		308	-5.071			
		313	-5.173			

		318	-5.534			
Cr(III)	Unmodified	-	-7.00	-42.148	-117.887	[85]
	Citric acid	-	-7.81	-5.839	6.611	[85]
	Unmodified	-	-7.00	-42.15	-117.95	[99]
	Sodium hydroxide	-	-8.83	-38.00	-97.93	[99]
	Citric acid	-	-7.80	-5.84	6.60	[99]
	Sodium hydroxide and Citric acid	-	-7.12	-15.84	-28.73	[99]
Zn(II)	Ethylene diamine tetraacetic dianhydride	-	-19.68	-	-	[109]
Pd(II)	Unmodified	-	-6.48	-17.37	-37	[85]
	Citric acid	-	-11.08	39.53	-95	
Ni(II)	Unmodified	298	-20.78	-74.32	332.29	[63]
		323	-22.07			
		338	-22.3			
Cd(II)	Mercerizing agent + succinic anhydride + 1,3-diisopropyl carbodiimide	-	-27.04	-	-	[101]
	Mercerizing agent + succinic anhydride + acetic anhydride	-	-26.08	-	-	[101]
	graft copolymerization	283	-4.79	33.65	0.136	[150]
		293	-6.5			
		303	-7.52			
		313	-8.97			

7. Knowledge Gaps and Future Perspective

While it is undisputed that the body of literature houses several studies that have explored the use of sugarcane bagasse for adsorption of metal ions from aqueous media, there exist few literature gaps that could be addressed in future studies. A probe into the body of literature revealed that several studies fail to report the adsorbent dosage used in their studies. This makes it quite herculean to reconcile the differences between adsorption capacities of sugarcane bagasse for different studies that have utilized similar optimal conditions. In the same vein, the lack of values on adsorbent dosage has made it quite challenging to draw a trend in the adsorption capacities of metal ions. This makes it quite impossible to draw a logical conclusion on the efficacy of modified sugarcane bagasse when compared to unmodified sugarcane bagasse. Therefore, future studies should endeavour to state the adsorbent dosage and other optimal parameters used in future studies.

The body of literature has seen most research carried out over the years employ the one-factor-at-a-time (OFAT) approach in determining the effect of a parameter on the adsorption capacity. With this approach, the other parameters are kept constant while the effect of one parameter is investigated. In the past years, very few studies have embraced the design of experiment (DOE) as an effective approach in determining the effect of multi-parameters at once in the adsorption of metals from aqueous media. However, this does not discount the fact that few studies [151-156] have utilized DOE techniques including response surface methodology, factorial design technique, full factorial experimental design, among several others in determining the effect of multiple parameters at once on the adsorption capacity of adsorbents. It is envisaged that future researches might utilize the design of the experiment (DOE) as a technique in determining the effects of these parameters on adsorption capacity.

PHREEQC is a geochemical package that aids in the determination of the transport of contaminants in aquifers and aqueous media. Consequently, it could be utilized in determining the concentration of metals in aqueous media and their kinetics of sorption. This could serve as a yardstick to measure the efficacy of biomass in adsorbing metals from contaminated media. Research by [157] previously sought to utilize this geochemical package in investigating the transport and sorption of some selected heavy metals, however, the scope of their research seems parochial as it only focused on determining the metal holding capacity of the soil. In this regard, future research should explore the use of this geochemical package to determine the metal binding capacity of adsorbents and inferentially, their adsorption capacity [157].

Various empirical models have been employed to describe the bio-sorption equilibrium in the adsorbent activity of sugarcane bagasse in the removal of heavy metals from aqueous solution, namely Langmuir, Freundlich, Radke-Prausnitz, and Temkin models. It is observed that the Langmuir equation is widely used and popular in a large number of studies. A gap identified is that the phenomena of bio-sorption in these empirical models and their physical characteristics are not duly represented. Pseudo-second order is the identified best-fit kinetics model for studying the bio-sorption of heavy metals from aqueous solutions using sugarcane bagasse. However, some researchers have failed to report the best-fit kinetic model used in their experiment. It is recommended that this is considered for replicability and reproducibility of reported data.

To increase the adsorption capacity of the sugarcane bagasse, the following are encouraged. Firstly, nanoparticles such as magnetic nanoparticles are known to have a large surface area and pore volume with smaller size and are known to be excellent adsorbents for heavy metal removal [158]. The high content of carbon in the bagasse makes it a good precursor for magnetic carbon nanocomposites, carbon nanotubes, etc. Therefore, the modification of the bagasse to nanoparticles should be explored. Secondly, adsorption is known to be very efficient in heavy metal removal but the combination of adsorption and other techniques such as membrane filtration [159] and chemical precipitation [160] have proven to be both efficient and time-saving. Therefore, other techniques are recommended to be combined with adsorption using sugarcane bagasse to improve the heavy metal removal process.

This review represents an extensive study on the adsorption mechanisms involved in the use of modified and unmodified sugarcane bagasse in the treatment of heavy metals. One question that is yet unanswered borders on the effective use of this biosorbent in treating real-world wastewater streams which would contain multiple heavy metal ions as well as other pollutants such as dyes. This presents a challenge when we consider the competition for adsorption sites due to their co-existence. In the years to come, it would be beneficial to consider wastewater in a real-life scenario and investigate the adsorption efficiency and mechanisms of sugarcane bagasse in its modified or unmodified state.

Finally, studies that focus on the competitive adsorption of heavy metals utilizing sugarcane bagasse in the presence of various competing species such as humic acid, NaCl, $CaCl_2$, KCl, $MgSO_4$, etc. in different concentrations are encouraged. This is necessary because it studies the relationship between these chemical species and the heavy metals as they compete to occupy the available adsorption sites in the bagasse. These chemical species are present in real wastewaters and therefore could either lead to an increase or decrease of the bagasse capacity to adsorb the heavy metals from the solution.

8. Conclusion

The concern over heavy metal pollution and its effect on water quality grows daily, and while the adoption of adsorption as a remediation technique may be a panacea to this menace, cost, reusability, and renewability of some adsorbents have often served as a limitation. This review, therefore, set out to investigate the prospect of sugarcane bagasse for the remediation of wastewater in a bid to provide solutions to issues bordering around cost, reusability, and efficiency. It was observed that adsorption of the sugarcane bagasse fits better in most cases to Langmuir and Freundlich isotherm and the adsorption mechanism was mostly due to electrostatic interaction and ion exchange. The findings also reveal that chemical modification significantly improved the adsorption capacity of the sugarcane bagasse due to surface functionalization. Based on the readily available nature and cost-effectiveness of sugarcane bagasse, this review, therefore, puts it forward as a promising adsorbent and alternative for the removal of heavy metals in wastewater. In subsequent studies, however, the reusability of this cost-effective adsorbent and its potential to serve as a pollutant in water bodies should be investigated.

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TOWARDS A CONCEPTUAL FRAMEWORK FOR ENVIRONMENTAL POLLUTION AND MANAGEMENT POLICY IN NIGERIA.

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Abstract: Nigeria as a developing country needs to tap natural resources (forest, minerals, oil, and gas) to tackle the socio-economic needs of the populace. The Nigerian populace has witnessed increasing pollution as a result of rapid urbanization, massive industrialization, a proliferation of agro-based chemical wastes, leading to resources depletion and uncontrolled destruction of flora and fauna. This is done without adequate environmental management policies to curtail the impact of pollution on human health. The emission of harmful substances in form of gaseous, solid, and liquid wastes requires an effective environmental management policy to prevent health hazards and encourage the preservation of environmental sustainability. A conceptual framework for an effective environmental management policy for Nigeria should aim to reduce environmental pollution to the barest minimum, create public awareness on the impact of climate change, provide environmental education and enact environmental laws through legislation in line with international laws and treaties. A policy that embraces enabling laws that focus on recycling and re-use of waste products, enforce industrial standards of production, enforce industrial waste taxation such as "Pay as You Pollute" and Environmental Impact Assessment (EIA) of complex projects was proposed.

Keywords: *environmental laws, health hazards, increasing pollution, massive industrialization, natural resources.*

1.0 Introduction:

The 1970s was the period of the oil boom in Nigeria which accounted for remarkable improvement in her foreign exchange income. The period witnessed rapid industrialization notably with the establishment of vehicle assembly plants, breweries, and distilleries, detergent and cement manufacturing, textile and paper mills, food and beverages processing factories, and iron and steel manufacturing. New highways and pipelines were built across the tropical and savannah forests. Thousands of generating sets, automobiles, ships, aircraft, air conditioners, and refrigerators were imported into the country due to high-level economic growth. However, these rapid economic growths and activities were not supported with any initiatives to protect the environment. Also, urban centers in Nigeria witnessed increased exposure to extreme weather events, such as heavy rainfall, flood, erosion, drought, high winds, and desertification. The risks from these events cause serious damage and disruption of human activities. These were observed from health hazards and disruption to public health infrastructures which further lead to increased disease incidences. Other health risks that were not adequately articulated are those related to the absence of disaster-preparedness and the inadequacies or poorly designed and managed responses after the disaster event. Though the problem of environmental pollution in Nigeria had been part of various governments' policies. For instance, the third and fourth National

Development Plans 1981 – 1985 highlighted some strategic policies for management of the environment and natural resources in the country, which dwelt on issues on land, water, and river basins, forestry, sewage, food and drugs production, waste disposal, public health, factories, and industrial establishments. Also, the Federal Environment Protection Agency (FEPA) created in 1988 drafted some enabling laws and guidelines to tackle the impacts of environmental pollution. Further, non-governmental organizations and international groups began to show interest during the period. Some literature and media publications and the author's investigation identified that major pollutions in the country include gas flaring in the Niger Delta; uncontrolled emissions from industrial and manufacturing activities; smokes from power generating sets; open solid waste incineration and slash-and-burn agriculture.

Major identified pollutants that degrade air quality include sulphur dioxide, hydrogen sulphide, nitrogen oxide, cement kiln dust, and other particulate matter and heavy metals, resulting from anthropogenic causes, i.e man. This paper is of the view that an effective institutional framework for private sector participation, environmental education and public awareness campaign, adequate budgetary allocation, and a well-articulated national policy is necessary for realistic environmental management. The exploitation of the environment for economic development conflicts with the ecologists' tendency to save it from extinction. This gap is vital for any effective environmental management policy. This paper is of the view that any environmental management policy should be backed by a well-spelled and fundamental legal framework; to avoid room for a chaotic and unpleasant environment.

The focus of this paper is on the environmental challenges faced with economic development which requires an effective environmental management policy to address the issues. This study, therefore, aims to examine the conceptual framework for environmental pollution and management policy in Nigeria. The objectives were to i) examine the environmental problems associated with climate change and human activities; ii) examine how economic production can be done for food, drugs, energy, water resources, and infrastructure development for the teaming population without causing damages to the environment iii) examine the management policies that will take into account the complexity of the phenomenon of climate change and human activities; iv) examine the legal framework that should be put in place for environmental management policies in Nigeria. The research questions are, therefore:

i) What are the environmental problems associated with climate change and human activities; ii) How can economic production be done for food, drugs, energy, water resources, and infrastructure development for the teaming population without causing damages to the environment? iii) What management policies will take into account the complexity of the phenomenon of climate change and human activities? iv) What legal framework should be put in place for environmental management policies in Nigeria? It is expected that the findings of this study will enable policymakers to formulate effective environmental management policies and enact environmental laws, standards, and legislation to protect the citizenry from health hazards in line with principles of environmental sustainability.

2.0 Context of Study

2.1 Location, Size, and Climate: Nigeria is located in the western part of Africa, between latitudes 4 16´N and 13 52´N; and between longitudes 2 49´E and 14 37´E. It occupies a total land area of 923,768km^2 with a population of 147million people as of 2006. The Nigerian climate is influenced by the interaction between the pressure belt of the South Atlantic Ocean and the Sahara annually. A highly whether pressure from the northern hemisphere develops over the Sahara and the South Atlantic Ocean with dry harmattan wind flowing over the whole of West African regions, with resultant air convergence known as Inter-Tropical Boundary (ITB) which moves over the country. The harmattan air is characterized by dusty and dry daytime weather and cold nights caused by radiation cooling as well as low humidity. While relative humidity ranges between 50 percent – 80 percent in the southern part of the country, it is as low as 10 percent in the northern region. During the summer period, the moist maritime air – the Southern Monsoon winds brings rainfall that spreads from the Atlantic coastal region to the northern part with annual rainfall totaling about 2,200mm. The mean annual rainfall ranges from about 450-700 mm in the northeast to about 3,500-4,300 mm in the coastal south-east, with rains falling within 90 to 290 days respectively. The mean annual temperature ranges from 21°C in the south to 30°C in the north with extremes of 14°C and 45°C. Climatic conditions are taken from weather observations over the longest period of temperatures and precipitation values, humidity, cloud, wind, air pressure, and solar radiation

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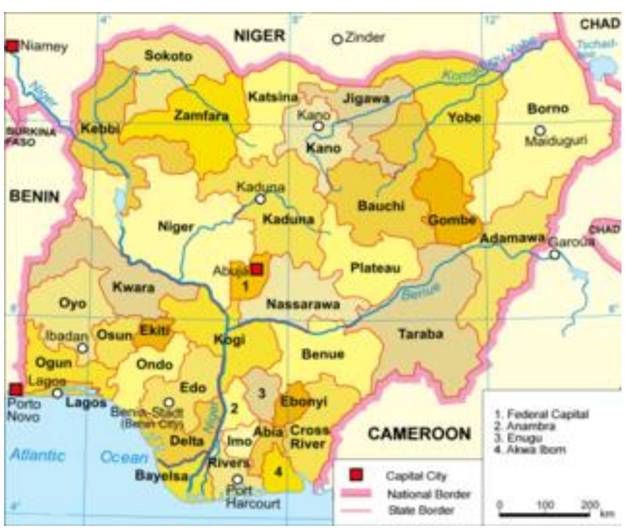

Fig. 1: Fig. 1: Map of Nigeria Showing the 36 States and the Federal Capital Territory, Abuja. Source: Geographical Map of Nigeria

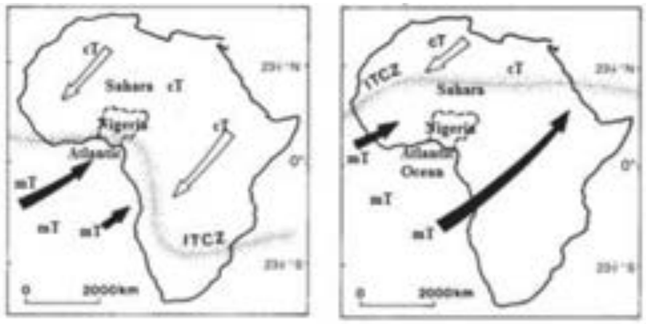

Fig. 2: Tropical Continental (cT) air mass and Tropical Maritime (mT).
Source: Geographical Map of Nigeria

2.0. Conceptual Framework and Literature Review.

From various literature, the term environment has been viewed from different perspectives. Sada, (1988) conceives the environment as a system within which living organisms interact with the physical elements. The importance of the environment man's survival resulted was brought into focus in the 'Agenda 21' of the Earth Summit in 1992, in which all nations were required to include environmental planning as an integral part of their development process. Environmental planning as viewed by Munn, (1975) in this context is those comprehensive planning activities relating to the preservation or enhancement of environmental quality. However, most developing countries, including Nigeria have over the years made various environmental planning and articulated laws and institutional framework to address certain environmental problems, but not all have been successful in alleviating those problems (Bell, 2002). Several empirical studies have been carried out on environmental hazards and the need for planning and control of the Nigerian environment. These include industrial solid waste in Enugu (Uchegbu.2002,) flooding (Obi, & Ubani, 2014) biodiversity (Phil- Eze, 2001,) soil erosion (Ofomata 2001), urban solid waste management (Omuta,1988; Ajakadike, 2001), among others. The legal framework for environmental pollution control has been examined by Uchegbu, (1988), Udotong, and Ikpang (2003). Nwafor, (2006) argues that the development and proper application of legal instruments in the field of environment are essential for the achievement of environmentally sound and sustainable development. Even, Arunsi (1998) had earlier suggested the inclusion of legislation on the control of hazards from exploration to implementation stages as possible strategies for environmental resource planning Specific areas he mentioned include land use demarcation/ planning/control, zoning, public participation in policy formulation, environmental education and enlightenment as well as a cost-benefit analysis of any action. In some areas of Northern Nigeria, some ecological disaster factors such as the invasion of the Quella birds in Jigawa and Adamawa State have constituted a threat to the environment and agricultural activities in general (Sharada, A, Lazarus, 2007). This paper, therefore, advocates governments' initiative in setting up in large cities, both institutional and legal frameworks that will control and guide development and environmental hazards.

4.0 Materials and Methods

4.1 Environmental Problems Associated with Climate Change.

1. Concept of Climate Change: Climate change caused is by "global warming" which denotes increases in the mean temperature of the earth's atmosphere by increasing heat-trapping greenhouse gases emitted or discharged in the atmosphere (IPCC, 2001). Climate change is also brought about by the effects of increasing emission or discharge of greenhouse gases mainly carbon dioxide CO_2 methane (CH4), oxides of nitrogen (NO_2) and Sulphur (SO_2), Water vapour (H_2O), and chlorofluorocarbons (CFCs) into the atmosphere. These gases can trap sun radiation that strikes the earth's surface from re-radiating back to the upper atmosphere and hold it on the earth's surface, thus increasing atmospheric temperature Montgomery, (2009). This phenomenon is known as the "greenhouse effect". Sources of greenhouse gases are listed below: Carbon dioxide: (Burning of fossil fuel, bush burning, and respiration) Methane: (decaying of organic matter, fermentation of animal dung, sewage disposal, and landfills). Nitrogen oxide: (Smoke from vehicle exhausts, fertilizer manufacturing plastic manufacture, and power generating stations). Chlorofluorocarbons: (refrigerators, general solvents, and foam). There are also natural causes such as volcanic eruptions that discharge a large volume of sulphur dioxide (SO_2). Environmental problems arising from climate change include rise in sea level, flooding, erosion, drought and desertification, and urban heat island. These are natural aspects of pollution associated with climate change. Anthropogenic sources of pollution include – oil spillage, waste generation (solid, liquid, and gaseous waste) which comes from industrial production, agro-based production, manufacturing, oil exploration and refining, mining, domestic waste, rapid urbanization, and other socio-economic activities including noise pollution and deforestation. Others include the burning of fossil fuels, vehicular emissions (transportation); power generation, and gas flaring.

2. Pollution: Pollution is the natural and anthropogenic induced changes in the environment that are harmful to man and other organisms and cause changes to the natural environment. It is the discharge or emission of harmful and destructive substances into the environment (land, water, air, and biosphere) which have negative impacts on living and non-living things.

3. Flooding: Nigeria and other third world nations within the southern atmosphere which are undergoing remarkable socio-economic changes with the high level of unplanned urbanization, poverty, and slum proliferation are increasingly vulnerable to flooding (Obi & Ubani, 2014) and other natural disasters (Galeemul, Huq & Remero, 2007) Increases in anthropogenic concentration of greenhouse gases chiefly carbon dioxide, methane, and nitrogen oxide are likely to have caused most increases in global average temperature. Other sources of greenhouse gases have sources from the ecosystem. The effects of greenhouse gases lead to an increase in sea level (melting of glaciers) which invariably contributes to flooding. The rainforest can maintain high infiltration due to forest cover. Urbanization leads to the removal of natural vegetation cover to give room for infrastructure development. This makes rainfall intensity to be higher than soil infiltration because of the proliferation of impervious urban ground surfaces, a condition that leads to flooding.

4. Drought: is a natural hazard associated with shortage or absence of water for a long period, sometimes due to unpredicted changes in seasonal rainfall patterns. Nwafor, (2006). Drought can also be said as a naturally occurring phenomenon that exists when precipitation has been significantly below normal record level causing a serious, physiological imbalance that adversely affects the productive system.

5. Desertification: It occurs in arid and semi-arid areas which exhibit desert-like conditions due to climate change. Human activities such as overgrazing, deforestation, and over-cultivation can lead to desertification which is a condition with reduction or total absence of vegetation cover.

6. Greenhouse Gases: Greenhouse gases occur naturally in the environment and also result from human activities. By far the most abundant greenhouse gas is water vapour, which is the most common greenhouse gas in the atmosphere, accounting for about 60 to 70 percent of the natural greenhouse effect. The evaporation of oceans, lakes, and rivers, as well as water evaporation from plants, increases the amount of water vapour in the atmosphere. Carbon dioxide constantly circulates in the environment through a variety of natural processes known as the carbon cycle. They also occur through volcanic eruptions and the decay of plant and animal matter which release carbon dioxide into the atmosphere. They also occur as a by-product of respiration, burning of fossil fuel, bush burning, and solid waste incineration. Methane is another important greenhouse gas emitted mainly during petroleum and coal mining. It is an extremely heat-trapping gas. Nitrous oxide is released by the burning of fossil fuels, automobile exhaust, and the breaking down of nitrogen fertilizers in the soil. Ozone (O_3) in the upper atmosphere is known as the ozone layer and shields life on Earth from the sun’s harmful ultraviolet radiation**,** which can cause cancer. Manufacturing processes use or generate many synthetic chemicals that are powerful greenhouse gases. Although these gases are produced in relatively small quantities, they trap hundreds to thousands of times more than an equal amount of carbon dioxide does. In addition, their chemical bonds make them exceptionally long-lived in the environment. Human-made greenhouse gases include chlorofluorocarbons (CFCs); a family of chlorine widely used in the 20th century as refrigerants, aerosol spray propellants, and cleaning agents. Scientific studies showed that the chlorine released by CFCs into the upper atmosphere destroys the ozone layer. As a result, CFCs are being phased out of production under a 1987 international treaty, the Montréal Protocol on Substances that Deplete the Ozone Layer. CFCs were mostly banned in industrialized nations beginning in 1996 and will be phased out in developing countries after 2010. The substitutes include hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and per fluorocarbons (PFCs). Diesel engines and some types of biomass burning produce black aerosols such as soot, which absorb the sun’s energy and therefore contribute to warming.

4.3 Environmental Problems associated with Anthropogenic Activities

1. Industrial Activities Rapid industrialization and intensive urbanization have led to the increasing discharge of industrial and domestic effluents. Water pollution and air pollution from our industries need serious attention for environmental control. This is lacking in our large industrial towns and cities, due to the absence of meaningful organized programmes for effluents and industrial wastes disposal. Many factories discharge their waste directly into our streams or rivers, drainage channels, causing serious environmental hazards. The pollutants generated from the industries include toxic metals and organic or inorganic solids and liquids**.**

2. Agriculture: The standard and ethics of modern agriculture require the use of many agro-chemicals to improve yield and to reduce possible damages that may affect crop plants, animals, and fishes. Unfortunately, the use of these chemicals has the potential to cause some harmful effects on non-target plants/animal species, some microorganisms, and man. The active compounds used in the formulation of these chemicals are likely potential carcinogens and are dangerous to health. Chemicals, through irrigation return to the water, also pollute water bodies thereby affecting water quality. Such effects may lead to the extinction of aquatic species – fish, plants, plankton, and other micro and macro-invertebrates (Osibanjo, and Jenson 1980)

3. Solid Wastes: Accumulation and disposal of large quantities of solid waste in our urban areas are one of the major environmental problems facing our cities. It is still a common practice in the country to dispose of refuse either by open incineration or by dumping on any available authorized or unauthorized open spaces. Observation has shown that the composition of our solid wastes has changed over time, thereby creating complicated problems of satisfactory disposal. Chiefly among these are "throw-away containers", vehicle scrap, and disused machinery on our streets and highways. Similarly, the dumping of faeces in our streams, rivers, and lagoons encourages the speedy spread of diseases since these contaminated waters are used along with their courses for domestic and other uses.

4. Population Growth: As population increases, more resources must be used up to feed, clothe and provide infrastructures (roads, houses, bridges, etc). The more people increase the more wastes to dispose of on land, hence the more pollution. Ostensibly, this policy will reduce the throughput of materials and energy in the economy and hence the disposal of residuals to the environment.

5. Institutional and Legal Framework of Environmental Planning in Nigeria. Environmental planning efforts in Nigeria can be traced back to the on-set of the Colonial rule in the 1900s when environmental protection efforts were promulgated through the colonial bye-laws. The colonial economic development policies and plans constrained weak regulatory frameworks to protect the environment from degradation. The main laws during this period were on water pollution and it included the Criminal Code of 1958 with section 246 aimed at controlling burial in houses, the Public Health Act of 1958 which aims to control the spread of diseases, slaughtering of animals, and disposal of night soil and refuse. It is instructive to note that the fines and penalties for violators during the period were liberal and poorly enforced. In 1964, a committee was inaugurated comprising of the various Federal Ministries with the mandate to study the problems of water pollution and formulate appropriate policies leading to the enactment of a Water Pollution Act of the Federation. Another major milestone in environmental planning in Nigeria was the setting up of the Expert Committee on Environmental Health of the National Council of Health in 1970. Again, the mandate of the committee was to review many proposals received on this subject to recommend the establishment of a sanitary inspectorate in the Federal Ministry of Health. Thus the formative years of institutional environmental regulation in Nigeria could be said to have been characterized by the absence of clear scientific criteria and standards on toxic wastes and pollution levels, while the enforcement of basic environmental and household hygiene depended largely on qualitative legal rules (Chokor, 1993). In 1979, the Federal Constitution focused on environmental hygiene, with emphasis on refuse clearance, and the management of liquid and solid wastes in abattoirs, residential homes, and streets, all of which came under the supervision of local government councils (Ola, 1984). Therefore, it can be argued that mainstreaming environmental variables into development processes in Nigeria is largely a post – 1980 effort. Budget allocations to environmental development and protection remained very low, being generally under 2% of the National budget until recently. The setting aside of 3% of the Federation Account in the 1999 constitution (from 1% in 1991) as an ecological fund for natural disasters of flood, erosion, etc, represents the most formal allocation to environmental activities (Chokor, 2005). In Nigeria, efforts at bringing about a cleaner environment have relied on the philosophy of pollution control. This has in some cases involved costly measures and controversial political decisions. Consequently, some stakeholders, poor communities, and financially constrained enterprises have often argued that the environment is an expensive luxury that diverts resources from more productive uses (Adelegan, 2005). In most parts of the world, the most common framework for the management of environmental problems is through appropriate regulations. The Nigerian method of environmental policies and implementation had not produced the desired result (Adelegan, 2005). One of the significant outcomes of Nigeria's participation in the United Nations Conference on Environment and Development (UNCED) was the signing of the Convention. Nigeria thus assumes obligations under the provision of the treaty according to customary international law. Section 20 of the constitution of the Federal Republic of Nigeria contains the country's environmental objectives that are meant, "to protect and improve the environment and safeguard the water, air, land, forest, and wildlife "In recognition of the need to protect her resources, Nigeria has put in place several legislations including the Forestry Ordinance, the National Parks Decree, the Federal Environmental Impact Assessment Decree, and the Environmental Impact

Assessment among others. The foregoing indicates the government's policy and legislation initiative and efforts in promoting environmental planning and protection in Nigeria since the early 1990s. The report of the 1987 World Commission on Environment and Development (WCED) on a major toxic waste dump at Koko, a small Port town in the then Bendel State, Nigeria, stimulated Government's resolve to fully and rapidly embrace the tenets of environmental protection (Bankole, 2006). The national policy on conservation and sustainable use of land is an integral part of the national policy on the environment. The policy was first developed in 1989 following the promulgation of the Federal Environmental Protection Agency (FEPA) decree no 58 of 1988 and revised in 1999. The decree provides the legal framework for the implementation of the policies on environmental protection, natural resources conservation, and sustainable development (Bell, R.G and Russell, C 2002). The Federal Environment Protection Agency (FEPA) was thus established by Decree No. 58 of 1978. In 1992, the Agency's mandate was expanded by Decree No 59 to cover the conservation of natural resources and biological diversity. By 1998, each of the 36 states and the Federal Capital Territory had established their specific Environmental Protection Agencies. A new Civilian Administration in 1999 gave environmental matters top priority attention in its development agenda by creating for the first time in our political history, a Federal Ministry of Environment in June 1999 which absorbed and took over the functions of the existing Federal Environmental Protection Agency. To have a holistic and coordinated approach to environmental management, the relevant Departments/Units from other Ministries were transferred to the new Federal Ministry of Environment. In the same vein, some of the States have now created full-fledged State Ministries of Environment to replace their existing Environmental Protection Agencies (Adelegan, 2005). This led to the establishment of the National Policy on Environment, in 1989 and revised in 1999; The National Agenda 21 (published in 1999); The National Guidelines and Standards for Environmental Pollution Control in Nigeria (published in March 1991); National Effluent Limitation Regulation of 1991; Pollution Abatement in Industries; and Facilities Generating Wastes Regulations of 1991; Waste Management Regulations S.I. 15 of 1991; Environmental Impact Assessment (EIA) Decree No. 86 of 1992; National Guidelines on Environmental Management Systems in Nigeria (June 1999); The Nigerian Urban and Regional Planning Law of 1992 and National Guidelines on Registration of Environment-Friendly Products and Eco-labeling (June 1999). Despite these environmental laws in Nigeria by various successive governments, paradoxically, environmental problems in Nigeria are on the increase due to poor implementation and enforcement of the various laws. It is against this background that the paper focuses on the problems of effective management and implementation of environmental planning laws in Nigeria.

4.5 The Management Policies that will take into Account the Complexity of the Phenomenon of Climate Change and Human activities;

1. Environmental Management Policy. Environmental management in many countries especially the developing countries is achieved through environmental legislation which is enforceable in the court of law and through administrative orders, technical standards which are applied through the three tiers of government i.e the Authority (Local Government) the Board (State) and the Council (Federal). There is a need for such a balance between developments aimed at upgrading the quality of life and the conservation of our environmental quality. To achieve this equilibrium, it would be pertinent to develop, through necessary research, mechanisms, and policies to encourage optimal resource allocation, to minimize the potential adverse impact of development and maximize benefits and provide adequate safeguards and standards in project planning, formulation, and implementation

2. Approaches to Conceptual Framework for Environment Management Policy in Nigeria. The quality of the environment is an essential component of the quality of life, and it is thus necessary and urgent to explore a conceptual framework emphasizing the full integration of socio-economic development and the environment. Such a conceptual framework should allow the consideration of a wide range of possible alternative forms and paths to development. Viewed against this background, developing an effective conceptual framework for environmental management in Nigeria should aim at the minimum disruption of the ecological process through control and reduction of environmental degradation and promotion of its protection and restoration

3. Current Government Intervention Programmes

The United Nations Conference on the Human Environment held in Stockholm in 1972, made emphasis on sewage treatment which many governments were blamed for showing little concern. Since then Nigeria's attempts to focus attention on environmental management have not made much impact. Sewage disposal still goes into rivers, streams, and drainage channels. There is the Water Ordinance of 1913 and the Federal Health Ordinance of 1958, and the Oil Pipeline Act 1958, with particular reference to the oil industry. Also, the Oil in Navigable Water Act No. 34, 1958, the Petroleum Act of 1969, are among few others. But these laws are inadequate and not comprehensive enough to be effectively applied as environmental laws. The defunct National Assembly created the Federal Environmental Protection Agency (FEPA) (similar to that of the United States) vested with powers to monitor and control the Nigerian Environment but the agency did not make much impact. The United States Environmental Protection Agency and Asian countries monitor their environment through the activities of their research centers which study the effects of environmental pollution on man and the biosphere, to identify means of prevention/reduction of pollutants. They also advocate the policy of recycling and recovery of waste as an economic resource. In contrast, there is no well-established environmental research center in Nigeria. Huge sums of money are spent annually to provide drugs and health care without serious inputs in preventive measures. Preservation of environmental quality requires new ideas, a new outlook, and a new vision to be integrated into our development process.

4. Environmental Impact Assessment (EIA) An Environmental Impact Assessment (EIA) is an analysis of the predicted environmental consequences of a proposed project. The EIA study will enable environmental baseline data to be established for any site and also provide a reference point for assessing future discharges into air, water, and land media when the industry is in operation. The requirement of government statutory bodies has been reflected in Principle 17 of the Rio Declaration on Environment and Development. Environmental Impact Assessment (EIA) should be carried out and linked to the cost-benefit analysis to ensure that environmental aspects are addressed and potential problems are foreseen at the appropriate stage of project design. This implies that EIA should be envisaged as an integral part of the planning process and initiated at the project level from the start.

5. Environmental Education. UNESCO's medium-term plan (1984-89) recognizes environmental education as lacking in environmental management and planning. Our environmental education programme should aim at propagating the incorporation of an environmental education programme into our school curricula and rouse a desire for active participation in a multidisciplinary approach, involving the natural sciences, engineering and political science, and law.

6. How economic production can be done for food, drugs, energy, water resources, and infrastructure development for the teaming population without causing damages to the environment

Environmental Management Systems (EMS). An EMS is a tool for managing the impacts of an organization's activities on the environment. It also paves the way for organizations to become ISO 14001 certified**.** This occurs through prioritization of activities and processes involving rating factors such as frequency of activity, severity or degree of impact, the potential scope of an impact, probability of an adverse impact, legal risk, and resource consumption. Waste reduction begins at the design phase through pollution prevention and waste minimization. At the end of the life cycle, waste is reduced by recycling. Sroufe, Robert. 2003.

7. The legal framework that should be put in place for environmental management policies in Nigeria.

Current Situation Concerning Environmental Policy in Nigeria is backed by environmental legislation administered by different organizations such as the National Environmental Standards Regulations and Enforcement Agency Act 2007 (NESREAA) and the 33 Regulations made by the Minister of Environment under section 34 of the Act. This statute was created under the 1999 Constitution of the Federal Republic of Nigeria (section 20) and repealed the Federal Environmental Protection Act 1988. The NESREA, the major federal body responsible for protecting Nigeria's environment is responsible for enforcing all environmental laws, regulations, guidelines, and standards. This includes enforcing environmental conventions, treaties, and protocols to which Nigeria is a signatory; Environmental Impact Assessment Act (Cap E12 LFN 2004) which sets out the general principles, procedures, and methods of environmental impact assessment in various sectors. Harmful Waste (Special Criminal Provisions) Act (Cap H1 LFN 2004) for the carrying, depositing, and dumping of harmful waste on land and in territorial waters. Endangered Species (Control of International Trade and Traffic) Act (Cap E9 LFN 2004) for the conservation and management of wildlife and the protection of endangered species, as required under certain international treaties. National Oil Spill, Detection and Response Agency Act 2006 (NOSDRA) for the coordination and implementation of the National Oil Spill Contingency Plan for Nigeria to ensure a safe, timely, effective, and appropriate response to major or disastrous oil pollution. National Park Services Act (Cap N65 LFN 2004). This makes provision for the conservation and protection of natural resources and plants in national parks Nigerian Minerals and Mining Act 2007. This repealed the Minerals and Mining Act No. 34 of 1999 and re-enacted the Nigerian Minerals and Mining Act 2007 to regulate the exploration of solid minerals, among other purposes. Water Resources Act (Cap W2 LFN 2004) aims at promoting the optimum development, use, and protection of water resources. Hydrocarbon Oil Refineries Act is concerned with the licensing and control of refining activities. Associated Gas re-injection Act which deals with gas flaring activities by oil and gas companies Nuclear Safety and Radiation Protection Act: The Act regulates the use of radioactive substances and equipment emitting and generating ionizing radiation. Oil in Navigable Waters Act prohibits the discharge of oil from ships into territorial waters or shorelines

5.0 Discussion. The country has been solely dependent on the exploitation of oil and other natural resources. Up till now, they have often destroyed habitats. Ecological disasters, environmental degradation such as sheet and gully erosion are common in Eastern Nigeria, flooding in Lagos and the issue of drought, deforestation in the Northern States, and the pollution of land, air, and water are common in the industrialized West-East axis. These are the identified physical problems that plague environmentalists and policy makers in Nigeria. The government has therefore enacted various environmental laws to guide usage as well as protect the environment. The challenge before her is the ability to effectively implement environmental laws. The main identified environmental problems in Nigeria include solid and liquid waste management, land degradation, flood and erosion control, desertification, inefficient utilization of energy resources, loss of biodiversity, environmental disasters, and deforestation. The main problems of implementation of environmental planning and protection laws in Nigeria include the limitation of the legal framework, institutional bottleneck and corruption, inadequate funding, inadequate environmental impact assessment (EIA), and ignorance. Acts intended to protect the environment seemed to be inconsistent and with no regard to fundamental human rights, because of their inability to guarantee access to a healthy environment. Thus organizations and individuals who pollute the environment are greeted with liberal charges, which have little or no effect on the organizations, society, or the individuals. The resultant impact of this anomaly has been an uncontrolled pollution activity and degradation of environmental quality in Nigeria. Even institutions created by law to monitor the industry's compliance with environmental standards have failed woefully to enforce the rules due to institutional bottlenecks and corruption. The environmental impact assessment law requires all major development projects to undertake environmental impact assessments, but no meaningful enforcement of this law has been in place. The gross inadequacy of funding is another major problem facing the implementation of the various environmental laws. For example, huge sums of money were earmarked by various State Governments for the execution of environmental projects, only a very small amount is released to the implementing agencies for actual operations.

6.0 Recommendations for Effective Implementation of Environmental Planning Laws in Nigeria.

1. Review of environmental laws and their regulatory institutions to uphold basic fundamental human rights to healthy environments

2. Review of the established liberal charges and taxes issued against violators of environmental laws and invoke the policy of "pay- as -you –pollute" principle to serve as a deterrent to offenders

3. The functions of Federal, State, and Local Governments in the administrative implementation of environmental planning laws should be streamlined to avoid overlapping of their respective duties. 4. Corruption among enforcement officers should be checked through proper methods such as direct bank payments/ mandatory sanitation fees.

5. Environmental impact analysis should be made compulsory for all major projects to provide relevant data for all stakeholders and policy makers.

6. Government should provide adequate funding and ensure that resources released for environmental management programs are judiciously utilized for the purpose for which it was released.

7. Poor environmental education calls for government attention to mount strategic environmental campaigns to raise public awareness through the various existing media in Nigeria. Environmental education should also be part of the curriculum of the social and behavioral sciences in Nigerian institutions of learning.

6.0 Conclusion

The paper concludes that Nigeria's degraded environment is a result of failure to implement appropriate policies, ineffective institutional arrangements for environmental management, poor funding, and a low level of environmental awareness among other factors. Addressing the situation requires a holistic approach from the Federal, State, and Local government level, which takes into consideration the political, economic, and social dimensions of livelihoods in the formulation of policies, as required by Agenda 21 of the Earth Summit**.** It is recognized that our environmental degradation is a factor of poverty, underdevelopment, and economic activities. Since we must exploit our environmental resources for economic growth, it has been suggested that we can have sectional development with the enhancement of environmental quality, both of which are important for the general well-being of our people. To be able to achieve this, some strategies have been suggested which, if incorporated into our development process, could enhance pollution prevention and abatement, resource conservation, and development of indigenous capabilities to predict adequately the environmental consequences of our economic activities and technological development. The biological environment is the universe of living things that surrounds man, including the man himself. The difficulty, in the face of deteriorating levels of pollution today lies in the non-enforcement of environmental legislation. This is aggravated by the fact that ecosystems despoliation in Nigeria had advanced appreciably before laws to protect them were drafted. A favourable social environment can improve health provide opportunities for man to achieve a sense of fulfillment and add to the quality of life.

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AWARENESS AND APPLICATION OF CLIMATE CHANGE POLICIES AND LAWS IN ENUGU STATE

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Abstract: The awareness and application of climate change laws were assessed in Enugu State. Four local government areas – Enugu municipal, the seat of government; Uzo Uwani; Awgu and Nkanu East local government areas were selected for the study. A total of 368 respondents were interviewed using a structured questionnaire and oral interactions. The data collected were analyzed using both descriptive and inferential statistics. In Enugu municipal, 95.42% of the people were found to be aware of climate change. In the same vein, the following percentage of respondents were found to be aware of climate change events – Uzo-Uwani 7.24%; Nkanu East 61%; Awgu 74.94%. Chi-square statistical method was used to test the hypothesis which states that "there is spatial variation in the level of awareness and application of climate change laws in Enugu state and the hypothesis was accepted". The results were shown using tables, graphs, and charts. Data analysis using the Pearson's Correlation Coefficient showed an inverse relationship between responses and distances from the local government area (r = -0.640) indicating that awareness decreased with distance from the state Capital at Enugu (Enugu State). Concerning the application of the laws, it was discovered that executive orders were used to meet with the climate change challenges as the National Assembly had not passed any Climate Change Act. The study concluded that there was the need to embark on a state-wide citizenship education program, particularly in the rural local government areas to prepare the citizens for any events of the future.

Keywords: *Awareness, Application, Laws, Climate Change, Government*

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INTRODUCTION

Background of the Study

The earth is a system made up of other sub-systems (Christopherson, 2006). We have the soil – rock systems, vegetation, water, atmospheric system, etc. on the human side we have the transport system, settlement system, cultural system, etc. Both the physical system and the human system constitute the earth system (Norton, 2010). Several studies have shown that the earth has never been stable in all of its histories, but undergoing changes (Norton, 2010). The earth's atmospheric systems also experience these changes from time to time based upon the fact that life on earth is conditioned by the state of the earth's climate system, changes in the earth's climate system bring about changes in the mode of life and living of all organisms on the earth including man.

Climate change according to IPCC refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 1988)

Climate change is defined in this study as the change in the state and dynamics of the earth's atmospheric system. The change is manifested in the departure of the values of the observed climatic variables from their former values (Odjugo, 2009). The variables that are the most important indicators of climate change are temperature and precipitation. The entire process of climate change hinges on the increase in the mean global temperature over some time (Ekwezuo, 2015). This global temperature increase is called global warming which will, in turn, affect the pattern and velocity of the global wind system (humidity, cloud cover, and wind speed) (IPCC, 2003; 2007). The change ultimately affects all the life cycles on earth which depend on the supply of moisture and heat from the sun.

Past climates change regimes that had occurred on the earth had no consequences for mankind except to the extent of shaping the earth's landscape as the current global population and civilization now sees and uses it. These earlier episodes have provided us with the platforms of our present existence. Mankind is now faced with the unfolding of another phase of climate change which produces variation in the earth's physical systems and largely drives and regulates the mode of human existence upon the earth. The already occurring and predicted effects of climate change demand and required responses from the global population if mankind will not be annihilated or nearly annihilated by the expected profound changes that may occur as consequences of climate change.

The earliest organized responses to observed quirky behavior of the global climate commenced in countries where the result of observations had produced the scientific communities and governments in these countries to look more closely at the atmosphere. The conflation of research results caused the convening of the first conference on global climate change was held in Berlin in 1995. The next stage of the investigation consisted of steps to find out the causes and dynamics of climate change, this next step was taken by the convening of the Inter-Governmental Panel on Climate Change (IPCC). The panel issued its first report in 2001 (IPCC, 2001) containing explanations on the scientific basis of climate change. Before 2001, the United Nations had put up the United Nations Framework Convention on Climate Change (UNFCCC), (UNFCCC, 2005). In the various advanced countries of the world, national agencies became increasingly devoted to observing the trend in the climate of nations and their regions. In the United Kingdom, the Hadley Centre for Atmospheric Research UK researches climate change while the National Center for Atmospheric Research oversees climate research in the United States of America.

The result from the various national and global bodies pointed towards the industrialized countries being responsible for the emission of greenhouse gases into the earth's atmosphere and causing global warming and ultimately climate change. The further computer-aided analysis identified carbon monoxide and chlorofluorocarbons such as trifluoromethyl sulphur pentafluoride (SF_5CF_3) (Fawehinmi, 2007). These findings implicated man via the effluent gases and gases from burning organic fuels as the main culprit causing climate change. The damaging of the action of man was traced to the manufacturing plants of the world's economically advanced countries that accounted for more than 85 percent of the finished goods consumed in the world (UNEP, 1992).

Statement of the Research Problem

The economically and technologically advanced countries initially denied their roles in inducing climate change by relying on the records of earlier global climate change episodes to claim that the current climate phenomenon was a natural cycle as had been advanced by Milankovich (1941). Their main grouse was that the demands upon them to reduce the Green House Gases emitted from their factories and plants translated to a reduction in quantum and varieties of the goods they manufactured and finally resolved into a surrender of their earnings, dominance, and standards of living. These advanced countries needed extra persuasion based on verified and verifiable scientific data to be drawn to the discussion table as to how mankind can save the earth by not damaging the umbrella of safety that shields the earth from the destructive rays of the sun.

An examination of Nigeria's Climate Change Bill (FG – NASS 2001) shows that there is a program for education, information, dissemination of technical information, and support in respect of climate change. This provision is very important because it is the capacity for adaptation to and mitigation of climate change consequences that enable populations to survive the impacts of climate change.

The legislation structure in the country envisages that other states would formulate and pass their policies and laws on climate change. It appears that it is only Lagos State alone that has made and is applying its laws due to the sensitivity of its environment in respect of flood hazards that occur there. It is a known fact that knowledge of a thing is a basic requirement for using or relating it to any such phenomenon (Thomas, et. al., 1991). Where knowledge exists it is relatively easy to react to certain phenomena and the contrary is true. This is why the problem of this study is formulated around the study of the awareness of and application of climate change law and policy in Enugu State. The following questions were posed as a means of guiding the study:

i. Are there institutions that have been assigned the dissemination of climate change information?
ii. Are the organs of the government of Enugu State and the people aware of climate change and its effect as a subject matter?
iii. Are there officially stated responses by the government and people of Enugu State to adverse climate change effects in the state?
iv. What percentage of the population of the people are aware of, and follow /apply any state policies to climate change-related problems in various parts of Enugu?

Hypothesis

"There is spatial variation in the level of awareness and application of climate change laws in Enugu State".

Study Area

Location and Size

Enugu State was created out of the old Anambra State in 1991. It lies between longitudes 6º 30´E and 6º 55´E; and latitudes 5º 15´N and 7º 15´N. It consists of seventeen (17) local government areas with a total of 3, 267,837 persons. The population consists of 1,596,042 males and 1,671,795 females. It has an area of 7,161 square kilometers (NPC, 2006). See Figure 1.

Fig 1: Sampled Areas. Source: Cartographic Unit, Department of Geog. UNN, 2018.

Climate, Relief, and Geology

The climate of the state falls within Koppen's Af which is relatively wetter south in Oji River, Awgu, and Aninri local government areas to the relatively drier northern parts at Uzo Uwani, Igbo Eze North, Igbo Eze South, and Isi Uzo local government areas (Enugu State Ministry of Chieftaincy Affair, 2016). The mean temperature is 26ºC.

The relief of the state consists of the western plains, formed on the Imo – Clay – Shale with a mean elevation of 65 meters. This plain is drained by the Do, Obima, and Ishe rivers. Eastwards from the western plain, the topography rises on a steadily increasing gradient to a central cuesta and attains a mean elevation above a mean sea level of 482 meters. See plate 1 below.

Plate 1: Showing the Eastwards Side of the Cuesta Source: Authors Fieldwork, (2018)

Plate 2: Showing the Scarp Face of the Cuesta
Source: Authors Fieldwork, (2018)

This central block is widest in Nsukka Local Government Area where it measures 50 kilometers and narrowest in the section covering Oji River and Awgu Local Government Areas (37 kilometers). The stratigraphic succession of the cuesta consists

This central elevation is formed from an uplift of a section of the land west of a series of fault lines created by the Maastrichtian – Santonian Orogenic Cycle. The uplift occurred by the plutonic intrusion of magma into the sub-layers of marine sediments from the Mt. Cameroon magma reservoir (Murat, 1970; Ugwueze, 2000). The uplifted materials vary from soft sandstone layers in the northern section from Enugu Ezike to Ekwegbe in the northern half while in the southern portion it consists of large massive fractured sandstone blocks (Aneke, 2007). In the section south of Enugu Ngwo between Udi and Akpugo, the block is tilted backward at an angle 3º - 5º of the horizontal plane. The scarp face is more defined in this section. See plate 2 below

as follows: The Imo Clay shale (Mamu Formation, Enugu – Awgu Shale) beneath overlaid immediately above by the false–bedded sandstones (Ajalli Formation) and Enugu. Awgu sandstone which is blocky, massive, and fractured on which rests the Upper Coal Measures – a layer of laterite with indurations that form dome-y round-topped and flat-topped residuals. In the Nsukka section, the residuals are separated by a network of dry valleys with a mean width of 1.10 kilometers. In the southern section, the elevations are separated by narrow stream valleys occupied by perennial headstreams of the Oji – Mamu river systems (Ofomata, 1975; 1978; Ebisemiju, 1976). This central elevation is the most settled in the state. East of the central elevation and the scarp face, the relief consists of a section of the Cross River plains serrated by varying many easts to southeast flowing streams which take their source from the foot of the scarp (Ofomata, 2001).

Soils and Vegetation

The soils on the elevation are ferralitic soils rich in iron derived from the laterization processes on the sandstone substrate. The sandstone is coarse to medium coarse and is porous allowing precipitation on the cuesta top to infiltrate downwards to the sandstone – shale interface and for the infiltrating water to issue as contact springs (scarp foot springs). The soils on the plains vary from gravelly sandy loam on the talus slope immediately beneath the scarp face to sandy clay and sand-clay loams on the toe slope of the plains proper (Njoku, 2013; Ndulue, Ayadiuno, and Mozie, 2020).

The vegetation of the state is densest in the south and on the plains particularly along with stream courses and lowlands and consists of grasses on the hill slopes. The plants consist of woody plants such as the Iroko (*Milicia exelsis*), and anthropic plants such as Mangoes, Guava, etc. Cultivated plots are mainly of the *Manihot spp* (Cassava), Coco yams, vegetables, etc, especially in the rainy/farming season (Uzozie, 1975; Ndulue, Ayadiuno, and Mozie, 2020). Grass species consist of the *hyparrhenia spp*., Elephant grass, Speargrass (*Pennisetum spp*), etc.

Population and Economic Activities

The population distribution in the state is presented on a local government area basis from data obtained from the National Population Commission database (NPC, 2006 – 2011 accessed on 21st of March 2018). The population distribution is contained in Table 1 below:

TABLE 1: Population Distribution in Enugu State.

LGAs	Population	Area	Pop. Density
Aninri	136,221	364km²	505.2/km²
Awgu	**197,292**	**330km²**	**597.1/km²**
Enugu West	**277,119**	**383km²**	**976.8/km²**
Enugu North	242,140	106km²	3,084/km²
Enugu South	**198,032**	**67km²**	**3,990/km²**
Ezeagu	170,603	633km²	363.8/km²
Igbo-Etiti	208,333	352km²	865.2/km²
Igbo-Eze North	258,829	293km²	1,192/km²
Igbo-Eze South	147,364	158km²	1,259/km²
Isi-Uzo	148,597	877km²	228.7/km²
Nkanu East	**153,591**	**795km**	**260.8/km²**
Nkanu West	147,385	225km²	884.0/km²

Nsukka	309,448	1,810 km²	863.0/km²
Oji-River	128,741	403km²	431.3/km²
Udenu	178,687	248km²	972.6/km²
Udi	238,305	897km²	358.6/km²
Uzo-Uwani	**127,150**	**855km²**	**200.1/km²**

Source: NPC (2006 - 2011) and Authors computation (2018).
Please Note: Highlighted Local Governments Areas are Sampled Areas

MATERIALS AND METHODS

Research Design

The aim and objectives of the study directly influence the methodological pathways to achieve both aim and objectives. The general rule is that the research method must enable the fulfillment of the aim via the achievement of the objectives and the acceptance or rejection of the hypothesis of the study.

Type and Sources of Data

The data used in this study include primary and secondary data. Primary data used was obtained from direct field observation, measurements, photographs, and oral interviews. While the secondary data that was used included maps, Library data, online data, published and unpublished articles, and textbooks.

Sampling Technique

It is not possible for the qualified respondents in every part of Enugu State to be examined. As such, certain representative, local government areas were chosen for the study out of the seventeen (17) local government areas in the state. The basis of the selection was the political division of Enugu State into senatorial zones. Three of these zones exist in the state namely the Nsukka (Enugu North), Enugu East (Nkanu - Awgu), and Enugu West (Udi – Oji River) Senatorial districts. From each of these zones, one local government area was selected based on the occurrence of climate change disasters from 2000 to 2018. In this respect, Uzo Uwani (Enugu North), Nkanu East (Enugu East) and Awgu Local Government Area (Enugu West) were selected. Enugu West and Enugu South that made up the municipality were also selected for sampling. Each of these local government areas has experienced climate change disasters within the period of the study. For example, Uzo Uwani and Nkanu East experienced floods in 2012 while Awgu had experienced rainfall-induced landslides in 2008 and 2010 also within the period. Enugu urban, the capital zone was also sampled as the central area of the study where the political, administrative, and economic control mechanism of the state resides.

Selection of the Respondents

The issue of climate change is now a common matter but it appears to be so only to selected groups. The study was designed to elicit information from two sides, viz: the state government officials at the state level in certain ministries that were selected such as Ministry of Agriculture, Works, Urban and Regional Planning, Health and Education.

The inclusion of the state Ministry of Health was to see if there is a policy of citizenship education as a measure to containing climate change as it is done in the developed countries (Wikipedia, 2017). Thus, respondents were identified as follows: In the selected ministry – the permanent secretary and two other directors, one section head whose schedule of duty is relevant to the subject of study making a total of five (5) top officers in each ministry giving a total of twenty-one (21) state officials at the state level. At the local government level, the same pattern was repeated with the Head of Personnel, six (6) supervising counselors in three (3) local government areas making a total of eighteen (18) officers.

In each of three (3) local government areas, three (3) communities that had suffered climate change disasters were identified making a total of nine (9) communities, Enugu the capital city was purposively chosen as the tenth location for sampling. From each of the communities, fifteen (15) respondents were chosen to make forty-five (45) respondents per local government area and a total of one hundred and thirty-five (135) respondents. In Enugu, respondents were randomly chosen to span the age range from twenty-five (25) years to sixty (60) years and covering the literate (50%), semi-literate (30%), and illiterate (20%) on an equal 50 – 50 bases between the sexes. A total of eighty (80) respondents were randomly interviewed with the act of recorders in randomly allotted points inside Enugu. A total of three hundred and eight (368) respondents were examined in all.

Method of Data Collection

The copies of the questionnaire were applied on a face–to–face basis in six months from July to December 2017. The physical contact eliminated the loss of copies of the questionnaire and greater and deeper probes of the respondents outside the questions on the questionnaire. The local language (*Igbo*), Queen's English, and the *pigeon* English were used in the exercise for effective interaction.

The Questionnaire Survey

One hundred and thirty-five (135) copies of the structured questionnaire were constructed as the tool of data collection since the study is based on fieldwork, questionnaire survey, and direct field observation in the study areas. The questionnaire scored 78% on Cronbach's Alpha Index added to the dry test run of its contents before it was approved for application to the respondents. The outcome of the dry test run was satisfactory and so the later copies of the questionnaire were reproduced for use during the fieldwork.

DATA ANALYSIS RESULTS AND DISCUSSIONS

The data collected were analyzed using both descriptive and inferential statistics, translated to frequencies and percentages, and the results as analyzed were shown using tables, graphs, and charts. Inferences were made from the responses, for example, the level of awareness of climate change in urban settings and rural settings were compared using Pearson's Correlation Coefficient statistics (Anyadike, 2009). The Chi-square statistical method was used for testing the hypothesis.

Level of Awareness of Climate Change Policies in Enugu State

The level of awareness by the solicited respondents is reported. It has been stated in the earlier part of this study that knowledge is a basic tool for meeting and overcoming climate change-associated problems in any part of the world (Muttarack and Pathisiri, 2013). While the government and people in the advanced nations have taken the time and expended resources, there is yet no certain data on how far the people and government of Nigeria have gone in this direction. Most of them became aware of what climate change could bring from the news media and social media. The source of information showed that the availability of smartphones as a means of information is not in doubt amongst the above-average salary earners. The use of smartphones was followed by radio – read news bulletins and to some extent newspapers. The urban poor were still largely unaware of what climate change means or being aware of the laws neither did they know about how relevant information can help them. Thus we found a situation that suggested a high tendency of timely and appropriate response in favour of the rich vis-à-vis the poor. This finding fits into the results of Shamshudoha and Chaudry (2009). The levels of awareness obtained in the various parts of Enugu State are shown in Tables 2 below:

TABLES 2a: Number of Respondents interviewed

Sampled Area	Number of Respondents interviewed				Total	Mean
	Head of Personnel	Supervisory Counselor	Farmers and Artisans	Others (FGD)		
Enugu Municipal	1	6	10	70	87	21.75
Nkanu East	1	6	60	30	97	24.25
Awgu	1	5	57	34	97	24.25
Uzo Uwani	1	6	10	70	87	21.75
Total	**4**	**23**	**137**	**204**	**368**	**92**
Mean	**1**	**5.75**	**34.25**	**51**	**92**	**23**

Source: Authors Computation (2018)

TABLE 2c: Respondents Level of Awareness (%)

Sampled Area	Respondents Level of Awareness (%)				
	Head of Personnel	Supervisory Counselor	Farmers and Artisans	Others (FGD)	Level of Awareness (%)
Enugu Municipal	100	100	95	100	95.42
Nkanu East	100	66	20	18.5	61
Awgu	100	100	33	15	74.94
Uzo Uwani	100	23	9.45	6.5	7.24

Source: Authors Computation (2018)

TABLES 2b: Awareness Level of Climate Change Policies in Enugu State

Zone 1 Enugu Municipal			
S/No	Official Respondent	Frequency	Level of Awareness (%)
1	Head of Personnel	1	100
2	Supervisory Counselor	6	100
3	Selected Respondents (FGD)	55	95
4	Farmers and Artisans	25	100
Total Number of Respondents		87	
Zone 2 Nkanu East (Amurri)			
1	Head of Personnel	1	100
2	Supervisory Counselor	6	66
3	Selected Respondents (FGD)	60	20
4	Farmers and Artisans	30	18.5
Total Number of Respondents		97	
Zone 3 Awgu LGA (Awgu)			
1	Head of Personnel	1	100

2	Supervisory Counselor	5	100
3	Selected Respondents (FGD)	57	33
4	Farmers and Artisans	34	15
Total Number of Respondents		97	
Zone 4 Uzo Uwani (Adani)			
1	Head of Personnel	1	100
2	Supervisory Counselor	6	23
3	Selected Respondents (FGD)	55	9.45
4	Farmers and Artisans	25	6.5
Total Number of Respondents		87	

Source: Authors Fieldwork and Computation, (2018)

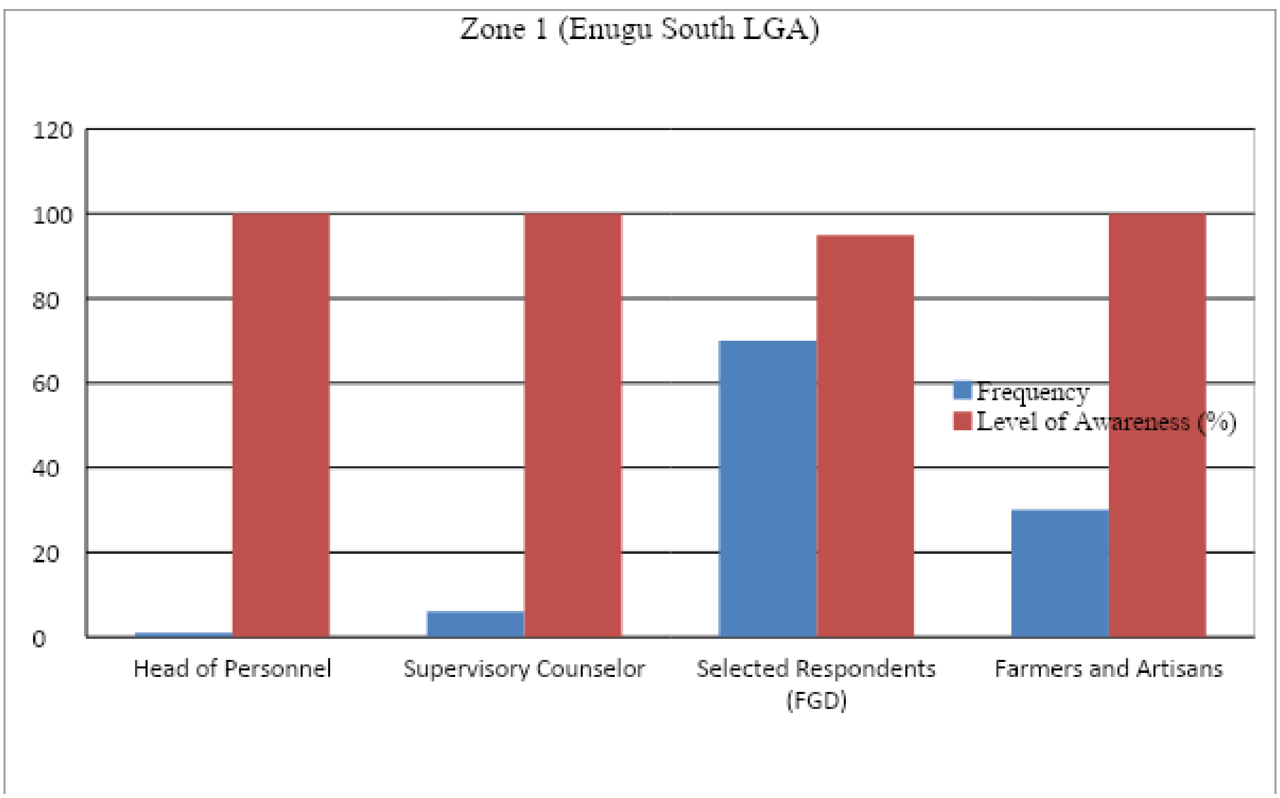

Fig 3: Graphical Representation of Respondents in Enugu South
Source: Authors computation (2018)

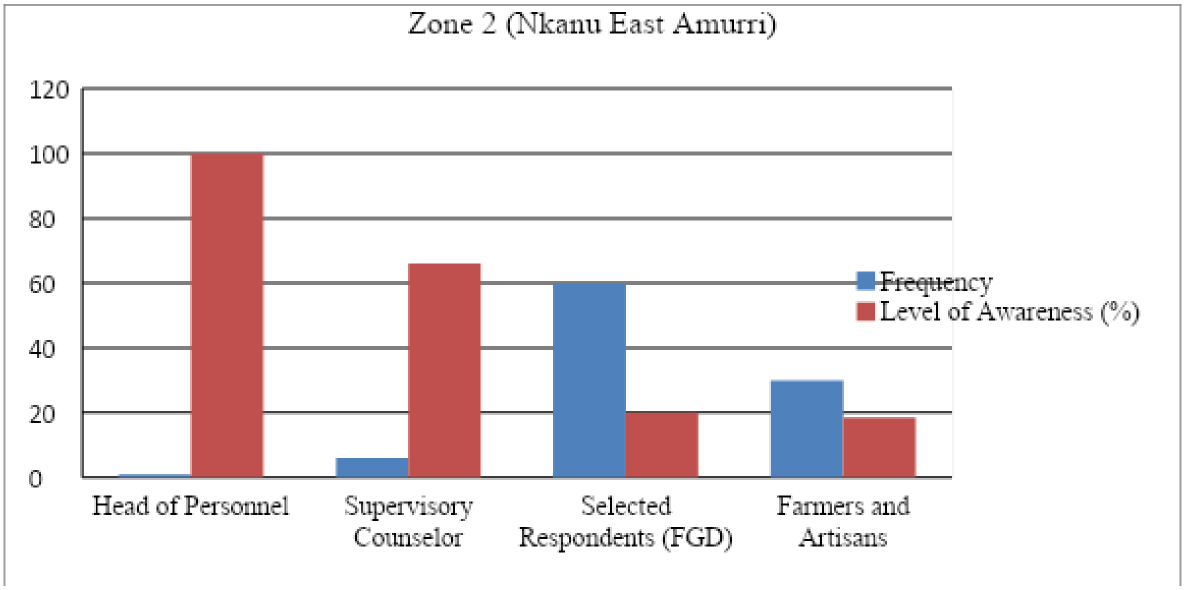

Fig 4: Graphical Representation of Respondents in Nkanu East
Source: Authors computation (2018)

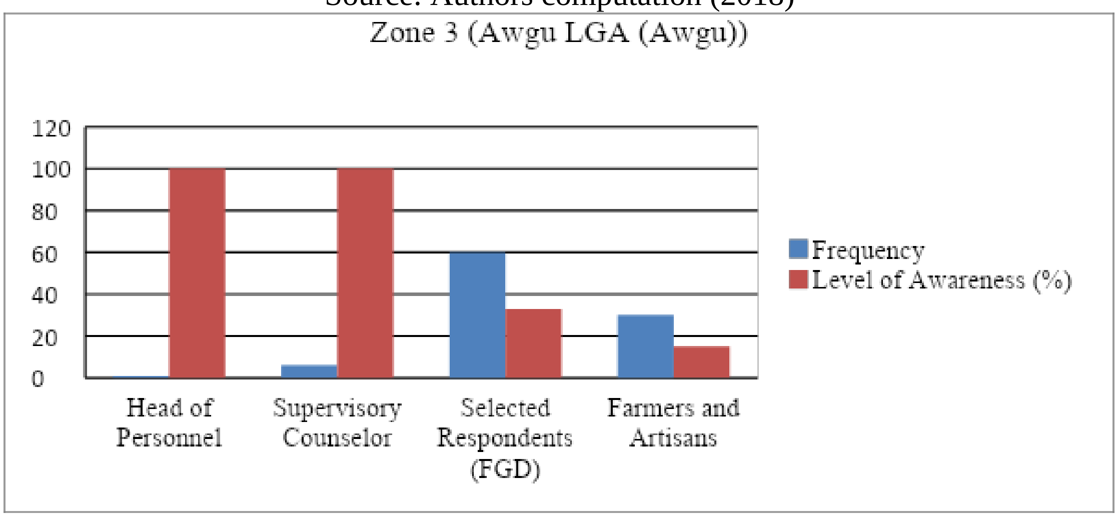

Fig 5: Graphical Representation of Respondents in Awgu LGA
Source: Authors computation (2018)

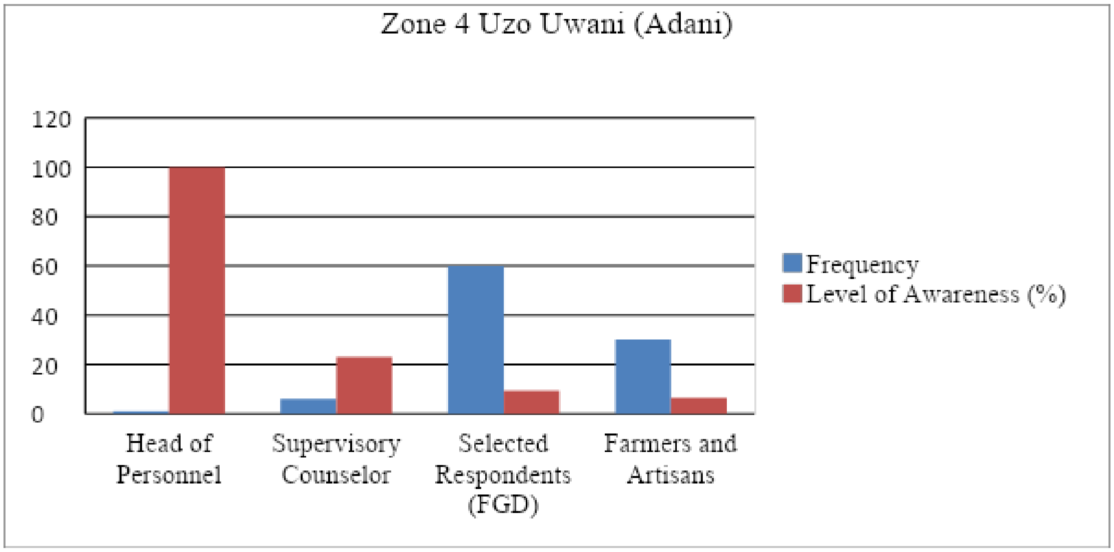

Fig 6: Graphical Representation of Respondents in Uzo Uwani
Source: Authors computation (2018)

With respect to Tables 2 above, the top personnel management officials in Enugu South said that they were fully aware of what climate change was all about by their social and educational status. They had access to information from the internet (social media), radio, television, etc. the six (6) supervisory councilors who also were graduates of Universities and Polytechnics said they were fully aware of climate change and its effects. They made specific reference to the 2012 floods in Nigeria. 95 percent of the respondents that were randomly interviewed in the area were aware of the subject – a matter of climate change. Once again there appeared to be a relationship between the awareness level, education, and the type of work the respondents were doing. The office workers and teachers were aware, while the artisans and other workers were not aware of climate change.

Within Enugu, the persons engaged in various farming activities such as poultry rearing had more awareness of the 75% scored by that group. Enugu scored a mean of 88% compared to other zones, Nkanu East scored 61%, Awgu Scored 74.94% and Uzo Uwani scored 37.24%. The spatial pattern of awareness was discerned as follows: The awareness of the respondents to climate change was seen as follows: In Enugu South (Enugu) zone, a high percentage of awareness was recorded (95.42%). This very high score is explained by the environment of work and habitation of the respondents. 99 percent of the respondents were graduates of higher institutions. Only one respondent had an Ordinary National Diploma (OND) from the Uwana Polytechnic Afikpo in Ebonyi State. The respondents said that they read newspapers or such information from their handheld global system for mobile (GSM) phones. They also receive information from their television sets. Above all these respondents were receiving salaries that could enable them to indulge in information collection and evaluation in respect of climate change and other political events in their surroundings.

In Nkanu East Local Government Area at Agbani, the level of respondents obtained was 61%. The top official was sound. He lived in Enugu and come to work from there. The other officials who are indigenes of the local government area were not so familiar with the subject – a matter of climate change. The respondents who were fully aware of the topic were all graduates of one University or the other and had access to information from their phones, radio, newspaper or television sets, etc. They agreed that climate change was a global problem and also recognized the effects of the recent floods in the area from Agbani towards the low-lying areas of Amurri, Nkerefi, Akpochi, etc on the plains of the Idodo River. They also commented on the losses of rice crops by the farmers in the study area.

In Awgu Local Government Area, a mean level of 49.74% was observed. Awgu town and the surrounding communities are predominantly rural. Hence, the majority of the top officials live in Enugu the capital city. They come to work on selected days in Awgu. They are reached by phone if and when there are scheduled activities. They showed a lower awareness of climate change even though events around them such as landslides and increased leakages of water from the rocks should prompt them. A mean awareness level of 49.47% was recorded. The pattern observed is that of a greater level of awareness at the very top end less than usual at the lower levels. Within the ordinary people, awareness was 15.30% down from 100% at the top where the officials were fully educated and had access to information. The observed difference between the responses by the top officials and the lower rung respondents is explained by the education and the social status of the respondents.

The lower result from Awgu with respect to its distance from Enugu the capital city is that it has no influencing institution unlike Nkanu East which has the Enugu State University of Science and Technology at Agbani and the Renaissance University also in Agbani. The influence of the two Universities and other institutions can be seen as causing the difference in the levels of awareness observed in the two areas. The influence of the higher institutions translates to greater educational opportunities and a greater level of modernity in the area as against Awgu Local Government Area which has a predominantly rural and less educated population. The counselor for the Mmaku community estimated that they had an 85% rural population in his ward and that it could be more.

In Uzo Uwani Local Government Area, the mean level of awareness of the people to climate change and its effects dropped to 27.24%. See figure 7.

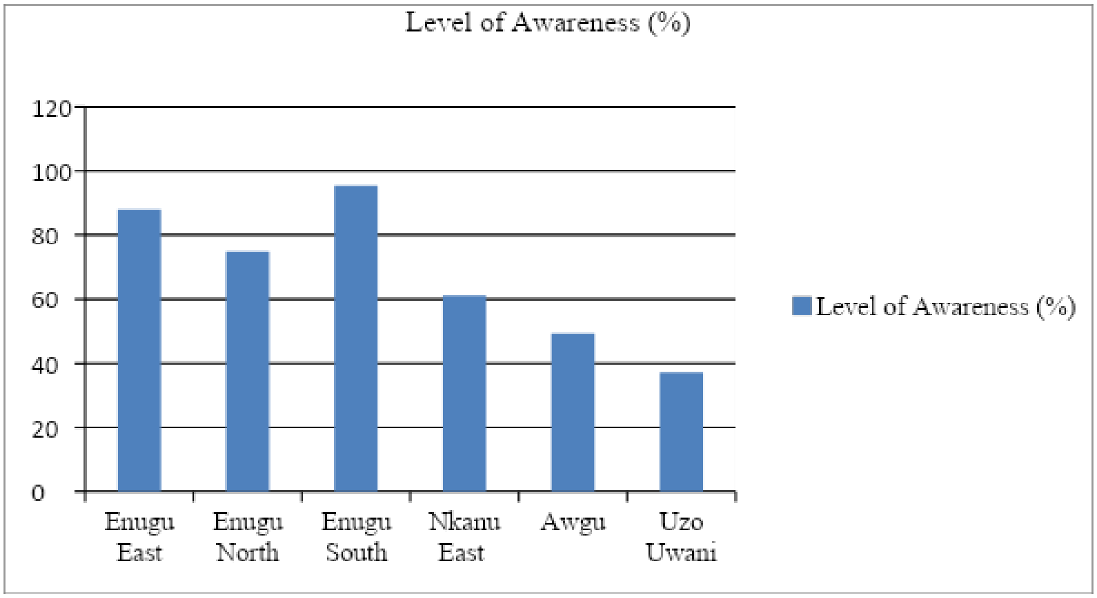

Fig 7: Graphical Representation of Level of Awareness to Climate Change
Source: Authors Computation (2018)

Uzo Uwani Local Government Area remotely removed from Enugu and Uzo Uwani. Its headquarters is in Umulokpa which is accessible from the 9th mile corner on a modern road. A respondent from Adaba the next community to Umulokpa who is a retired staff of the Enugu State Ministry of Finance said that the people were very largely farmers. It was on one of the Mondays in 2017 August that the respondents were interviewed. No top official or even the middle-level officers were in the place. The mass of the people lives with their families in their communities where they engage in full-time farming and trading. The student's visit to Adani the other sizeable community in Uzo Uwani showed that attention was on rice cultivation by the people. The respondents talked of the floods called '*iji*' but had no idea of the cause of the floods *'iji'*. They appear to have started adjusting to the new normal by cultivating their food crops slightly earlier and after the floods, they do a follow–up cultivation of rice which they keep in their nurseries.

The spatial pattern of awareness to the phenomenon of climate change observed is that the highest level of awareness was observed in Enugu South in the capital city of Enugu, Enugu State Nigeria. The relationship is that, the farther away from the local government area of observation from the capital city, the less level of awareness. A correlation coefficient of distance – decay junction model (Todaro, 2002) was calculated using Pearson's Coefficient of Correlation (Anyadike, 2009) to obtain a coefficient of – 0.640, which is a negative correlation.

In the light of the visible influence of educational levels as a major factor of the awareness, it was reasoned that level of education connotes reasonable employment, reasonable payments, access to information, and high levels of awareness of the educated respondents to climate change information.

The role of education in disaster preparedness was carried out in a seminal paper by Muttarack and Pathisiri, (2013). Their findings were that the more educated people about climate change hazards the better prepared they were to meet with the emergencies of the situation and the lower the effect of such emergencies on the educated population. Awareness comes from the reception of information (Menan, Slater, and Flintz, 2011 and Muttarack and Pathisiri, 2013). Information was a change or modification of attitude and response to an existing or anticipated event. The better a person is educated, the more aware he or his group is. It has been established that awareness or education is important in the building of resilience and reduction of vulnerability of persons and groups in their response to climate change (Frankenberg, et. al., 2013). The implication of the intergroup and intragroup disparity in the awareness of the respondents observed in this study will be discussed in the summary of this research as it holds a grave implication for the survival of the masses in Enugu State from climate change hazards. These findings directly suggest that the people in general and the people in the rural area are in particular should be put under a region of tutelage about environmental hazards before it is too late.

Test of Hypothesis

"There is spatial variation in the level of awareness and application of climate change laws in Enugu State".

Apart from mere description of the data collected, some useful explanations, inferences, and deductions were done by subjecting the stated hypothesis at a 5% level of significance to Chi-Square Statistical analysis and the result is presented in table 3 below.

TABLES 3: Chi-Square Tests

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1104.000[a]	21	.000
Likelihood Ratio	1019.225	21	.000
Linear-by-Linear Association	.021	1	.883
N of Valid Cases	368		
a. 8 cells (25.0%) have an expected count of less than 5. The minimum expected count is .95.			

Source: Authors Computation in SPSS Version 25 (2018)

The result presented in Table 3 revealed the level of awareness and application of climate change laws in Enugu state. It was found that the Pearson Chi-Square Value = 1104.000, df = (21), and the Chi-Square test is significant with P-Value at .000. Since P-value is less than 0.05 level of significance, therefore the hypothesis is accepted which states that *"there is spatial variation in the level of awareness and application of climate change laws in Enugu State".*

Existence and Application of Climate Change Laws in Enugu State

The study also captured the issue of the existence of extant laws is considered and followed up with the provision of the answer as to whether in the face of the unfolding climate change any new pieces of legislation have been passed to help the government and the people of Enugu State to meet with the exigencies of climate change in the state.

At the least level, the student investigated the attitude of the government of Enugu State and her population whether there are measures put in place to ameliorate the harshness of climate change. In such state as Lagos State, the effects of climate change as in the widespread annual floods had brought down the reality of climate change to the people and government of Lagos State, and steps have been put in place to contain the problems stunted from the laws made on tree planting, clearance of waste, construction of drainage ways for free flow of floods, etc.

This inquiry is carried out from three perspectives namely the perspectives of some of the members of the government in Enugu State who are placed in positions of trust and authority as makers of the laws in the State House of Assembly, as leaders of the judiciary in the State Justice Ministry, officials of government agencies who are expected to apply any existing or new laws that affect the environment.

Key Informant Interviews were used in this exercise and the results are presented:

The student was able to interview the following persons – some Commissioners in the government of Enugu State, members of the State House of Assembly, and some of the knowledgeable persons (directors) in the ministries of Urban Planning, Agriculture, Health, and Works in Enugu State.

The Extant Laws of the Environment

The fundamental law that underlies all the other environmental laws is section 20 of the 1999 Constitution of the Federal Republic of Nigeria as amended. The section provides as follows:

"That State shall protect and improve the environment and safeguard the water, air, and land, forest, and wildlife in Nigeria". There is also guarantees in the constitution for the security and welfare of the people of Nigeria as the primary purpose of government at section 14(b), a dynamic economy for the prosperity of the people at section 1b of the constitution and other Acts and Laws of the states of the country which deal with the general and specific aspects of the protection and enhancement of the lives of the people in Nigeria.

It is observed that scholars and authorities have stated that climate change and its effects come largely from the activities of man (IPCC, 2007). This claim is to be interpreted as meaning that the wrong use and management of the natural resources that are available to man is largely responsible for climate change and its consequences. This assertion expands the scope of events that occur and affect the people when climate-related hazards occur. Since climate change has its roof in atmospheric pollution and the alteration of the relation quantity of the gases that constitute the atmosphere in favour of the Green House Gases (GHGs) the Petroleum Act (1969) is first considered.

Environmental Impact Assessment Act (1992)

According to Mozie (2009) and Uchegbu (2012), this Act is nationwide and is Nigeria's response to the outcomes of the

United Nations Conference on Environment and Development also called the Bruntland Report (1986). The Act called E. I. A. Act provides for a pre-development evaluation of every intended project as to its impact on the environment including the people, the atmosphere, water, air, land, and vegetation (Uchegbu, 2000). The E I A Act provides that all the activities on the environment conform to policies that safeguard the people and their environment under the doctrine of "control" such that land-use types in any part of the environment result from an interaction of the needs of the people and the environmental standards contained in the relevant Act or policies (Salau, 1981; Mozie, 2010). The Petroleum Act is now almost replaced by the Petroleum Industries Governance Bill which is yet to be signed into law by the Senate and the House of Representatives (UN - NASS).

Urban and Regional Planning Act (1988)
This Act regulates town planning practice in Nigeria. The essence of urban and regional planning is to assure that the physical structures on the landscape are situated in the proper places relative to other existing structures and other structures planned for in the future (Uchegbu, 2000).

Land Use Act (1978)
The land use Act was promulgated in 1978. It nationalizes all lands and places that are under the control of the governors of states in the states and the control of Local Government Chairmen in the local government. This Act places to land in the public domain and gives the government the right to allocate land to any beneficial use and to revoke the grant of any piece of land all in the public interest. It complements the EIA Act and the Urban and Regional Planning Act because it provides for the government of a state to be aware of and approve any intended use of the land in any place through the grant of Certificate of Occupancy. There are the Statutory Certificate of Occupancy which lasts for 99 years and is renewable in the urban areas and the Customary Right of Occupancy in the rural areas issuable by the local government chairmen. Information on the Land Use Act was supplied by Town Planner Ugwu of the Nsukka LGA, Urban and Regional Planning Office (Ugwu, 2017).

National Oil Spill and Drilling Regulatory Agency (NOSRA) 2004
Because oil spills are popular in the Niger Delta and oil reserve has been identified in parts of Enugu State, this Act was itemized by the Enugu State Ministry of Environment under the headship of Chief Fidel Ayogu, the Honourable Commissioner for Environment. The Act which may later be found to be accommodated in the Petroleum Industries Governance Bill (PIGB) creates a special regulatory agency to take charge of all oil field practices by oil companies in Nigeria. It is meant to protect the environment by upgrading the oil field practices in Nigeria to the international standards of safety.

National Emergency Management Agency (NEMA) Act (2000)
This Act created the agency as the sole emergency management agency of the Federal Government of Nigeria. The agency has acquired personnel, equipment, and expertise from within and outside Nigeria. It can use modern technology to cause would be population to adjust out of danger and to also provide post-disaster recovery support (NEMA, 2017). The agency is linked to the global network of satellites for environmental

disaster monitoring, search and rescue operations through the National aerospace Research Development Agency (NARSDA) at Abuja. Upon the creation of NEMA Enugu State and other states in the Federation also enacted laws that gave birth to the State Emergency Management Agency – the Enugu State Emergency Management Agency (ENSEMA).

National Environmental Standards and Regulations Enforcement Agency (NESREA) Act (2007)

This Act created NESREA to control the inflow of hazardous goods into the country. The hazardous goods are mainly chemicals and electronics. The chemical wastes could upon wrong storage or handling generate other harmful substances such as dangerous gases that could be fatal to persons. The latest case reported by Nkwopara (2016) is that of harmful waste material from which harmful gas was evolved and killed seven (7) persons in Nnewi Anambra State. Such cases have been reported in Lagos from sewage and solid waste dump sites. There also has been the case of soot from the petroleum processing plant that affected Port Harcourt in July 2018 (Nkwopara, 2016).

National Climate Change Commission Bill (2009)

This Act is Nigeria's effort to join and comply with the protocols, conventions, and agreements of the global climate change order of domesticating climate change legislation to suit the local environment, economics, and politics following Nigeria's subscription to the various global climate change agreements. The Bill remains in the legislative houses without being passed as some controversies attended it.

Application of Climate Change Laws and Policies

In Enugu State, there is no policy on tree planting as a response to climate change as against what obtains in Lagos. Discussions with some Key Informants in the ministries of Environment, Lands and Urban Development, Water Resources and Agriculture led this student to make a finding that the current effects of climate change do not manifest on a large scale in Enugu State and may account for relatively mute approach and response to climate change challenges in the state.

With respect to the responses from the members of some of the seven (7) legislators reached in the course of this research, five (5) out of the legislators showed good familiarity with the issue. The members representing Nkanu East, Aninri, and Uzo Uwani clearly remembered the difficulties that their people encountered during the 2012 rainy season floods but said that the reaction of the state government was through the ENSEMA and the executive orders of the State governor.

The response was stimulated from the information from the affected population through the family heads to the chiefs and the councilors. The councilors went on to reach the chairmen of the local government councils who confirmed the disaster information often by speaking to the traditional leaders of the affected communities. Modern telephony and picture technology make it possible for the relevant information to be captured by camera phones and transmitted to relevant persons and authorities.

The local government chairmen with the councilors then reach out to the commissioners and stakeholders in the affected local government areas and then approach the leaders of the executive and legislative arms of the state government. The Governor of the state upon receipt of the documented evidence reaches out to the relevant departments of the Federal Government which respond as they deem it appropriate by mobilizing personnel, equipment, and even funds as they did after the nationwide 2012 floods when funds were distributed to the states to help them cope with the burden of post-disaster resettlement of their citizens.

Pre and post-disaster responses

If examples are to be drawn from the advanced countries of the world such as the United States of America, some specific laws and policies cause the government and her agencies to issue pre-disaster warnings, followed by evacuation of the would-be victims to safer places and finally the embarkation upon post-disaster rehabilitation and other measures to rehabilitate the affected citizens.

4.0 **CONCLUSION AND RECOMMENDATION**

This study presents ample facts that Nigeria has not "*left the ground*" in terms of containing climate change adaptation and mitigation by not having passed its Climate Change Commission Act since 2003. There is a line of thought that the passages of the law which may have a negative impact on the Petroleum Industries Governance Bill (PIGB) will affect the revenue generation power of the country and ipso facto the economic development of the country. Enugu State is part of Nigeria. The only laws in Enugu are the Enugu State Waste Management Authority Law and the Enugu State Emergency Management Agency Law all of which are operated via direct or indirect executive orders from the State Governor. The inverse relationship between the levels of awareness of climate change laws and the applications of the laws points to the potentially higher risks to which the rural dwellers and the poor people in the state are exposed. This political and ecological variation calls for a remedy by way of statewide citizenship hazard response education. The inability of the local people to predict and prepare for emergencies such as in Ugwueme calls for a revision and reading of points by the government to address the creation of hazard monitory and prediction units in the State Ministry of Environment. In sum, the current state of awareness of climate change and the dangers associated with it must be of great concern because the environment system is dynamic and can change its state slowly as not to be noticed until the danger comes on very quickly as to force a disaster upon the people at short notice. Whichever way, a new statewide hazard reduction plan must start especially by teaching the pupils in the primary and secondary schools up to the universities. The reaction of the people in the city of Abuja to the earth tremor provides a good ground for this program to start now (Omokhunu, 2018)

The paper, therefore, recommends that Enugu state under the present executive leadership and political structure should recognize and apply any existing climate change laws by way of domesticating any law made by the National Assembly into the body of laws in Enugu State through the State House of Assembly (FRN, 1999). As events stand at the national level, there is yet no platform on which Enugu State can make any direct climate change laws but to rely on the pre-existing pieces of legislation made by the National assembly already in force.

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PUBLIC PERCEPTION OF PAINTING AS AN EFFECTIVE COMMUNICATION TOOL FOR CLIMATE CHANGE EDUCATION IN NIGERIA

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Under the Sub-theme
Climate change education and awareness creation

Abstract: The objective of this study is to determine public perception of painting as an effective communication tool for promoting climate change issues in Nigeria. To achieve this objective, the researchers made use of a survey research design with a questionnaire as the instrument for data collection. The study was guided by five research objectives that were converted to research questions. The sample size was made up of 384 respondents with knowledge of painting and communication. In the analysis data for the study, the researchers made use of descriptive statistics such as simple percentages and means. The result was presented in charts. It was found that the respondents reported that painting can serve as an effective communication tool for educating the general public on climate change issues. It is expected that the result of this study will be useful in developing approaches on how to address the problem of climate change. Recommendations are made on how to improve awareness of climate change issues in Nigeria through the instrument of painted works.

Keywords**:** awareness; climate change, communication, effective, painted works

INTRODUCTION

Climate change is one of the problems facing 21st-century society. Global leaders and governments of countries are also faced with the problem of making sure that climate change does not significantly impact humanity or that the impact of climate is reduced. Adedeji et al (2014) say that climate change has a significant impact on society to an extent that international bodies and organizations are battling to ensure that the impact of climate change on society is reduced. Commenting further on the impact of climate change, Adedeji et al. note 'from shifting weather patterns that threaten food production, to rising sea levels that increase the risk of catastrophic flooding, the impacts of climate change are global in scope and unprecedented in scale.'' Typically, when there is a climate change, humans feel the impact because such a change directly affects the environment. On the other hand, the environment is the home to all humans and any threat to the environment directly affects humans. This then means that knowledge of climate change is important.

Considering the impact of climate change on humans and the environment generally, knowledge of climate change is important because climate change has an impact on humans. Researchers (Nwankwoala, 2015;

Onuoha, 2015) agree that climate change has negative health consequences, economic impact as well as agricultural activities. The implication is that people need to have adequate knowledge of climate change. The implication, therefore is that communication is an important consideration in coming up with ways of addressing the problem of climate change.

Communication is key to climate change because it will educate people on how they can contribute their quarter in ensuring that climate change impacts are minimized (Akinfeleye, 2008 Age *et al* 2012; Ajayi & Gunn 2009, 2009). Additionally, communication has an important role to play in ensuring that human beings do not engage in activities that pose a threat to the environment. This is because man-made activities together with natural activities can as well result in climate change. Therefore, through the instrumentality of communication, people will have adequate knowledge of their roles in minimizing the impact of climate on the environment as well as how to control climate change. Communication takes place through channels. Before now, the common channels of communication included radio, television, newspapers, magazine, interpersonal, among others. Painting can also serve as a communication tool.

Painting as an art describes the use of colours to communicate. It entails the combination of different colours and placing them on objects in manners that pass meaning to those who view it. Painting is a branch of visual communication. As a part of visual communication, painting can attract attention, sustain that attention, and influence behaviour. Despite this, researchers are yet to examine public perception of how painting can serve as a communication tool in educating the general public on issues related to climate change, hence the need for the current study.

Objectives of the Study

The general objective of this study was to investigate the public perception of the role of painting as a communication tool for educating the general public on issues related to climate change. The specific objectives were:

1. To examine the public perception of the impact of climate change on the general public.
2. To ascertain the public perception of the extent painting can serve as a tool for educating the general public on issues related to climate change.
3. To investigate Public perceptions of how to make use of painting as a communication tool for educating the general public on climate change issues.
4. To ascertain how to deliver painted messages on climate change to the general public.
5. To determine the challenges to using paint to communicate information on climate change.

Research Questions

This study sought answers to the following questions:

1. What is the public perception of the impact of climate change on the general public?
2. What is the public perception of the extent painting can serve as a tool for educating the general public on issues related to climate change?

3. What are public perceptions of how to make use of painting as a communication tool for educating the general public on climate change issues?
4. What are the strategies to be used to deliver painted messages on climate change to the general public?
5. What are the challenges to using paint to communicate information on climate change?

Materials and Methods

The researchers made use of a descriptive survey to examine public perception of the painting as a communication tool for educating the general public on issues related to climate change. The choice of the survey was because it is normally the best approach when a researcher seeks to explain an issue, explore it or even describe it. The study was conducted in Enugu State, South-East Nigeria. The total number of people in Enugu State according to the Bureau of Statistics (2012) forecast up to 2016 is 4,411,119. The sample size for the study was 384 respondents who were sampled with the aid of an Australian calculator. The sampling technique that was used in this study was simple random sampling. The researcher made use of a simple random sampling technique. The choice of simple random sampling technique was to ensure that all the residents of Enugu State stood who know about painting as well as communication took part in the study. The sample elements were drawn from Enugu city the state capital. The instrument for data collection was a self-developed questionnaire. The questionnaire was considered useful for the study because it has the potential to generate large days for the study. The instrument sought both bio-data and psychographic information of the respondents. The response format was a combination of multiple options and the Likert scale. Three communication experts at the University of Nigeria validated the questionnaire. The comments of the experts assisted the researcher in preparing a final draft of the questionnaire copy. The test re-test approach was deployed to determine the reliability of the study. The interval that was used for the retest analysis was two weeks. The reliability analysis yielded an outcome of a correlation coefficient of .77. This implies that the instrument was reliable. Regarding data analysis, the researcher made use of descriptive statistics like simple percentages. The analysis was done with Statistical Package for Social Sciences (SPSS) version 22. The results of the analysis were presented in charts for graphical illustrations.

Results

Out of the 384 copies of the questionnaire that were administered to the respondents, 366 copies were retrieved and found useful. This represents a return rate of 95%. The implication is that the attrition rate was 5%, which was insignificant to affect the outcome of the study. The sample was 61% and 39%, female. Also, the mean age of the respondents was 39 years. A majority (81%) of the respondents had tertiary education. The result of the psychographic features of the respondents is further presented as shown below:

What is public perception of the impact of climate change on the general public?

The result of the study to answer the above research question is presented below:

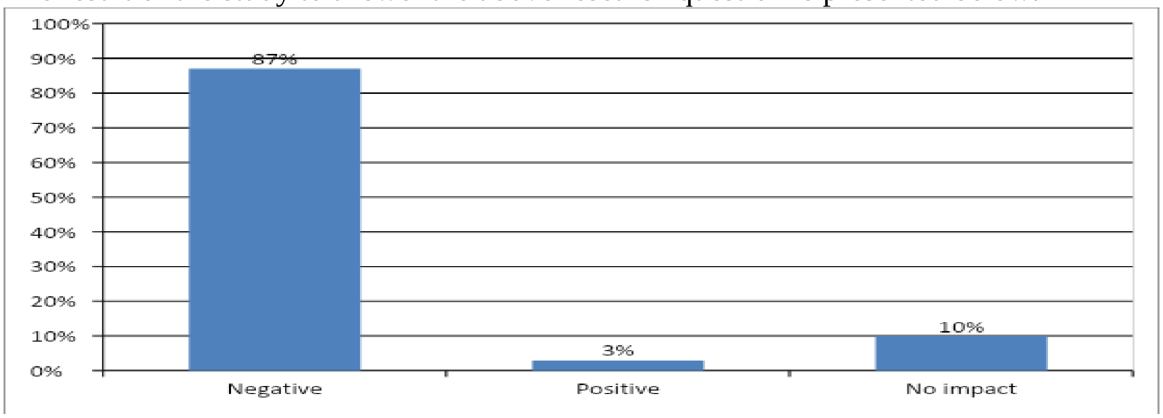

Fig 1: Public perception of the impact of climate change on the society

In the chart above, the researchers examined public perception of the impact of climate change on society. Accordingly, it was found that the majority of the respondents were of the view that climate change has a negative impact on society. On the other hand, only a negligible percentage reported no impact. A very negligible percentage reported a positive impact.

2. What is the public perception of the extent painting can serve as a tool for educating the general public on issues related to climate change?

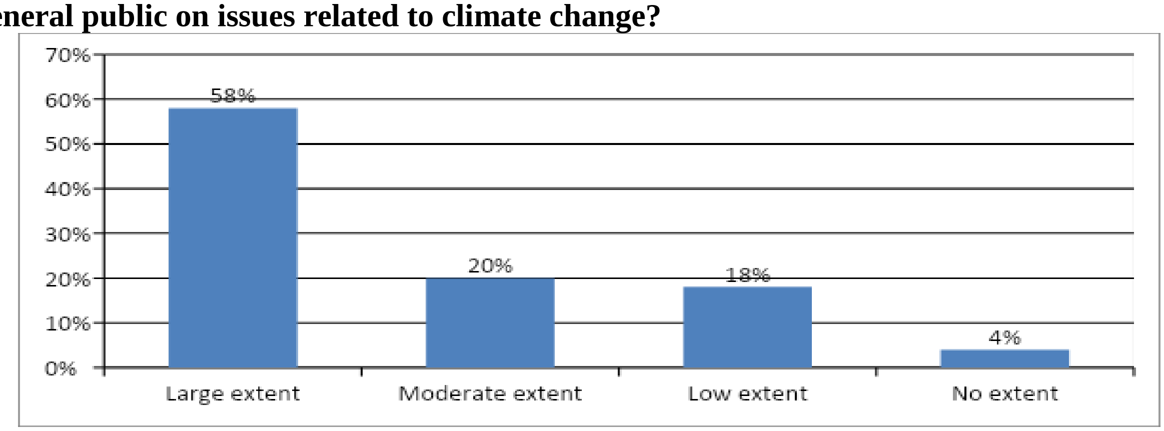

Fig 2: Public perception of the extent painting can serve as a tool for educating the general public on issues related to climate change

In the chart above, the researcher examined public perception of the extent painting can be used as a communication tool to educate the general public on issues related to climate change. It was found that more than half of the respondents reported that painting can serve as an instrument for communicating climate change issues to the general public to a large extent. Very few of the respondents reported no extent. We then took another step to examine how to make use of painting as a communication tool for educating the general public on climate change issues. The result of the analysis is presented in the following figure.

3. **What are Public perceptions of how to make use of painting as a communication tool for educating the general public on climate change issues**?

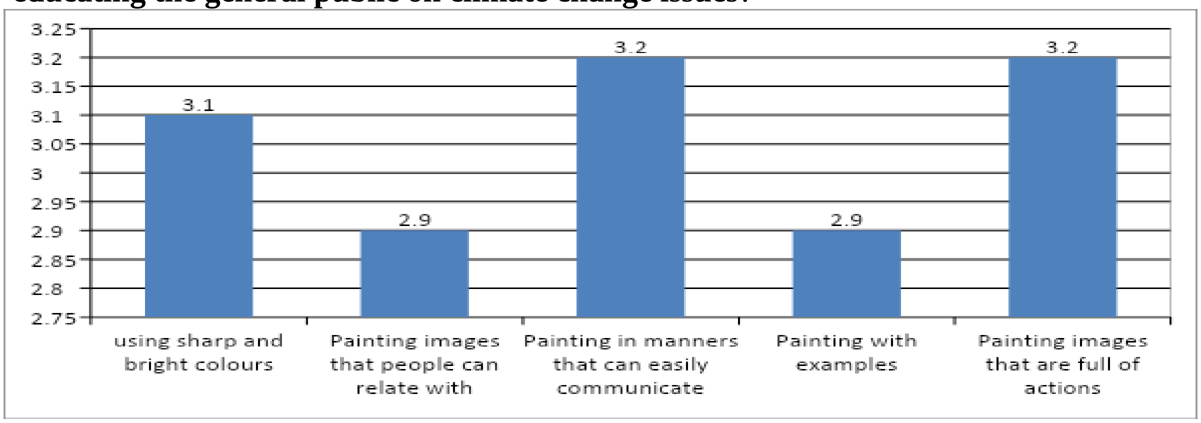

Fig 3: Public perceptions of how to make use of painting as a communication tool for educating the general public on climate change issues

In the figure above, the researcher examined public perceptions of how to make use of painting as a communication tool for educating the general public on climate change issues. The result of the study as presented above showed that all the items presented were accepted as ways by which painting can be used to educate the general public on climate change issues. This is because all the items had mean scores of 2.5 and above which was the benchmark for accepting or rejecting items. As a follow-up, we examined we also examined the strategies to be used to deliver painted messages on climate change to the general public. The result is presented in the chart below:

What are the strategies to be used to deliver painted messages on climate change to the general public?

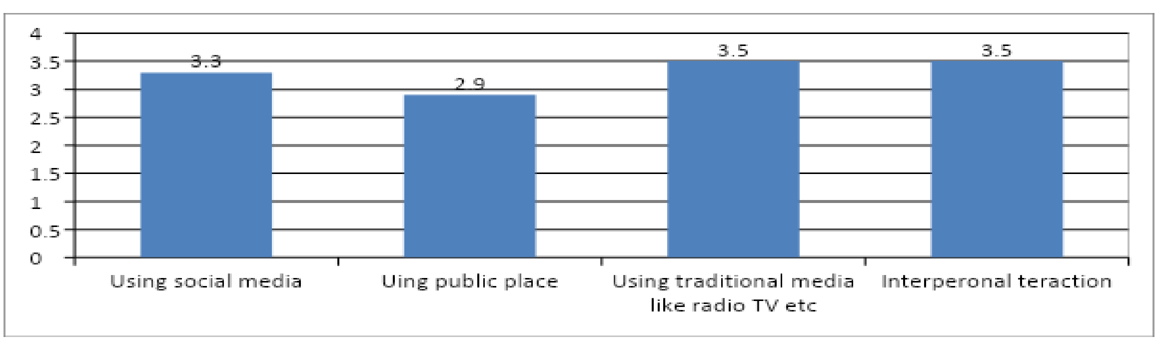

Fig 4: The strategies to be used deliver painted messages on climate change to the general public

The essence of plotting the chart above was to determine public perception of the strategies that can be used to deliver painting messages to the general public on issues related to climate change. The result of the study showed that the respondents reported that all the items presented are ways that will be efficient in delivering messages on climate change to the general public. Finally, the researchers examined challenges confronting the use of painting as a communication tool for information sharing on climate change. The result is presented below:

What are the challenges of using painting to communicate information on climate change?

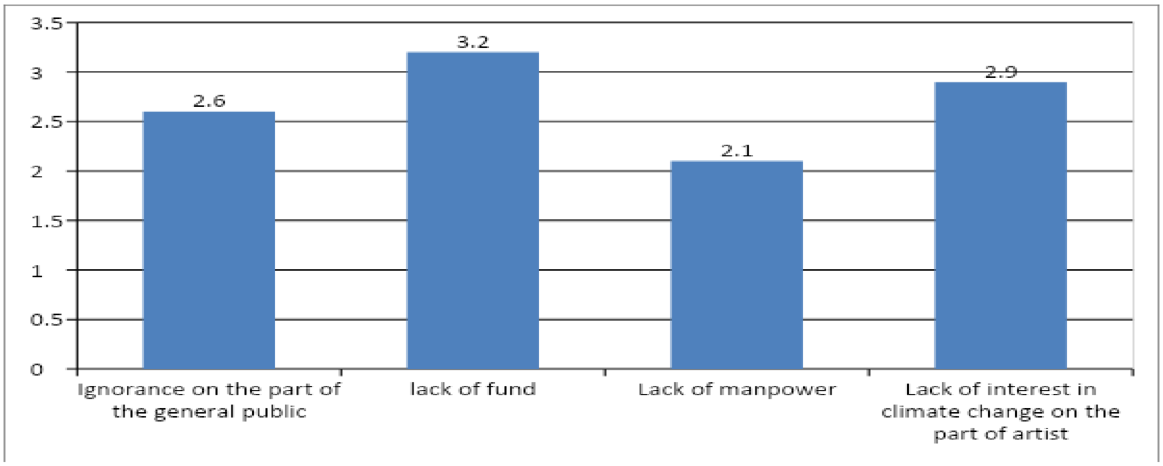

Fig 5: Challenges to using paintings to communicate information on climate change

The objective of the chart above was to determine the challenges to the use of painting as a communication tool for educating the general public on issues related to climate change. The result of the study as presented in the chart above showed that the challenges to using painting as a communication tool include lack of funds, lack of manpower, ignorance on the part of the general public as well as lack of interest in climate change issues on the part of artists.

Discussion of Findings

In this study, the researcher examined public perception of the role of painting as a communication tool for educating the general public on issues related to climate change. To researchers pursued five objectives. In the first objective, the researchers sought to examine the public perception of the impact of climate change on the general public. In the second objective, the researcher sought to ascertain the public perception of the extent to which painting can serve as a tool for educating the general public on issues related to climate change. In the third objective, the researchers sought to investigate Public perceptions of how to make use of painting as a communication tool for educating the general public on climate change issues. In the fourth objective, the researchers sought to ascertain how to deliver painted messages on climate change to the general public. Finally, the researchers sought to determine the challenges to using painting to communicate information on climate change.

The result of this study showed that the general public perceived painting as an important communication tool that can be used to create awareness about issues related to climate change. The current study has extended previous (Adedeji *et al*., 2014; Nwankwoala 2015) literature related to climate change. This is because although researchers acknowledged that information exchange is essential in combating the challenges that climate change poses. Additionally, the current study has extended arguments related to the impact of painting on behaviour change. Therefore, the current study has added to existing literature related to both climate change and painting. Also, the current study has extended (Akinfeleye, 2008 Age *et al* 2012; Ajayi & Gunn 2009, 2009) literature related to behaviour change communication by highlighting the critical role that painting plays in behaviour change communication. Our conclusion in this study is that painting is an important communication tool for educating the general public on issues related to climate change. This study has made contributions in the area of behaviour change communication by showing how painting can serve as a tool for communication. The study has also contributed to the area of climate change by showing how painting can serve as a tool for combating climate change. This study recommends that climate change promoters should consider the utilization of painting as an important communication strategy. Additionally, it is recommended that communication and painting experts should form a synergy with climate change promoters to come up with a communication campaign that effectively educates the general public. Finally, further studies should be conducted to test the effect of painting on knowledge and attitudes towards climate change.

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COPING WITH THE ECONOMIC EFFECTS OF CLIMATE CHANGE: A STUDY OF SELECTED LOCAL GOVERNMENT AREAS IN KADUNA STATE

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Abstract: Studies have shown that climate change which is the disruption in the long-term seasonal weather patterns that are caused by global warming, will pose serious risks to total GDP in developing countries especially in the area of agricultural productivity. This study explores this line to investigate what economic effects, (if any), climate change has brought on communities in three local government areas in the northern part of Kaduna State of Nigeria. Using primary tools of analysis, it is observed that the effects of climate change are apparent in shocks to grain productivity, livestock productivity, and agricultural labor supply. It is also a major cause of the sustenance of herders-farmers conflict. These effects on commodity supply and (consequently) prices as well as factor wages and demand have a significant influence on the welfare of the households in the sampled communities. Part of the recommendations of the study is the need to raise awareness on issues of climate change at the grassroots level. Another recommendation is for the government and NGOs to revive the tree planting program and raise awareness for individuals in rural communities to plant trees.

INTRODUCTION

Climate change refers to the disruption in the long-term seasonal weather patterns that are caused by global warming. Globally, as of August 2020, the average temperature has risen over 1 degree Celsius, or about 2 degrees Fahrenheit, since 1880. This is known to be faster than at any other time in the history of the Earth. Climate change can even be rightly referred to as climate destabilization. This is so as it creates extreme and frequent blizzards, heat waves, and other forms of extreme weather. In this class of extremes are tornados, wildfires, hurricanes, floods and landslides, droughts, and violent storms (whether they be dust, hail, rain, snow, or ice).

It has been established that climate change is principally a major problem caused by the increase in human activities. More often than not, the human mismanagement of the earth leads to several direct and indirect impacts on health. The harmful effects are wide-ranging and include an increase in heat-related mortality, dehydration, the spread of infectious diseases, malnutrition, damage to public health infrastructure, migration of both man and animals among others.

The climate summary of Nigeria shows that the country has a diverse climate with nine distinct ecological zones, ranging from an arid north (with both lowlands and a plateau region) to tropical south. In the south, annual average temperatures range from 17–37°C and in the north from 12–45°C. Annual rainfall amounts decrease in a gradient moving south to north – the south receives an average of 3,000 mm of rainfall per year versus 500 mm in the northeast. The timing of rainfall is seasonal and varies by region: the south experiences rainfall throughout much of the year (although less in November–March), while the north has a long dry season that can last up to seven months (October–April). Harmattan winds bring hot dry air from the Sahara Desert to Nigeria during the dry season and moist air from the Atlantic Ocean during the rainy season.

Historical climate trends in the country include: increase in temperatures of an average close to 1°C between independence in 1960 and the year 2019, larger increases in the northern region, significant variability of precipitation between years and climate zones, and a decrease in predictability for seasonal rains. Conflicting information exists on annual precipitation across the country, but some analyses show a decrease of 3.5 mm per month per decade between1960–2019. In the same vein, while historical sea-level rise cannot be confirmed, significant inundation of coastal towns has already occurred and the consistent flooding in several states in the past five years is a pointer to the fact that Nigeria like other countries of the world has its own experience of climate change disasters, (Olaniyi, Ojekunle, & Amujo, 2013).

Also, whereas the Lake covered an area of over 40,000 square kilometers forty years ago, it now encompasses a mere 1,300 square kilometers. Noticeably, the section of the lake that lies inside Nigerian territory is drying up rapidly. As the negative trend continues unabated, the land is being laid to waste by the rising temperature culminating in the rapid southward expansion of the Sahara Desert. Farmlands and surrounding villages are becoming barren as they are swallowed up by advancing desertification. A result of this is a massive migration of people in search of more fertile terrain from the northeast towards the greener plateau and middle belt regions.

Just as desertification is devastating vast areas of the north, rising sea levels are threatening the coastal regions of Nigeria. The Niger Delta, though a source of oil wealth, is characterized by a low-lying terrain and criss-cross of waterways that make it extremely vulnerable to flooding. Apart from being at the risk of rising sea levels, it has fallen victim to extreme oil pollution. Climate change is also reflected in the massive flood experienced in the south of Nigeria. In 2012, houses, farms, farm products, properties, and even human beings were swept away. Also, the statistics released by the southwest zonal office of the National Emergency Management Agency (NEMA) in 2016 show that no fewer than 5000 persons were affected and 60 houses were destroyed in a windstorm that occurred in four states in the south -west region.

The object of this study is to identify and enumerate the economic effects that climate change has brought on communities in three local government areas in the northern part of Kaduna State of Nigeria. Ikara, Kubau, and Soba Local Government Areas (LGAs) are situated in the north of Kaduna State of Nigeria. The three LGAs are rural and the people are predominantly farmers (not less than 95% of the population) while a small part of the people engages in other things like trading, civil service, artisanship, etc. The areas have particularly been affected as over time, logging for farming and firewood for cooking has stripped a greater part of this area of its vegetation cover. The paper should add to the discourse on the need to preserve, protect and promote the environment which at present constitutes a headache to many nations and dominate discussions and activities of government and non-government organizations across the globe.

LITERATURE REVIEW

There is no gain saying the fact that man depends on his environment for existence and sustenance such that man's life is shaped by his environment and this underscores the need for the protection of the environment from all forms of degradation, especially those brought about by the activities of man. Realizing the significance and inevitability of the environment for the survival of man, environmental experts have been arguing all over that man cannot exist without the environment since human activities are made possible by the existence of his environment. Though the greenhouse effect is a natural phenomenon, the increase in greenhouse gases is linked to human activities.

It is thus no surprise that the world's leading climate scientists believe that human activities are very likely the main cause of global warming since the mid-twentieth century, mostly because of:

Fossil fuels- The massive use of fossil fuels is the first source of global warming, as burning coal, oil and gas produces carbon dioxide - the most important greenhouse gas in the atmosphere - as well as nitrous oxide.

Deforestation- The exploitation of forests has a major role in climate change. Trees help regulate the climate by absorbing CO_2 from the atmosphere. When they are cut down, this positive effect is lost and the carbon stored in the trees is released into the atmosphere.

Intensive farming- Another cause of global warming is intensive farming, not only with the ever-increasing livestock but also with plant protection products and fertilizers. Cattle and sheep produce large amounts of methane when digesting their food, while fertilizers produce nitrous oxide emissions.

Waste disposal- Waste management methods like landfills and incineration emit greenhouse and toxic gases - including methane - that are released into the atmosphere, soil, and waterways, contributing to the increase of the greenhouse effect.

Mining- Modern life is highly dependent on the mining and metallurgical industry. Metals and minerals are the raw materials used in the construction, transportation, and manufacturing of goods. From extraction to delivery, this market accounts for 5% of all greenhouse gas emissions.

Overconsumption- Overconsumption also plays a major role in climate change. It is, in fact, responsible for the overexploitation of natural resources and emissions from international freight transport which both contributes to global warming.

Economic literature shows that climate change affects the growth rate of the economy, by shrinking the size and productivity of the labor force and the capital stock, which in turn cause invests (and consequently future output) to go down, (Fankhauser & Tol, 2005 and Lemoine & Kapnick, 2016). Also, Dietz and Stern (2015) as well as Moore and Diaz (2015) agree with (Solow 1956) who claimed that climate change would also affect technological progress and that this would have a large effect on economic growth. The authors thus conjecture that the dynamic impacts of climate change would dominate the static ones.

The empirical evidence that climate change has an impact on economic growth is further provided by Dell, Jones, and Olken (2009) and Horowitz (2009) who found that higher temperatures reduce income, particularly in poor countries. Earlier, Bloom, Canning, and Sevilla (2003) had reported that hot and wet conditions and large variability in rainfall reduce long-term growth in poor countries (but not in hot ones) and increase the probability of being poor. Barrios, Bertinelli, and Strobl (2008) also found a large impact of anomalous rainfall on economic growth in sub-Saharan Africa. Andersen, Dalgaard, and Selaya (2016) echo the argument that the reported impact of climate on development is an impact of ultraviolet radiation.

In essence, while the literature on the impact of climate (change) on development is yet to reach firm conclusions, it is agreed that climate change could reduce the rate of economic growth and even trap people in poverty. Also, by and large, the negative impacts of climate change are for the most part being borne by developing economies. This latter view is so as some studies have shown that the relative impacts of climate change decline as per capita income rise. Particularly, Adger (2006) and, before it, Yohe and Tol (2002), show that developing countries are more vulnerable to the impacts of climate change for three reasons. First, poorer countries are more exposed to the weather because of the important role of agriculture and water resources in the economy. Second, poorer countries tend to be in hotter places. Third, poorer countries tend to have a limited adaptive capacity which depends on a range of factors, such as the availability of technology and the ability to pay for those technologies.

For the aforementioned reasons, poorer countries often do not possess modern technology that can help protect against the weather (e.g., air conditioning, malaria medicine, crop insurance). Concurrently, they also do not have the institutions, ability, and even the political will to mobilize the resources for large-scale infrastructure such as irrigation and protection of their coastal regions. It was in this spirit that Yalew, Hirte, Lotze-Campen, and Tscharaktschiew (2017) assessed the economy-wide and regional effects of climate change-induced productivity and labor supply shocks in agriculture in Ethiopia. The study shows, in a worst-case scenario, the effects on national GDP may add up to -8% with uneven regional effects ranging from -10% in agrarian regions to +2.5% in urbanized regions.

In summary, globally, the economic impact of climate change has manifested diversely in higher costs of insurance, lower Gross Domestic Product, losses of employment (especially in agriculture, fisheries, and forestry), increased mass migration, a higher threat to national and international security, declining productivity, and consequently and most threateningly, rising food prices.

METHODOLOGY

This research aims to bring to fore the economic effects of climate change on the inhabitants of Ikara, Kubau, and Soba LGAs which are situated in the northern part of Kaduna State of Nigeria. It is a qualitative study mainly based on primary data collected over the course of two years. This came about as a result of the author's involvement with a non-governmental organization that undertakes developmental efforts through education in the study area.

The instruments of data collection were observation and interview. Data collected were critically reviewed content-wise to especially identify the relationship between climate change and emerging threats in human security as represented in the economies of the study area.

DISCUSSION OF FINDINGS

The inhabitants of the study area are predominantly engaged in agriculture. Particularly, they produce, on a high scale, food crops like rice, beans, soya beans as well as grains like maize and guinea corn. The agricultural practice of the people depends mostly on rain even though there are pockets of dry season farming especially along the banks of the streams and rivers. Findings reveal that there is now an unpredictable rainfall variation throughout the area and the temperature is unusually high. The lowered rainfall has made it difficult for farmers to plan their operations as the cropping season and length of growing days are reduced.

Also, it was observed that one of the consequences of the higher than normal temperature in the three LGAs for parts of the year is drought. This has translated to decreasing farmland and dovetailed thereby increasing crop failures and declining crop yields. In essence, climate change has resulted in a decline in agricultural productivity as crop yields have reduced. Just as Ogbuabor and Egwuchukwu (2017) report, the reduced yields manifest among, particularly, crops cultivated under rain-fed conditions. This in turn has led to a threat to food security not only in the affected areas but in the nation generally. For several seasons, crop failure of different categories has been a recurrent decimal in the study.

The prolonged dry spells also affect livestock production. Livestock farmers are finding it difficult in an increasing manner to find water and green pastures due to reductions in surface water resources and available pasture land. Consequentially, there is no growth consistency in animal production in terms of numbers and weight. The loss of weight for animals makes them not produce enough meat, milk, and hides.

In another scenario, sometimes, there are incidences of increased rainfall intensity. The intensity is such that flooding and erosion of farmland occur and this also results in reduced agricultural production. For instance, excessive rains in 2019 and 2020 led to the flooding of the streams around Maigana, Kodoro, Gubuchi, Anchau wards and resulted led to the washing away of several acres of farmlands being used for rice production. Equally affected were producers of beans, pepper, and onions whose investments failed massively.

Thus, the economic effects are manifest in the reduction in areas suitable for crop cultivation, loss of net farm income per hectare, losses of livestock, and a general reduction in agricultural jobs and opportunities. These primary effects have gone on to affect commodity supply and prices as well as factor wages and demand which have tended upwards in an unchallenged manner over the past two years. Ultimately, the effects of climate change in Ikara, Kubau, and Soba Local Government Areas of Kaduna State is having influence is felt in the welfare of rural (as well as urban) households. As climate change increases factor competition among agricultural activities, it drives up wages of agricultural labor and rent on land. This translates to higher prices leading to loss of welfare. Heat stress associated with climate change is also a challenge to poultry farmers due to its adverse effect on chicken growth and productivity. In the past two years, poultry farmers in the study area have experienced losses of product chicken and eggs due to heat waves. The drought conditions have also resulted in less drinking water. As the households are rural, they naturally depend on rain for a significant portion of their total water consumption. But this source has suffered as a result of the sharp drop groundwater tables in the entire northern part of Nigeria due to less rain.

The effects of climate change have also exacerbated the conflict between the farmers and the herders in the study area. As arable land becomes more scarce as a result of desertification, the resultant water, and food scarcity (for humans and animals) make disagreements break out in several. Added to this is increasing migration to the area by farmers and herders displaced from other areas as a result of insecurity.

CONCLUSION AND RECOMMENDATIONS

This study has shown that like any other developing country, agriculture is the most climate-sensitive economic sector in Nigeria. For the fact that the sector is yet subsistence, virtually rain-fed, dominated by food crops, and with smallholder farmers producing not less than 80% of the total agricultural output, the adaptive capacity of the sector is very low. Therefore, there is the need to mainstream climate change into national, state, and even local government development plans. And given the cross-cutting nature of the impact of climate change, such plans and the attendant policies must be such that can provide an important intersection between development and climate change.

Likewise, as an integral part of government initiatives, such must be capable of adaptation and remediation in the quest to reduce the root causes of vulnerability to climate change. Other steps that could be taken include raising awareness on issues of climate change which is presently at low ebb especially amongst vulnerable groups like women, children, even at the grassroots (especially rural dwellers) as well as reviving the tree planting program by raising awareness for individuals to plant trees.

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ENVIRONMENTAL SIGNIFICANCE OF RUBBER PLANTATIONS IN A CONTEXT OF CLIMATE CHANGE: CHALLENGES, OPPORTUNITIES & OPTIONS

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Abstract: The global warming and climate change problem results mainly from anthropogenic emissions of greenhouse gases into the atmosphere from energy production (fossil fuel burning) and industrial/agricultural activities. This problem is exacerbated by biodiversity loss due to deforestation, forest degradation, and the conversion of forests to various forms of land-uses. Plantations of major tree crops including rubber are increasing rapidly in the tropics, creating opportunities for development and adaptation. This, however, also raises concerns about the impacts of these plantations on the environment as environmental conservationists have cried out against the increasing expansion of rubber monocultures which causes biodiversity loss. The objective of this review was to expound on the environmental significance of rubber plantations in the context of the climate change problem. Climate change mitigation efforts were identified to include switching to renewable alternative sources of timber and sequestration of carbon dioxide from the atmosphere of which rubber plantations have an enormous role to play. Retention of necromass (the dead portions of trees, branches, and coarse woody debris) was found to play a significant role in optimizing the carbon sink potential of rubber plantations. Approaches to the enhancement of the biodiversity value of rubber plantations were also identified which include a variety of rubber-based agroforestry, and promotion of natural undergrowth (biologically diverse understory vegetation) in rubber plantations as well as avoidance of weeding/herbicide application.

I.0 INTRODUCTION

There is an increasing concentration of carbon dioxide (CO_2) in the atmosphere which is understood to be the principal greenhouse (heat-trapping) gas causing the present-day global warming and climate change problem. As of 2001, the biggest carbon source (6.3 Gt C year^{-1}) originated from energy production (fossil fuel burning) and cement production (Prentice *et al.*, 2001; IPCC, 2013); followed by emissions from land-use change (2.2 Gt C year^{-1}) which are not negligible, resulting mainly from tropical deforestation (Houghton, 2003).

The global warming and climate change problem is increased by biodiversity loss, and the tree-deficit situation in the globe due to deforestation and forest degradation caused by unsustainable removal of timber; and the conversion of both primary and secondary forests to farmland, pasture lands, and other forms of land-uses; especially in tropical and subtropical developing countries, including Nigeria (Okali, 1997; IPCC, 2013; Samuel *et al.*, 2020). Land-use sustainability is important in achieving the goals of the Paris Agreement on Climate Change.

Plantations of major tree crops including rubber and oil palm are increasing rapidly in the tropics, creating development opportunities. This, however, also raises concerns about the impacts of these plantations on the environment. Rubber plantations are suitable for sustainable tree crop development with many value chains worldwide (Gitz *et al*., 2020). Outcries from the environmentalists against the increasing expansion of rubber monocultures which causes biodiversity loss cannot be ignored (Carnus *et al*., 2006, Ahrends *et al*., 2015). Rubber plantations in Nigeria are established mainly for latex production with little or no emphasis on management practices for sake of the ecosystem.

The socio-economic benefits of rubber plantations are tremendous (Abolagba *et al*., 2003; Omokhafe, 2004), and can be promoted with climate-smart practices such as agroforestry, conservation of rubber groves, REDD+ application in the centers of origin of rubber, rubber tree based tree farming, rubber tree-based forest restoration/reforestation, etc. The objective of this review is to expound on the environmental significance of rubber plantations in the context of the climate change problem.

2.0 ENVIRONMENTAL SIGNIFICANCE OF RUBBER PLANTATIONS

2.1 Rubber Plantations as Forest Resource

The quest for environmental sustainability, eco-friendliness, and renewable alternative sources has necessitated attention to rubber tree plantations which have been classified as forest tree crops by the FAO (Onyekwelu and Fuwape, 2008). Forest tree crops intended for timber and non-timber products have a valuable role in relation to climate change. Similar to natural forests, rubber tree plantations can be ~~sources and~~ sinks of carbon. Rubber plantations as forest resources offer several ecosystem services including soil conservation, carbon sequestration, watershed protection, afforestation/restoration of degraded lands, and provision of timber/wood.

2.1.1 Soil Conservation and Nutrient Recycling

Research on the ecological impact of rubber plantations on degraded soils has demonstrated an improvement of soil properties after the establishment of *H.brasiliensis* plantations (Sethuraj *et al*., 1996). Rubber plantations adopting proper agroforestry management practices (including terracing, silt pitting, and bundling; and the growth of leguminous cover plants between the rows to assist with Nitrogen-fixation) were found to help in the enrichment of organic matter, which consequently improved soil physical properties such as bulk density, porosity, moisture retention and infiltration (Krishnakumar *et al*., 1990). An increase in organic matter was also observed (Krishnakumar *et al*., 1990). Natural rubber tree does not impoverish the land upon which it is grown. Rubber plantations have approximate closeness to the rainforest system, in terms of the canopy, leaf litter, and nutrient cycling (Goldthorpe, 1996).

2.1.2 Carbon Sequestration Potential of Rubber Plantations

Carbon sequestration (by terrestrial ecosystem) is the net removal of CO_2 from the atmosphere or the avoidance of CO_2 emissions into the atmosphere from terrestrial ecosystems (IPCC, 2000).

Cultivation of rubber trees on non-forested land could act as a carbon sink by sequestering carbon in biomass and indirectly in soils. Rubber plantations' effectiveness in this respect is probably at least equal to that of virgin forests and may even exceed it (Sethuraj *et al*., 1996). According to some researchers, Physiological studies have shown that rubber tree (*Hevea brasiliensis*) is more effective in taking up CO_2 than teak grown in plantations (Sethuraj *et al*., 1996). The biomass production potential of tree species is related to its photosynthetic capacity per unit leaf area and the total leaf area produced per plant. In full sunlight, the photosynthetic rate of a mature rubber leaf is about 11 ⌠mol/m^2/s as compared with (5 – 13) ⌠mol/m^2/s in other tree species (Sethuraj *et al.*, 1996). The total leaf area produced by a mature rubber tree is quite substantial; the leaf area index of a mature rubber plantation can be as high as 6 – 7. Because of the high photosynthetic rate and leaf area index, the biomass production per unit land area within a given time is very high in *Hevea* (rubber plantations).

Cheng *et al.* (2007) reported ~~a~~ 30 years' lifetime carbon sequestration of 272 t C ha^{-1} in rubber plantations on the island of Hainan. Comparing this to the sequestration rates of rainforests and secondary forests on Hainan, 234 and 150 t C ha^{-1} over the same period, the high productivity of a rubber plantation becomes discernable (Cheng *et al.*, 2007).

2.1.3 Rubber plantations: a sustainable alternative source of biomass energy.

Being a cheaper source of fuelwood, charcoal, and thermal energy; rubber wood has similar calorific values of about 130,000 BTU/lb (Sung and Cheang, 1977), which is equivalent to 72,280 kcal/kg (kilo-calories per kg). Where: 1BTU/lb = 0.556 kcal/kg; 1 Btu/lb = 2.326 kJ/kg, and 1 kJ/kg = 0.2389 kcal/kg (Engineering ToolBox, 2003). Malaysia started exporting processed rubber wood to Japan in the 1980s. In Sri Lanka, rubber wood is exploited as raw material for paper industries.

2.1.4 Rubber Plantations: Sustainable Source of Alternative Timber

The quest for renewable alternative sources has necessitated attention to rubber tree plantations for the supply of timber and fuelwood. Rubber plantations are a sustainable alternative source of timber and industrial wood. In the past, old rubber trees that had exhausted their latex supply were burnt or left to rot. However, it was discovered that this wood, when dried and treated, was suitable for the production of furniture and other commodities. Thus, timber production is an aspect of rubber tree cultivation that has gained significance (Mydin *et al*., 2005; Gonçalves *et al*., 2005 Goncalves *et al*., 2011).

The rubber tree is a very fast-growing species; new plantations can be re-established on a 25-year rotation period on the same land management unit. If rubber plantations are well managed on a 25-year rotation, they could constitute an alternative source of commercial timber (Pengprecha, 1976). The global rubber wood study carried out under the auspices of the International Trade Centre estimated yield at 140 to 200 m^3/ha, with higher ranges observed in countries (e.g. Malaysia, Thailand, India, and Sri Lanka) where plantations are carefully managed (FAO, 2000). A total of 240,000 hectares of rubber plantations could be a good source of pulpwood if replanting is done at the rate of 8,000 ha/yr. in a 30-year rotation. This guarantees a continuous yield of rubber wood at the rate of about 816,000 tones per year or about 102 tones/ha (Jayasingham, 1974).

2.1.5 Endearing Physical Properties of Rubber Wood

Rubber wood possesses favourable woodworking and timber properties. Rubber wood has a medium air-dry density of 560-650 kg/m^3. This makes it suitable for a wide scope of applications (Sekhar, 1992, FAO, 2001). Studies on the physical and mechanical properties of rubber wood show that rubber wood can be easily steam-bent or stained to resemble any other timber depending on consumer demand. Its light-creamy colour is an added advantage and favorable quality, making it a good substitute for other highly ranked furniture-making timber. The natural colour of rubber wood is the principal reason for its popularity in Japan where it is increasingly used to replace more conventional timber (FAO, 2001). The physical and mechanical properties of rubber wood in comparison with that of teak Teak (*Tectona grandis*) are presented in Table 1.

Table 1: Physical and mechanical properties of *Hevea brasiliensis* wood in comparison with *Tectona grandis* wood (Source: Shukla *et al.*, 1985)

PROPERTY	TEAK (DRY)	RUBBER (DRY)
Moisture Content (%)	12.0	12.0
Specific gravity	0.60	0.56
Weight at given moisture content (Kg/m^3)	670	515
Modulus of rupture (MOR) (kg/cm^2)	959	756
Modulus of elasticity (MOE) (kg/cm^2)	119.6	82.0
Compression (kg/cm^2) parallel to grain	532	374
Compression (kg/cm^2) perpendicular to grain	101	101
Hardness (Kg): side	512	538
Hardness (Kg): end	488	627
Shear, Parallel to grain	102	113.6
Tension perpendicular to grain	62.0	60.0

Working qualities and finish adaptability of rubber wood in comparison with teak indicate that it is suitable for the manufacture of all types of furniture items and bent articles. The working quality index is 130 while the teak is about 100 (Shukla *et al.*, 1985). Under standard conditions, its adaptability is rated about 94 percent of teak. The suitability indices of rubber wood and its strength properties in comparison to that of teak (Shukla *et al.*, 1985) are shown in Table 2.

Table 2: Suitability indices of rubber wood (Source: Shukla *et al*., 1985)

Property	**The Suitability Index**
Weight(12% moisture content)	93
Strength as beam	62
Stiffness as beam	77
Suitability as post	52
Shock resistance	75
Retention of shape	77
Shear	92
Hardness	74
Splitting coefficient	75

Rubber plantation has become an important source of timber of commercial value (Sekhar, 1992). In 1993, rubber wood contributed more than 10 percent of the total log production in Malaysia (Najib and Rami, 1996). The annual rate of deforestation is so alarming that a country like Thailand has completely banned logging from natural forests. Therefore, rubber wood has become the main non-forest timber resource decreasing the logging pressure on natural forests in some rubber growing countries. This is a good example for Nigeria.

3.0 MITIGATING BIODIVERSITY LOSS IN RUBBER PLANTATIONS

Biodiversity increases the resilience of agro-ecosystems; as such, it is a means for risk reduction and adaptation to climate change. Granted, plantations do little to conserve biodiversity, but they do sequester carbon and conserve soil, so governments should place a high priority on promoting them (Rudel *et al*. (2005). Although plant species richness in mature rubber monocultures was found to be roughly three times lower compared with natural forests (Beukema *et al*., 2007), the increase in structure and density of understory ground cover in rubber plantations is suitable to provide important conservation services complementary to natural forest areas (Barlow *et al*., 2007) (Figures 1–2).

Biodiversity in plantations depends very much on plantation age. Development of litter and humus layer increasing over time, and microclimatic conditions understory facilitates natural re-growth. Understory vegetation is also considered to be a good predictor of faunal diversity. The undergrowth in rubber plantations can provide additional habitat and resources for various forest species, provided that natural forest plots exist in the vicinity (Aratrakorn *et al*., 2006, Meng *et al*., 2012, Chang *et al*., 2013, Meng *et al*., 2013, –35). This includes young plantations with an open canopy and natural undergrowth of light-demanding herbaceous plants.

Rubber agro-forests could be a key component of the ecology and biodiversity of the local, regional and global environment. As a forest, rubber plantations hold a great promise of saving the earth from the effects of deforestation. Rubber-based agroforestry is an auspicious platform for biodiversity conservation. Rubber plantations are a suitable habitat for bees. Apiculture (honey bee-keeping) thrives profitably in rubber plantations, as well as rabbitry and heliciculture (snail farming).

3.1

Options for Enhancement of the Biodiversity Value of Rubber plantations

Approaches to improve biodiversity conservation in landscapes where intensive agriculture is expanding include land sharing, land sparing, and ecological restoration (Fischer *et al*., 2014, Paul *et al*., 2015, Barral *et al.*, 2015) and are also suggested for the enhancement of the biodiversity value of rubber-dominated landscapes. Land sharing involves integrating production and biodiversity conservation goals on the same land. Referring to rubber cultivation, this approach includes options of intercropping to promote system diversity.

Numerous types of diversified rubber-based production systems exist in Thailand (Somboonsuke *et al*., 2001, Longpichai, et al., 2012). The systems range from (a) temporarily intercropped rubber plantations with annual crops established between young rubber trees before canopy closing; (b) permanently intercropped rubber plantations of two or more crop species such as cocoa, tea, coffee, or banana; (c) diverse mature rubber plantations intercropped with fruit trees and partly other perennial crops in the shrub and understory layers including valuable spices such as ginger or vanilla. Commonly found in Indonesia, are low-intensity rubber agroforests ('jungle rubber') that structurally resemble a secondary forest. Furthermore, research has been done in Malaysia resulting in the development of more productive latex-timber clones that can produce timber in a short period with other tropical species and can be densely planted (Balsiger et al., 2000).

3.1.1 A Feasible Concept: Promotion of Rubber Understory Vegetation

A feasible strategy of rubber monoculture improvement for biodiversity would be the promotion and maintenance of the natural understory vegetation in rubber monoculture plantations through the cease of weeding and herbicide application (Figure 2.). A study from India (Hu *et al.*, 2013) revealed that a no-weeding practice in mature rubber plantations did not negatively affect rubber yield over the study period of 10 years (He and Martin, 2016). Therefore, this measure can be economically acceptable, considering reduced labour and cost savings for herbicides. In addition, the option to integrate ecologically suitable and economically valuable food or medical plants from the natural forest (Ghorbani *et al*., 2012) might increase the acceptability of this measure by farmers.

Fig. 1. Mature rubber plantation, undergrowth vegetation removed.
Source: Inga Häuser, 2016.

Fig. 2. Young agroforestry rubber plantation with biologically diverse undergrowth
Source: Eric Penot from CIRAD/FTA.

4.0. CONCLUSION AND RECOMMENDATIONS

Plantations of major tree crops including rubber are increasing rapidly in the tropics, creating development opportunities. This, however, also raises concerns about the impacts of these plantations on the environment. Nevertheless, rubber plantations render numerous ecosystem services including natural rubber and timber (wood biomass) production as well as carbon sequestration. Sustainable development of rubber plantations in the context of the climate change problem is important. Balancing environmental and economic goals is crucial to managing rubber plantations sustainably. Climate change mitigation involves efforts aimed at reducing emissions of greenhouse gases to limit the magnitude and/or rate of long-term climate change. These efforts include switching to renewable low-carbon energy sources, switching to renewable alternative sources of timber, expanding forests and other sinks to remove greater amounts of carbon dioxide from the atmosphere, and promoting biodiversity. In this regard, the role of rubber plantations is enormous.

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ASSESSMENT OF URBAN DRAINAGE OBSTRUCTION FLOWS ON FLUVIAL FLOOD OCCURRENCE IN MINNA METROPOLIS, NIGERIA

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Abstract: This research aims to assess how insufficient and blockage in urban drainage due to poor municipal solid waste (MSW) management, increases the risk of urban flood in the Minna metropolis. Data used consists of geographic coordinates of existing MSW dumpsites collected using the Global Positioning System (GPS). A questionnaire survey was also carried out to solicit information from the inhabitants. The administrative map was collected from the Niger State ministry of physical planning and the urban drainage network was digitized from Google earth map of the study area. Spatial data were integrated into the Geographic Information system (GIS), processed, and analyzed using point in polygon overlay and query operation. Copies of the questionnaire were administered systematically to 384 respondents. An interview guide was also designed and used to solicit relevant data. Findings revealed that 116 MSW dumpsites were found within the metropolis. 66 (52.6%) locations of MSW dumpsites were found within drainages. It is also discovered that 56% of the dwellers were optimistic that poor waste management in the study area contributes to flooding. Floods risk are influenced by a range of factors as attested by the respondents, including the overflow of the two rivers (50%) that transverse the study area, unprecedented rainfall amounts and intensity (79%), insufficient drainage systems (82%), and urbanization (56%). These were perceived to severely impact urban drainage flows. The study recommends that dumpsites should be located away from the drainage system.

***Keywords*:** Dumpsites, Drainage, Flood, Location.

1. INTRODUCTION

Flood is the most common natural disaster worldwide and is a critical issue that has been causing degradation of the environment, loss of life and properties, and most importantly interruption to the natural ecosystems. These harmful effects of floods often pose a big barrier to the cultural, economic, and urban development of both developed and developing countries. Floods result from a combination of meteorological (such as rainfall, cyclonic storms, small-scale storms, temperature, snowfall, and snowmelt) and hydrological extremes (such as soil moisture level, groundwater level before a storm, natural surface infiltration rate, presence of impervious cover, channel cross-sectional shape and roughness, presence or absence of over bank flow, channel network, synchronization of run-offs from various parts of the watershed and high tide impeding drainage). In most cases floods are additionally influenced by human factors. for instance: land-use changes, increase run-off and may be sedimentation, Occupation of the flood plain obstructing flows, Inefficiency or non-maintenance of infrastructure, too efficient drainage of upstream areas which increases flood peaks, climate change affects magnitude and frequency of precipitations and floods as well as an urban microclimate which may also enforce precipitation events. Although these influences are very diverse, they generally tend to aggravate flood hazards by accentuating flood peaks. Thus, flood hazards in built environments have to be seen as the consequence of natural and man-made factors.

As a result of different combinations of causal factors, urban floods can be divided into local floods, riverine floods, coastal floods, and flash floods. However, the common causal factors of fluvial floods are related to very high rainfall intensity and duration during the rainy season sometimes caused by seasonal storms and depressions and exacerbated by saturated or impervious soil. Additionally, built environments like cities generate higher surface run-off that is more than local drainage capacity, thereby causing local floods. Local drainage capacity is primarily made up of a local storm-water drainage system composed of storm drainpipes, curb inlets, manholes, minor channels, roadside ditches, and culverts. This system is intended to convey storm flows efficiently to the community's reservoir, such as the main river channel or the nearest large body of water.

Unfortunately, in third-world nations, many urban drainage facilities were not in good shape due to a lack of cleaning and maintenance. In addition to indiscriminate dumping of municipal solid waste (MSW), rubbish and debris tend to clog the bottlenecks of drainage facilities, thus reducing the drainage capacity and leading to increased surface runoff and backup effects. Depending on the local hydro-geological situation, groundwater rising or subsurface flows can be other causes in the generation of floods. Though, these events may particularly become difficult to observe and predict as a result of small Spatio-temporal scales of floods, relative to the sampling characteristics of conventional rain and discharge measurement networks (Daniele *et al.,* 2011). However, due to higher generated runoff and less concentration in urban areas, small streams can also rise rapidly after heavy rain (Ozcan and Musaoglu, 2010). Changes in rainfall storm intensity in the urban area produce higher flows that exceed the small culverts' capacity under roads designed for non-urbanized areas. can drain excess water. Therefore drainage system is one of the most important urban infrastructure assessments [5], [6]. Although when designed, such structures can be adequate, their capacity may turn out to be less accommodative and thereby cause overflows, creating new waterways (Associated Programme on Flood Management-APFM, 2012). These types of floods are generally confined to rather small geographical areas and are normally not of long duration. However, in regions of extended rainy seasons (monsoon climates), floods may last for weeks, resulting in widespread destruction (Moses, Ijeoma, and Bitrus, 2015).

The trend of poor MSW in the Minna metropolitan area is worrisome. Igoni, Ayotamuno, Ogajim, and Robert (2007) observed that the problem of solid waste management in Minna town was not different from other urban areas in Nigeria where poor MSW disposal leads to illegal waste dumpsites, blocking waterways, leading to aesthetic health and environmental hazards. Mohammed (2014) also disclosed that Minna being among the fastest-growing cities in Nigeria was faced with solid waste disposal problems. The consequence was severe when the city was growing rapidly without a corresponding increase in construction of new drainage systems and the existing MSW were not efficiently managed. Improper management of solid waste was a result of population growth and insufficient facilities for waste management. This study aims to use a Geographic Information System (GIS) to determine the spatial distribution of MSW dumpsite sites in relation to the urban drainage system, and assess public perception on the impact of clogged drainages on floods occurrence in Minna metropolis, Nigeria.

2. STUDY AREA

Minna, the capital of Niger State is located between Latitudes 9^0 $36^/$ and 9^0 $61^/$ North of the Equator and Longitudes 6^0 $33^/$ and $6^0 55^/$ East of the Greenwich Meridian. Minna urban area consists of two Local Government Areas, Bosso and Chanchaga spanning, from Malkunkele in the north-east and Chanchaga in the South-eastern part of Minna, The study covers Minna town in Niger State which consist of twenty-four (24) neighborhood (Figure 1). It covers about 76,363km^2 with a projected population figure of 296,496 by 2016. The study area is bordered by Shiroro in the North, Shiroro, and Paikoro to the East, Paikoro and Katcha in the South, and Wushishi and Gbako in the West (Figure 1). Minna is situated in a tropical region with a tropical continental climate. It is characterized by two main seasons, the wet season between April to October and the dry season between November and March. The highest and lowest mean monthly temperatures are recorded in March at about 3^{0}C and December and January at about 25^{0}C respectively. The mean annual temperature increases northward from about 30^{0}C to 37^{0}C. Annual rainfall ranges from about 1,2300mm to 1,600mm. Trading activities take place along the major roads and all the streets. The main market of the town is The Central Market (daily) and Gwari market (weekly) (Maxlock, 1979; Ati and Sawa, 2008).

Figure 1: The Study Area
Source: Administrative and Topographic maps.

3. MATERIALS AND METHODS

Reconnaissance Survey was carried out in the Minna metropolis and different neighborhoods were visited to get the researcher acquainted with the nature of the drainage network and MSW dumpsites in the study area. Data used for the study were collected from both spatial and non-spatial sources. Thus, a record of existing MSW dumpsites was collected from Niger State Environmental Protection Agency (NISEPA). All were traced and their geographic coordinates were collected using Global Positioning System (GPS). Microsoft Excel was employed to organize the coordinates into a relational database. The administrative and topographic maps of the area were scanned, and alongside the MSW database were integrated and spatially overlaid in a GIS software interface. The drainage networks were digitized from Google earth map of the study area and the distribution of the dumpsites was mapped. Using Standard Query Language (SQL) operation, all MSW dumpsites within urban drainages were queried, mapped, and studied. Tables and Maps were used to summarize the results. The questionnaire survey was used to capture community perception on the potential risks posed by the illegal MSW dumpsites. An interview guide was also used to acquire supplementary data. Available population census figure of 2006 shows that Minna had a population of 234,619. However, using the national population growth formula (equation 1), the population figure was projected to be 434,000 by 2019 (Niger State Bureau of Statistic (2011).

$P_n = P_i\,(1+r/100)^n$ …………..equation 1
Where P_n = Projected Population
P_i = Base Year Population (2006)
r = Growth Rate (2.8%)
n = Projected Period (2006-2019 = 13 Years)

A total of 384 respondents were sampled for questionnaire administration based on Krejcie and Morgan's (1972) sample size selection table. Thus, it is stated that given a population size above 99,999, a sample size of 384 is appropriate. The questionnaire was administered proportionate to the population figure (projected) of each neighborhood using Krejcie and Morgan's (1972) formula (equation 2). To select respondents in the study area, a systematic random sampling technique was used which involved sampling the 1st, 5th, 10th 15th 20th, etc. (an interval of 5) houses in each street within the neighborhoods. This was done to ensure an unbiased and proportional spatial coverage of responses across the study area.

q=nx384N……………………equation 2

Where: q = sample size (copies of questionnaire)

N=Projected population figure of the study area

n = Population of each neighbourhood

4. RESULTS AND DISCUSSION

a) Distribution of MSW Dumpsites

The existing MSW dumpsites as the locational data are displayed in Table 1. The Table shows one hundred and sixteen (116) traced and identified dumpsites as well as their number and percentages within the study area. To understand visually their distribution spatially, Figure 2 is generated after subsequent mapping within ArcGIS to further portray their location. Analysis from Table 4.1 revealed that Bosson Town (37.1%) had the highest share of MSW dumpsites. The least (1.1%) MSW dumpsites traced are located at Makera and Minna Central respectively.

Table 1: Distribution of MSW in the Study Area

S/N	Neighborhood	Number of Dumpsites	Proportion (%)
1	Makera	1	1.1
2	Sango	3	3.1
3	Minna Central	1	1.1
4	SabonGari		
5	SaukaKahuta	6	5.1
6	Bosso Estate	1	1.1
7	Barkin Sale	10	9.0
8	Bosso Extension		
9	Kpakungu	7	6.0
10	Bosson Town	43	37.1
11	Tudun Fulani	2	2.1
12	Tayi Village	4	3.0
13	Tunga		
14	Maitumbi	4	3.0

15	Nassarawa	5	4.0
16	F-Layout	1	1.1
17	Nigeria Army Barrack		
18	Fadipe	5	4.0
19	Duten Kura Hausa	6	5.1
20	Dutsen Kura Gwari	4	3.0
21	Tudunwada North	5	4.0
22	Tudunwada South	4	3.0
23	G.R.A	5	4.0
24	Chanchaga	3	3.1
	Total	116	100

Source: Adapted and modified from NISEPA

From figure 2, MSW dumpsites are virtually located everywhere, however, the sizes and volume of waste generated might differ, with the large heap of waste visually observed to be more accumulated at the extreme south-west and north-eastern part of the study area around Bosso town and Barkin-sale.

Fig. 2: Spatial Distribution MSW (Source: Author’s Analysis, 2019)

a. MSW Dumpsites and Urban Drainage Proximity

Figure 3 and Table 2 shows the results of the query operation carried out. From Figure 3 MSW dumpsites presented in red were those located along the urban drainage in the study area, whereas those in green color separation were not. The former constitutes the majority with 56.9%, while the latter accounted for the least with 43.1% (Table 2). Observation from the field placed the waste as more dense and humid due to the prevalent consumption of fresh fruits and vegetables, as well as unpackaged food. There could be a high chance of breeding more mosquitoes, flies, and rodents a swell as environmental uncertainties. Depending upon the volume of MSW generated and the efficiency of MSW management strategies in place. This is in line with Aderoju *et al.,* (2014) whose findings showed 31 major dumpsites which were situated mostly along major roads and watercourses in Minna of Niger State.

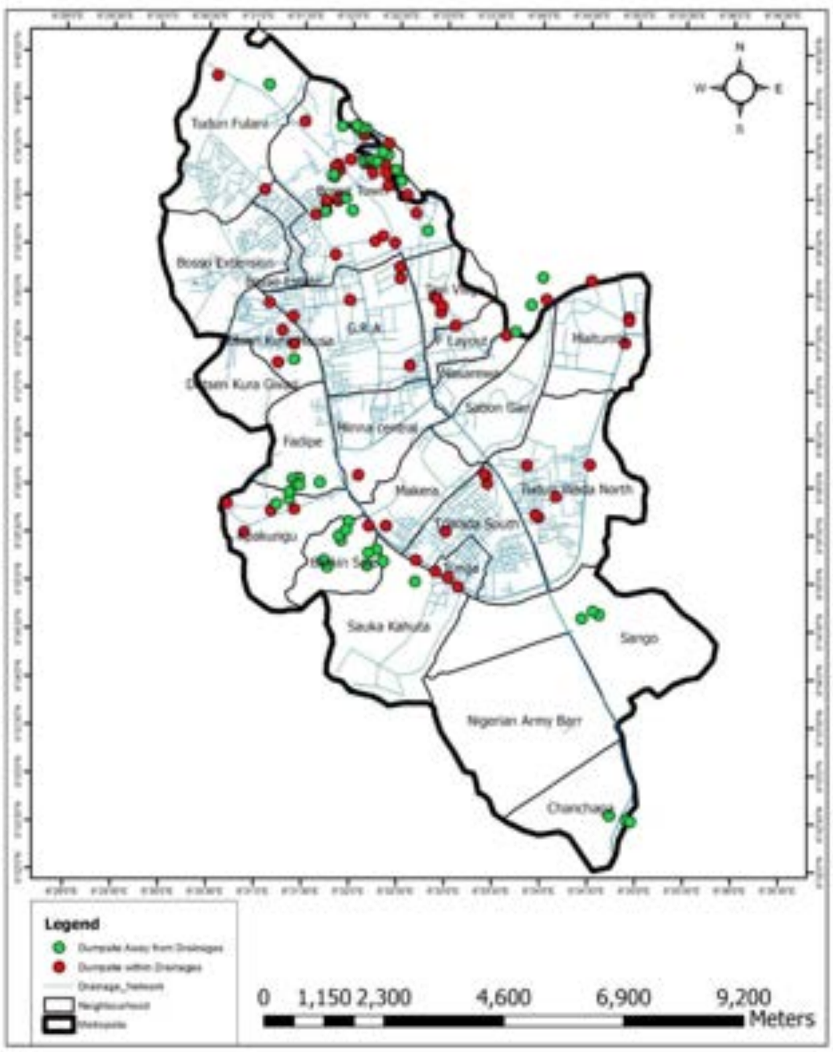

Fig. 3: Spatial Proximity of MSW Dumpsites to Urban Drainage
Source: Author's Analysis, 2019

Table 2: Number of MSW Dumpsites in Proximity to Urban Drainage

S/N	Dumpsites Location	Number of dumpsites	Proportion (%)
1	Dumpsites away from Drainage Network	50	43.1%
2	Dumpsites within Drainage network	66	56.9%
	Total	**116**	**100**

Source: Author's Analysis, 2019

b) Effect of MSW Dumpsites on Urban Drainage System

Major risks posed by the dumpsites to the inhabitants of the neighborhood were scored by the resident who has experienced these risks in one way or the other. The professed effect of Dumpsites on the drainage system is presented in Figure 4. As a result of drainage blockages by MSW dumpsites, Figure 4 showed that 56% of the dwellers experience severe floods within the environment, while 83% appealed to have experienced very serious water-related diseases outbreak, majority moderated the effect to water pollution (25%). This perhaps might be attributed to the unsanitary behaviour of the inhabitants indulged by the ineffectiveness of waste management agencies and inadequacy of management facilities and equipment which, Aderoju *et al.*, (2014) revealed to be the major challenge affecting ample MSW management in Minna.

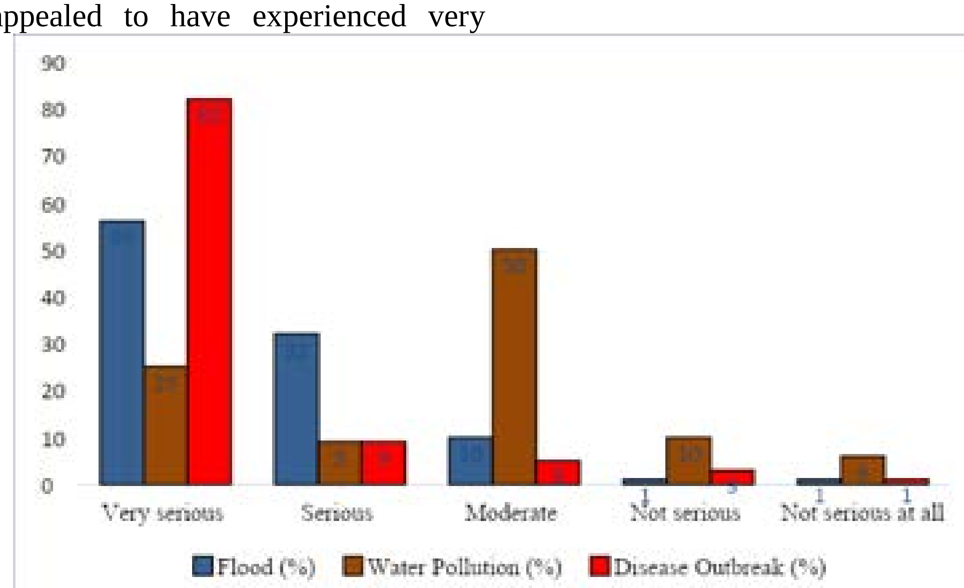

Figure 4: Types of Risk Posed by Dumpsites
Source: Author's Analysis 2019

Moreover, according to the inhabitants interviewed, there have been serious negative implications of the MSW dumpsites on the nature of seasonal flood incidences in the study area. Most of them were of the common opinion the:

…Many among the dumps were sited within the drainages constructed to accommodate surface runoff thereby obstructing the free flow of water leading to flood which is common during the rainy season in the Metropolis.

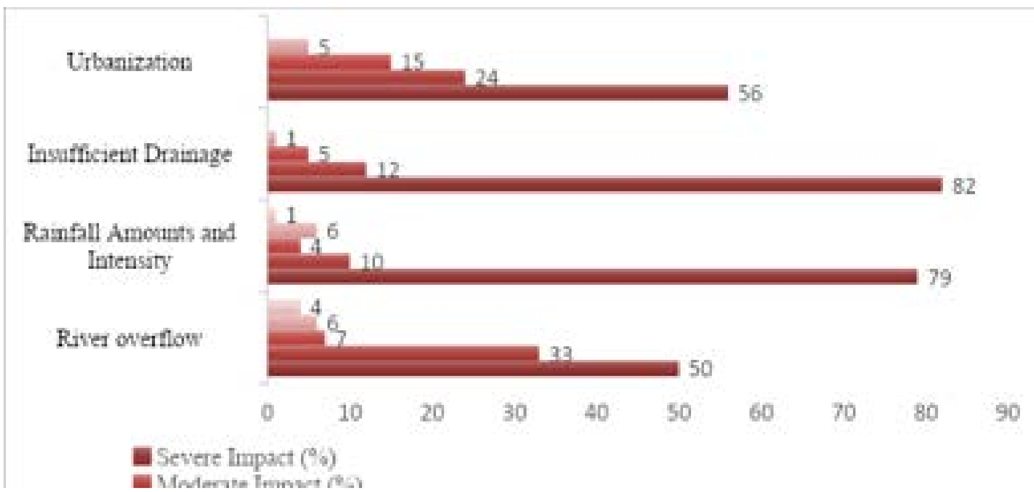

Figure 5: Impact of Urban Drainage Obstruction Flows on Flood Risk (**Source: Author's Analysis 2019)**

From figure 5, flood risks are influenced by a range of factors as attested by the respondents, including the overflow of the two rivers (50%) that transverse the study area, unprecedented rainfall amounts and intensity (79%), insufficient drainage systems (82%) and urbanization (56%). These were perceived to severely impact urban drainage flows. This implies that inadequate maintenance of the drainage channels, and debris and solid waste disposed into such drainage systems accentuate flood. The rainfall-runoff process, additionally, is highly complex, non-linear, and spatiotemporally varying because of the variability of the terrain and climate attributes (Chang and Guo, 2006). The respondents also added that:

…Urbanization mostly in the city suburb is one of the major causes for high MSW generation and disposal which is assuming alarming proportions evidenced by the increasing dumpsites and abandoned wastes and deposits in the city streets and along the water course. Also, residences often neglect to construct drainages while building houses and commercial facilities. It is therefore very common to find drainage lines and even streams within the study area being filled up with refuse after rainfall.

5. CONCLUSION

The study recommends that dumpsites should be located away from the drainage system, and should be appropriately managed to abate its risks to floods. The community should control the litter and monitor its volume as its accumulation caused drainage blockage.

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THE HEALTH IMPACTS OF CLIMATE CHANGE: A STUDY OF INFANT DEATHS IN NIGERIA

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Abstract: Climate change has emerged in recent times as a crucial factor affecting human health. This issue afflicts the developing world in general and Nigeria in particular. Though several attempts have been made in the empirical literature to investigate these issues. However, many of these studies emphasize more on developed countries. Those on Africa and Nigeria focused largely on climate change-food security and economic growth. While studies on the effects of climate change on health in developing nations, such as, Nigeria is limited. Therefore, this study investigates the health impacts of climate change with focus on the infant-health in Nigeria.The study applied regression technique for its analysis. The results of the study show, among other things, that the lower the heat burden from climate change, the more improve the infant-health indicators. That is, the variability of climate changes significantly and negatively affects newborn health in Nigeria. The findings thus suggest that sufficient measures should be taken to adequately increase access to health and priority attention given to health of infant.

Keywords: Climate change, Health and Human Capital, Nigeria

JEL Classification: Q54, J11, I15, C13

1.0 INTRODUCTION

The instability and frequency of extreme weather events, such as heavy precipitation and droughts, and the increasing global mean temperature have attracted enormous debate in the literature on applied economics, particularly in the developing economies, as the climate change impacts on human health seem to be many and complex. One major reason adduced for this is that climate changes could extremely alter weather with floods and storms, affect air quality, and increase diseases resulting from air pollution (World Health Organization, WHO, 2003; Geruso and Spears, 2018). Broadly, climate changes and their variabilities increase or decrease vector-borne diseases, the prevalence of malaria, and outbreaks of waterborne diseases, such as cholera and diarrhea (Gemeda and Sima, 2015). Their main argument is that the variabilities of climate might be hazardous to health. For instance, Cho (2018) attributed the aggravate poor health conditions such as asthma to the rise in heat waves in Florida. These, therefore, suggest that climate changes could pose serious health challenges that require close and urgent attention.

Globally as observed by WHO (2003), the last decade was the warmest since instrumental records began in the 19th century, and also contained 9 of the 10 warmest years ever recorded. Amongst other things, climate changes represent a factor that affects human health both directly and indirectly through changes in biological and ecological processes and via the influence of several infectious diseases (Grasso *et al.* 2012; Geruso and Spears, 2018). This implies that the health impacts of climate change are considered important for analysis. This is because, in many developing countries (including African nations), human health status is placed amongst the most worrying indicator of well-being as it constitutes a key component of human capital. In addition, the African region seems to be the most susceptible continent in the world to climate change-related health challenges due to her poverty experiences, unemployment, and weak institutions to deal with health challenges posed by climate change (United Nations Economic Commission for Africa, 2011).

Furthermore, the low adaptive capacity in African nations and their high exposure to climate variability make the region the most vulnerable continent in the world. Wu and Xu (2016) argued that Africa's vulnerability is due to the continent's low level of economic development that reduces her capacity to adapt to the impacts of climate changes. The instability of climate change-health impacts is also attributed to African reliance on agriculture as well as their lower technical, financial, and institutional capacity to adapt its variability (Gemeda and Sima, 2015). This is noted because several African countries still depend mainly on subsistence and small-scale farming. As a result, the changes in climate and weather, such as increased temperature and declining rainfall pose considerable risks to their health outcomes and livelihoods (Olsson *et al.* 2014).

Though several attempts have been made in the empirical literature to investigate these issues. However, many previous studies emphasize more on developed countries. Those in Africa and Nigeria focused largely on climate change-food security and economic growth (see, for instance, Kala et al. 2013; Gemada and Sima, 2015). Those studies on the effects of climate change on health in developing nations, such as Eke and Onafalujo (2011) utilized aggregated morbidity rates based on the response from medical practitioners. Rabassa et al. (2012) focused on rural Nigeria from 2003 and 2008 Nigerian Demographic and Health Survey. Unlike these limited studies, the contribution of the study lies, first, in quantifying the effects of climate change on newborn deaths in Nigeria. Second, in the use of a long yearly time series which is not the case in most other studies. The consideration of these became necessary because the health impacts of climate change affect people's welfare, labour productivity, and economic growth.

The outline of the study was as follows. For more insight, the literature was reviewed in section two. Section three presented the methodology, four discuss and interpret the results obtained. Finally, the paper concluded with summary and policy recommendations in section five.

2.0 LITERATURE REVIEWS

2.1 Stylized Facts on Climate Change and Health

Climate change is the biggest global health threat and a leading human and environmental crisis of the 21st century (WHO, 2003). It is also one of the major challenges confronting African people, their governments, and the African Union (AU) in recent times. The concept is defined as any change in climate over time due to natural variability. It is also associated with an increase in average global temperatures. It is often believed that natural events and human activities contribute to the rise in global temperatures. Furthermore, climate change from the burning of fossil fuels and the associated release of climate pollutants, are causing significant changes to the global climate system (W.H.O, 2014). This implies that climate change is a factor that can increase the frequency and severity of health challenges, that is probability of ill health or instantiate it (Eke and Onafalujo, 2014; Wu and Xu, 2016). It might also accentuate health risks and morbidity rates.

Again, climate change affects human health indirectly, through changes in food production, water resources, migration, and economic growth (Lee and Kim, 2016; Kula et al. 2013). It also changes the quality of water, air, and food which disturbs health outcomes indirectly. It could likely discomfort the environmental and social conditions of citizens which might lead to social and economic disruptions. And the survival of mosquito and malaria parasites is also highly sensitive to climate change and temperature patterns. Over the past four decades, the spread of malaria to highland areas of East Africa, Indonesia, and Afghanistan, has been linked to climate change. This was a rare phenomenon in the cooler highland areas about 50 years ago. Therefore, climate change represents a factor that can affect human health, particularly the newborns, both indirectly and directly through changes in ecological and biological processes (Grasso *et al.* 2012).

Infant mortality is the numbers of deaths recorded before newborn babies reach the age of 12 months or a year. Numerous pieces of evidence have shown that the number of newborn deaths in the sub-Saharan Africa (SSA) region is more comparatively. Figure 1 indicates the SSA and global average of infant deaths. It is observed that compared to the global average and OECD members indices of approximately 53 and 11 per 1,000 in the year 2000, respectively; the SSA average was as high as 92 per 1,000 (World Bank, 2019). Though these trends decline between 2000 and 2018 across the global average and OECD members. For instance, these rates declined greatly to 29 and 6 per 1,000 in the year 2018 for worlds and OECD members averages, respectively. However, the SSA infant deaths were still as high as 53 in every 1,000 newborn babies less than 12 months.

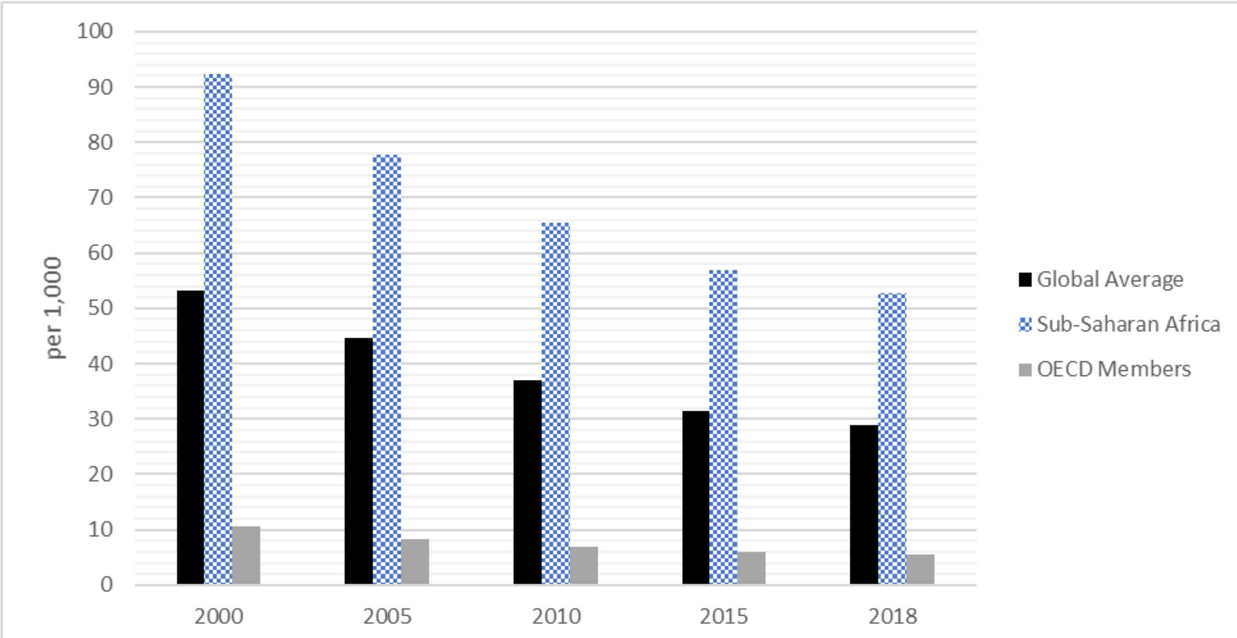

Figure 1: Global Comparative of Infant Deaths
Source: World Bank (2019)

Table 1 present the five nations that accounted for half of the global newborn deaths for the year 2017. It is important to note that among the several countries in the SSA region, only Nigeria and Congo (the Democratic Republic), in addition to India, Pakistan, and Ethiopia accounted for half of all newborn deaths in 2017 globally. Surprisingly, after India and Pakistan, Nigeria is the third-largest contributor to newborn deaths in the world (see Table 1). This implies that Nigeria contributed approximately 9% of infant mortalities to the global percentages. This statistic is twice of the Democratic Republic of Congo in the SSA region with Nigeria. Majority of these deaths often occur within the first week of birth mainly due to complications during pregnancy, delivery, and post-delivery; reflecting the link between their survival and quality of maternal care (UNICEF, 2015).

Table 1: Five Nations Accounted for Half of the Global Infant deaths in 2017

Countries	Global Percentages of New-born deaths
India	24%
Pakistan	10%
Nigeria	9%
Congo (Democratic Republic)	4%
Ethiopia	3%

Total	***50% of the World's Newborn deaths***

Source: WHO (2018)

Figure 2 presented the compared infant deaths of Nigeria with Ghana and South Africa. It was further observed that the newborn mortality rate is still relatively higher in Nigeria compared to Ghana and South Africa indices, and global averages. The figure (Figure 2) clearly shows that infant deaths in Nigeria are still high compared with peer countries and the global average. Although improvements are visible over time (between 1990 and 2019).

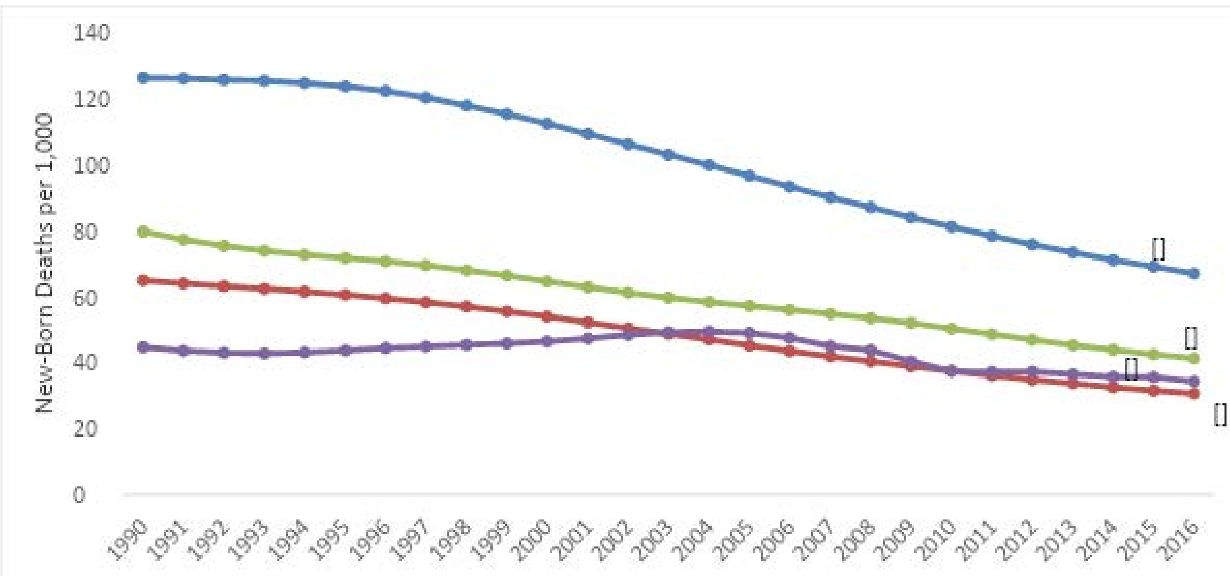

Figure 2: Infant Deaths in Nigeria
Source: World Bank Development Indicators, 2018

2.2 Theories

The linkage between climate change and infant health for human capital development, economic productivity could be established through both microeconomic and macroeconomic mechanisms. Insights from the microeconomic-dimension side reveal that good health could make newborn children and adults alike more productive in the future and current periods, respectively. For instance, improved health of children could lead to fewer days off school or increased output for adults while working. Generally, it contributes to the prosperity and well-being of households and their society (Cho, 2018). Therefore, increased temperature could lead to ill-health, which in turn may impede capital accumulation, labour supply, and productivity.

However, the argument from the macroeconomic side suggests that the nexus between climate change and health could influence the *level* of current and future outputs, such as agricultural yields (food security) and economic outputs (Kula et al. 2013). The newborn ill-health contributes to declines in the economic welfare of not only these infants but also their parents in most developing economies. It also affects parents' labour force participation, their number of hours worked, their wages and earnings, and early retirement from economic activities (Gresso et al. 2012; Lee and Kim, 2016).

Thus, the health protection for infants from climate change risks can be more enhanced by ensuring improved and more equitable access to the social and environmental determinants of health, enhancing health, and targeted interventions to specifically address climate risks (WHO, 2014). As Gallup et al. (1999) note, vector-borne diseases, particularly malaria, can have such a large effect on labour force supply and productivity which could make many nations in SSA, particularly, Nigeria be trapped in a vicious cycle of disease–low productivity–poverty–deficient health care. This has implications for the future welfare of these infants.

2.3 Empirical Reviews

Geruso and Spears (2018) examined the nexus between heat, humidity, and infant mortality in the developing world. They studied how extreme weather exposure impacts children's survival. Their study focused on 53 developing countries that span five continents, they found the impacts of hot days on infant mortality that are an order of magnitude larger than corresponding estimates from rich country studies, with humidity playing an important role. However, the study by Lee and Kim (2016) presents a projection of future temperature-related mortality due to both climate and demographic changes in seven major cities of South Korea. Their results showed increased mortality in the elderly group, significantly increasing the overall mortality.

Vardoulakis *et al.*(2015) explore a range of health risks in the domestic indoor environment related to climate change, as well as the potential health benefits and unintended harmful effects of climate change mitigation and adaptation policies in the United Kingdom housing sector. They observed that climate change mitigation and adaptation measures in homes can benefit health.

Rabassa *et al.*(2012) indicate that weather shocks exacerbate child mortality and morbidity in Nigeria and are of considerable magnitude. From their findings, rainfall shocks have a statistically *significant* and robust impact on child health and the incidence of diarrhea. Similarly, it was indicating that diarrhea is the leading cause of child malnutrition, and the second leading cause of death for young children (in the country underscores the severity of the impact on human development and long-term welfare implications of weather changes, while the intensity is highest in hottest regions).

In Nigeria, Eke and Onafalujo (2011) examine health risks that could arise from climate change. They employed a structured survey to elicit risk perception responses on health risks and climate change from health personnel in Nigeria and other citizens. The study also adopts Z-score and simple regression analyses to test the extent of the relationship between climate change and morbidity rate and descriptive statistics on society's illusion of climate change. Their finding also shows that there is a prevailing illusion on climate change and there is significant evidence for an increase in health risks and morbidity rate instantiated by climatic variability.

Traerup *et al.*(2010) investigate the incidence of cholera and the health impacts of climate change in Tanzania. The study links the incidence of cholera to socio-economic and environmental factors from 1977 to 2004 and uses socioeconomic data to control for impacts of general development on the risk of cholera. Based on primary data collected from the Ministry of Health, Tanzania, and the Tanzania Meteorological Agency on rainfall and temperature, their result shows a *significant* relationship between cholera cases and high temperature in Tanzania.

Tang *et al.*(2009) examine the dynamic nexus between climate, health, and income from 152 nations, by partitioning the effects of climate change on mortality into the pure climate effect, the pure income effect, and the overlapping effect, and show that African nations exhibit a large pure climate effect but a negligible pure income effect, while non-African countries exhibit the opposite pattern. The findings have key implications in the context of climate change, as global warming is likely bringing about worsening climatic conditions in poorer nations that could see many of them sinking deeper into a climate trap of underdevelopment in health

Shakoor *et al.* (2006) employed time series models to analyze mortality due to thermal stresses during heatwaves compared to total mortality occurring throughout the whole summer. Keatinge*et al.* (2000) estimated the heat-related mortality due to climate change in Europe using time series data and taking into account the threshold temperature where mortality is lowest. The findings suggest that the European population have adapted to average summer temperature and might adapt to future higher temperature with only a minor increase in heat-related deaths.

Bosello *et al.* (2005) employed computable general equilibrium (CGE) and simulation experiments to model the impacts of climate change on human health. They found that investment falls (rises) if health impacts are negative (positive), which would imply that the economy would shift away from those sectors that are negatively affected by climate change. This would also reduce global vulnerability to climate change but increase the regional and country-wide impacts.

In summary, the empirical survey highlights several dominant issues on the impact of climate change on health-related indicators. However, Rabassa et al. (2012) focused only on rural Nigeria from 2003 and 2008 Nigerian Demographic and Health Survey. This analysis ignored the urban areas in Nigeria. Eke and Onafalujo (2011) similarly utilized one-point data and morbidity rates based on responses from medical practitioners. Generally, these Nigerian studies neglect the climate change effects on infant deaths over time. It is worthy of note that the consideration of these became necessary because the health impacts of climate change affect the infant and their parents' welfare, labour productivity, and economic growth.

3.0 METHODOLOGY

3.1 Theoretical Framework

Figure 3 presented the theoretical framework for the study with insights from both theories and empirics. The arrow lines indicate the direction of the impact of climate change on infant health. For instance, from the pioneering work on human capital by Becker (1964) and Grossman (1972), improved infant health has consumption and investment effects on the current and future times (see Grossman 1972). The consumption effect of health status reflects how health enters directly into the utility function of individuals through consumption. The investment effect posits that good health provides extra healthy time to infants' parents to engage in productive activities that determine their welfare, earnings, and the quality of life of infants. Thus,

$$Qt=Q\ (Qt\text{-}1,\ Gt,\ \ Vt,\ Zt) \qquad (1)$$

where Q is the stock of the health of individuals, G and V are material and time inputs into health production (Novignon, *et al.* 2015); and Z is a vector of exogenous factors. Hence;

$$Zt=Z\ (Ct\text{-}1,\ Ht,\ ) \qquad (2)$$

where C represents climate change and H the impacts of the infectious disease as shown in Figure 3.

Notably, some of the features of the climate change effect include *pathogen*, *host*, and *transmission*. Pathogen refers to a wide range of disease agents such as fungi, bacteria, and viruses. The impact of climate change on pathogens can be *direct*, through influencing the survival, reproduction, and life cycle; or *indirect*, via their habitat, environment, or competitors.

On the other hand, temperature affects infant health by impacting the life cycle of pathogens. First, they need a certain temperature range to survive and develop. Second, *the rising* temperature can influence the reproduction and incubation period of pathogens, for example, mosquitoes develop at a temperature of 22-23°C (Wu *et al.* 2016). However, hosts refer to living animals or plants on or in which disease pathogens reside. Vectors are intermediate hosts and they carry and transmit the pathogen to living organisms that become hosts. The geographical locations of insect vectors are closely associated with the patterns and changes in climate. Thus, climate change may cause changes in the range, period, and intensity of infectious diseases (Tian *et al.* 2015).

As the temperature continues to rise, the insects in low-latitude regions may find new habitats in mid- or high-latitude regions and areas of high altitude, leading to more diseases. Recent studies found that some human infectious diseases, including malaria and yellow fever, have been distributed to a wider range (see, for example, Wu and Xu, 2016). All these affect the health and survival of newborns.

3.2 Econometric Specification

This model for this study was built on the study of Grasso *et al.* (2012). They considered the comparative risk assessment related to climate change. However, the current study's model differs from the aforementioned in that the study account for infant mortality rates as proxied for infant health (IHt), climate change effects are denoted by CCt, rainfall (RF) and temperature rates (TR), and the control variable of population growth (PG)in Nigeria.

Thus, the model is specified as:

$IHt = \alpha + 1RFt + 2TRt + 3PGt + \varepsilon$(3)

where *t* denotes time considered.

The approach by Grasso *et al.* (2012) accounted for (i.) the rainy season (season with the highest rainfall and lowest temperature) from May to September; and (ii.) the dry season which lasts from October until April determined by high temperatures and low humidity, mostly affected by warm winds coming from the Sahara Desert to the North. The study theoretically expects that the relationship between infant deaths and the rainy season should be positive. Perhaps the relationship between dry season and longevity could be negative.

3.3 Data Issues

The sources of data for this study are annual data from the World Bank Development Indicators (WDI, 2019) and World Bank Climate Change (2018). The study also covers the periods between 1981 and2018. The scope is based on data availability.

4.0 RESULTS AND DISCUSSIONS

4.1 Descriptive Statistics

Figure 4 indicates the monthly temperature in Nigeria. For instance, between 1981 to 2018, Nigeria experiences the lowest monthly temperature of 22°Celcius in January 1983, while the highest monthly temperature was 32°Celcius in April 2010 in Nigeria. This probably explains the high level of malaria cases across all regions of Nigeria because mosquitoes frequently develop at the temperature of 22 to 23°C (Wu *et al.* 2016). This affects the infant the most.

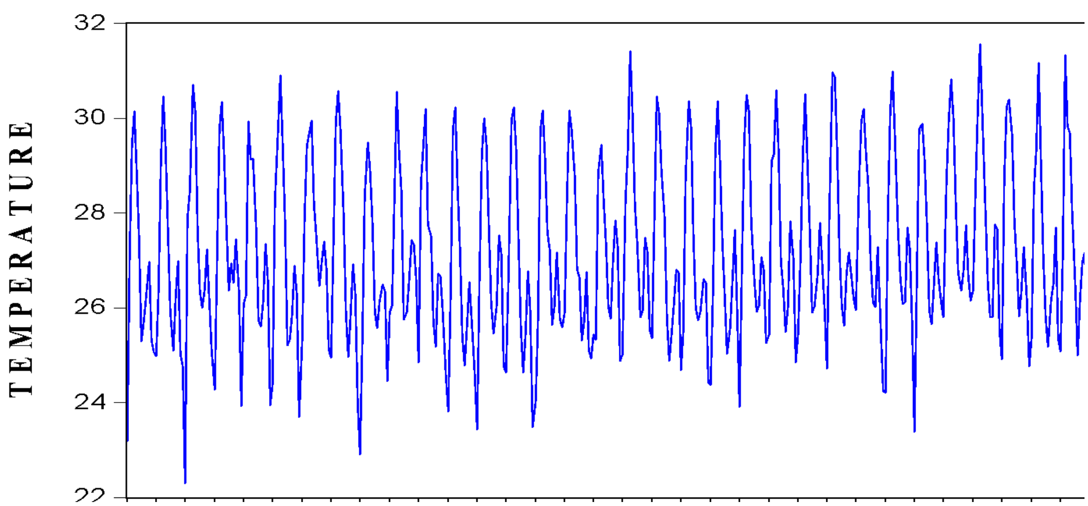

Figure 4: Monthly Temperature in Nigeria (1981 – 2018)

Source: World Bank Climate Change Knowledge Portal (2018)

Again, as the temperature continues to rise, the insects in low-latitude regions may find new habitats in mid- or high-latitude regions and areas of high altitude (like Nigeria), leading to more diseases (Tian et al. 2015). For monthly rainfall, Figure 5 shows that the average lowest rainfall in Nigeria was also in January 1983 of 0.052mm and the highest rainfall was 314.6mm in July 2008.

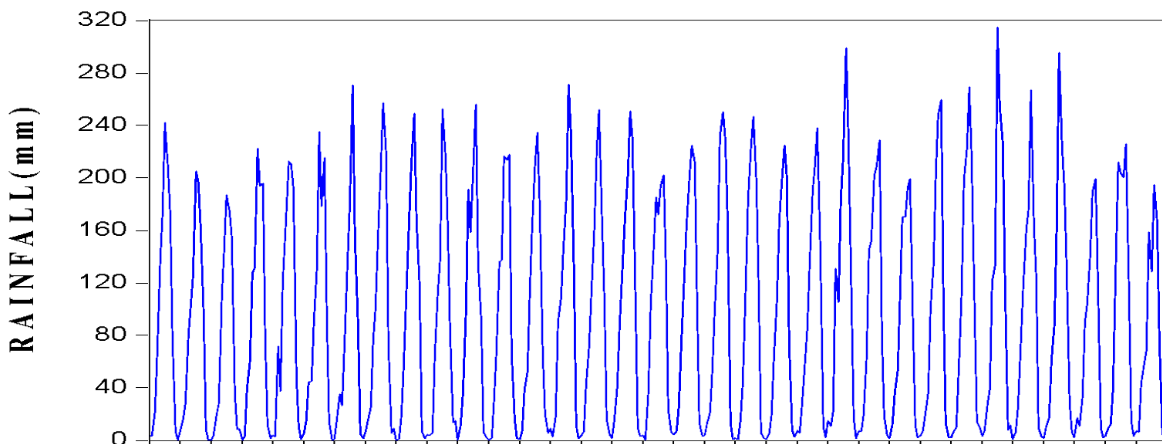

Figure 5: Monthly Rainfall in Nigeria (1981 – 2018)
Source: World Bank Climate Change Portal (2018)

Table 2 showed the summary statistics of newborn deaths in Nigeria. The average of infant deaths between 1981 and 2018 is 105 per 1,000 live births in Nigeria. This implies that more than 10% of babies born over the periods die before they reached their first birthday. The lowest deaths were recorded in the year 2018 when 76 children per 1,000 live births died. This might be associated with the United Nation's Millennium Development Goals (MDGs) that ended in the year 2015. Thus, much emphasis on the newborn health and their mothers is paramount to further reducing the deaths of infants in developing countries, such as Nigeria.

Table 2: Descriptive Summary of Infant Deaths in Nigeria (1981 – 2018)

Mean	Maximum	Minimum	Standard Deviation	Observations
105	126	76	19	36

Source: World Bank Development Indicator (2019)

4.2 Estimation Results

Tables 3 and 4 show the estimation results from the Ordinary Least Square (OLS) technique. Table 3 indicate that all the variables except high rainfall are statistically significant and correctly signed. For instance, low temperature is statistically significant at a 5 percent level. It implies that reduced heat is key to reducing infant deaths in Nigeria. This result is not surprising as excessive heat exposure has been identified as an emerging risk for pregnant women and their babies (Rylander et al. 2014). In addition, increasing humility in hot areas adds to the heat stress and health risks. For instance, if the air is hotter than the body, heat will be added to the body. Strong heat radiation that reaches the skin through sun rays also adds heat to the body, irrespective of the clothing or shading facilities.

Table 3: Low Temperature and High Rainfall on Newborns Deaths in Nigeria

	Infant Mortalities
Low Temperature	-7.3** (-2.3)
High Rainfall	0.0042(0.05)
Population Growth Rate	-154.4*** (-4.0)
Constant	684.1*** (5.8)
Probability	0.0004

Note: *, **, and *** represent 10%, 5%, and 1% respectively. The t-statistics is in parenthesis

Source: Compiled by the Author using Stata 13

The table further shows that heavy rainfall increases newborn deaths. The finding is consistent with the results of Wu *et al.* (2016) and Cho (2018), they reveal that rising temperature affects the reproduction and incubation of diseases, and its variability might be hazardous to infants- and their mothers' health. Perhaps the developing fetus and infant are often considered the most sensitive at tender periods of human capital development. They will thus be the most vulnerable in terms of the environmental effects of climate change.

Table 4: Low Rainfall and High Temperature on Newborn Deaths in Nigeria

	Infant Mortalities
High Temperature	12.2* (1.9)
Low Rainfall	2.1 (1.12)
Population Growth Rate	-124.3*** (-4.5)
Constant	802.4*** (4.4)
Probability	0.0002
Observation	35

Note: *, **, and *** represent 10%, 5%, and 1% respectively. The t-statistics is in parenthesis

Source: Compiled by the Author using Stata 13

Table 4 indicates the high temperature and low rainfall impact through climate changes on infant-health indicators. The findings show that high temperature is highly significant at 1%. This implies that as temperature or heat burden increases, the heavy sweating, weakness, headache, diarrhea, and high body temperature increases which could result in newborn deaths. This is also in line with the result of Cho (2018). He shows that humility in hot areas adds to the heat stress and health risks. For instance, if the air is hotter than the body, heat will be added to the body.

5.0 CONCLUSION AND POLICY RECOMMENDATIONS

This study has shown that the variability of extreme climate change afflicts a significant proportion of the Nigerian population. The issue is more pronounced among infants. The study further shows, among other things, that Nigeria experiences the lowest monthly temperature of 22°Celcius in January 1983, while the highest monthly temperature was 32°Celcius in April 2010 in Nigeria. It suggests that the high level of malaria cases across all regions of Nigeria from mosquitoes might be associated with the high temperature. This affects the infant the most. This is because malaria cases often relate to the temperature of 22 and23°C (Wu *et al.* 2016). It was also found that between the periods of 1981 and 2019, low temperature significantly reduces newborn deaths in Nigeria. That is, the lower the heat burden from climate change, the more improved the infant-health indicators.

Therefore, given that climate changes negatively affect newborn health in Nigeria, the Nigerian government should take urgent and adequate steps to optimally address the problem. Furthermore, sufficient measures should be taken to adequately increase access to health and priority attention given to the health of infants.

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INTERACTIVE IMPACT OF CLIMATE CHANGE AND ARMED CONFLICT ON GENDER VULNERABILITY IN SUB-SAHARAN AFRICA

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Abstract: This study investigates the impact of climate change and armed conflict on gender vulnerability in Sub-Saharan Africa (SSA). The system-GMM panel data of 35 SSA countries for the period, 1997 to 2018 was employed. The empirical results reveal that climate change and armed conflict have a positive and significant impact on gender vulnerability in SSA. Contrary to the hypothesis that climate change promotes gender vulnerability through armed conflict, we find evidence that the direct impact of climate change on gender vulnerability is greater than the indirect impact. The result further reveals that population growth, output growth, unemployment rate, natural rent, exchange rate, and inflation rate are significant drivers of gender vulnerability in SSA. Based on the findings, we recommend that while reversing climate change and deescalating armed conflict are extremely important, economic reforms that promote massive investment in infrastructure and mainstream safety net that offer protection to the most vulnerable girls and women due to climate change and armed is also very crucial.

***Keywords*:** Climate Change, Armed Conflict, Gender Vulnerability, Gender Inequality Index, Panel Data Analyses, Sub-Saharan African.

INTRODUCTION

Sub-Saharan Africa (SSA) is generally considered a climate variability and conflict-prone region compared to other regions across the globe. For example, out of 30.9 million people displaced globally in 2017 due to disasters (mainly weather-related) and armed conflict, SSA accounted for 8.03 million, representing 26.3% of the global record behind East Asia and Pacific with 9.31 million, which is 30.5% of the total (Internal Displacement Monitoring Centre, 2018). Though men and women are vulnerable to conflicts and disasters, it is observed that they have varied levels of impact. The gender susceptibility differences between men and women are caused by differential distribution of resources, social roles, culture, and responsibilities of the divide in the society. However, evidence shows that women and girls are more vulnerable to climate change risks than men during and after disasters (Alam & Rahman, 2017; Rahman, 2013; Sharmin & Islam, 2013; Goh, 2012); likewise before, during, and after violent conflicts (Buchowska, 2016; IFRC, 2015; Kangas et al., 2015; Internal Displacement Monitoring Centre, 2014; Harris, Keen & Mitchell, 2013; Nordas, 2011; Bob, Potgieter & Perry, 2010).

While research and discourse on gender-differentiated impacts of climate change and armed conflict have gained space in disaster management, humanitarian emergency management, and development economics in recent years (Wedeman & Petruney, 2017), little is known about the extent of vulnerability of girls and women to climate risk and armed conflict in SSA in particular. The fact that disasters often occur in areas of conflict suggests that gender vulnerability, climate change disasters, and armed conflict should be given more attention in academic debate, on a global scale and conflict-prone regions like SSA in particular. Another motivation is that mainstream approaches to climate change adaptability and armed conflict reconstruction seem to have failed to recognize how the twosome exacerbates gender inequality vis-à-vis gender vulnerability. Again, it is argued that COVID-19 may further exacerbate the vulnerability of women and girls to climate change and violence in Africa, as a recent study shows a strong link between COVID-19 and rising cases of gender-based vulnerability gender in Africa. For instance, there is evidence that gender-based violence to 35% in Mali and Cameroon during the pandemic. WHO (2020) noted that violence against women during the pandemic period takes the forms of stress, increase in intimate partner violence due to stay at home restrictions and decrease in access to health services as a result of movement restrictions. The anecdotal evidence from WHO (2020) that the pandemic may have worsened the already precarious gender vulnerability situation in SSA provided a strong justification for the study.

The pertinent question addressed in the study is: what is the direct impact of climate variability risks and armed conflicts on gender vulnerability in SSA? Since some scholars have argued that the impact of climate on gender vulnerability might not be direct, but can be transmitted through armed conflict, what then is the indirect impact of climate change on gender vulnerability? To answer these questions, the study investigates gender vulnerability to climate change risk and armed conflict in SSA. This study represents the first effort that strives to establish the joint impact assessment of climate change and violent conflicts on a global scale and in SSA in particular on gender vulnerability.

The remaining part of this paper is structured as follows: Next section sets the stage with the concept of vulnerability and the drivers of gender vulnerability. Section three highlights gender vulnerability cases in SSA and the recent developments in the region that exacerbate gender-specific impacts of violent conflicts as well as climate variability risks. While section four explores the theoretical underpinning and empirical intersections between gender vulnerability, armed conflict, and climate change. While section five presents the methodology adopted as well as the data used in the study, the penultimate section discusses the findings and the policy implications thereto; and section six concludes with a highlight on the contributions of and limitations to the study.

2. Review of Related Literature

2.1 Concept of Vulnerability

Vulnerability is a social risk management term that gauges the relations between poverty, risk, and management of the risk (Alwang, Siegel, & Jorgensen, 2001). The degree of vulnerability experienced by an individual or group depends on the characteristics of the risk and the ability of the victim faced with such risk to respond to the outcome. Risk and response are the two major components of vulnerability assessment: Risk + Response = Vulnerability.

The response measures the level of adaptation and ability to cope with the risk which depends on the assets at the disposal of the group or community. Goh (2012) outlined the assets needed for a better-coping strategy in the face of risk and they include natural capital, physical capital, human capital, financial capital, social capital, and political capital. Focusing on the outcome rather than the risk, UNISDR AP (2013) defines vulnerability as the inability of a person, a community, or a social system to withstand the effects of a hostile environment. The vulnerability concept is a multidisciplinary one with different definitions and measurements. However, Alwang, et al. (2001) developed a risk-response-outcome framework in analyzing the conceptual and operational definitions of vulnerability from a different disciplinary perspective such as economics, sociology/anthropology, disaster management, environmental science, etc. The study concludes that irrespective of the discipline, that vulnerability depends on a "portfolio of risks and related portfolio and risk responses".

Gender vulnerability is the "inability to prepare, adjust, or adapt due to constraints inherent in a particular form of gender relationship" (Schroeder, 1987, p.33). As gender is a socially constructed role and relations between males and females (Sharmin & Islam, 2013), vulnerability is a long-range effect from the moment of hazard to the long period of recovery from shocks and stresses. The two dimensions of vulnerability in livelihood are resilience and sensitivity, which can be either high or low. The intercept of low resilience with high sensitivity is "very vulnerable", while the case of high resilience with low sensitivity produces "not vulnerable" (Davies, 1996). Oliver-Smith (2004) noted that gender vulnerability is conceptually located at the interlink of nature and culture, which in turn, links social and economic structures, cultural norms and values, and environmental hazards. Vulnerability is a structural issue and not an attribute of vulnerable groups, yet some groups are vulnerable such as women, children, the elderly, and other socially vulnerable groups, are highly exposed to disasters and conflict-related hazards. Achieving low sensitivity to risk with high resilience to hazards emanating from climate variability and violent conflicts is key to gender impact balance.

2.2 Drivers of Gender Vulnerability

Gender vulnerability has five dimensions--physical, cultural, social, economic, and political dimensions, which increases the susceptibility of vulnerable groups to the impact of hazards. Women, for example, are disadvantaged when it comes to the needed capital in the form of natural, social, physical, funding, and human capital which are fundamental factors in their susceptibility. They have limited access to resources such as information, means of livelihood, and technology. These disadvantages emanate from their traditional gender roles, educational levels, and traditional marriage customs (UN Women, 2016). Other determinants of gender vulnerability, apart from social roles, are access to resources and information, for example, lack of access to early warning information to women caused a higher rate of fatality to women compared to men in the 1991 cyclone and flood disaster in Bangladesh (Sharmin & Isllam, 2013). Sharmin and Islam (2013) noted that the early warning information about the flood incidence in Bangladesh was transmitted by men to men and such were not relay to the rest of the family members, so more women were taken unawares by the flood.

O'Riordan (2002), on the other hand, identified poverty, exclusion, marginalization, and inequities in material consumption as the drivers of vulnerability. Meanwhile, women from marginalized groups are more vulnerable to conflicts- during and after (Fraser, 2009; Kangas et al., 2015). Holmes and Jones (2011) further noted that the susceptibility of members of a household depends on the family demographic composition such as dependency ratios, sex of the household head, number of boys and girls in the household; ownership and control of assets such as land, labor, financial capital, livestock, time; access to labour markets; social networks; social capital; and levels of education. Women and girls are lagging in all these parameters in Africa, because of the level of development. They have lower levels of education, less access to ownership and control of productive assets and different social networks. In Africa, women produce 60-80% of food (in developing countries), 33% of the paid labor force, 70% of agricultural labor days, 100% of food transformation, 80% of food storing, 90% of spinning and weaving, 60% of harvesting and market activities, but only 2% land ownership or land rights (FAO, 2002). Gender vulnerability is also noticeable in assets stripping during and after conflicts. The "underlying gender biases may mean that women's or female-headed households' assets are more vulnerable to stripping than those of men, the impact of which may be longer if what has been sold cannot be replaced. (Holmes & Jones, 2011).

Being more specific on climate change, the pre-existing gender inequalities in women's access to and control of resources and decision-making power are exacerbated women's vulnerability to climate change impacts (BRIDGE, 2016). Rao, et al. (2017) document high levels of poverty, lack of social safety nets, natural resources, climate-dependent livelihoods, and low asset bases as factors that exacerbate drought and water scarcity in the semi-arid regions of Africa and Asia. The United Nations also specified a few gender characteristics of climate change pointing out that women are affected by the effects of climate change due to their social roles, discrimination, and poverty. They advocated that women should be sufficiently represented in decision-making processes, adaptation, and mitigation strategies on climate change as they are more vulnerable to climate hazards than men. Altogether, the factors that drive gender vulnerability are conflict is context-specific, multi-causal, and multidimensional in approach. However, vulnerability can be turned into resilience by recognizing the capacity of the vulnerable group (women and men) and putting such into consideration when drawing interventions and providing financial or technical support to the group to enhance and utilize such capacities (UNISDR AP, 2013).

2.3. Case Studies of Gender Vulnerability in SSA Region

The key issues of vulnerability to climate change and armed conflicts are the adaptation and coping strategies to shocks and stresses. The extent to which men and women adapt and cope during and after a shock and stress emanating from disasters determines the extent of vulnerability. Climate change causes a change in weather and climate patterns, which in turn, causes a change in temperature and rainfall. The magnitude and frequency of extreme weather cause sea level rise and various associated effects that threaten human existence (CARE, 2014, p.

12). Goh (2012) showed that climate change impacts differently between men and women in developing countries in what he called six “impacts areas”, namely: (i) impacts related to agricultural production, (ii) food security, (iii) health, (iv) water and energy resources, (v) climate-induced migration and conflict, and (vi) climate-related natural disasters. Compared to men, Goh (2012) showed that women are in those impact areas.

Being particular to Africa, the nature of armed conflict and the intensity have significantly changed to new generation threats such as election violence, extremism and terrorism, drug trafficking, maritime piracy, and other criminality (Marc, Verjee, & Mogaka, 2015; Ezeoha, 2015) as well as land-related conflicts (Bob, 2010). Many African countries have been caught in the web of armed conflict, for example, Sudan (Darfur Region), Rwanda, Sierra Leone, DR Congo, Central African Republic, etc since the 1970s (Buchowska, 2016; Obasanjo, 2018).

The causes of these conflicts vary from one country to another. Haider (2014, p.6) noted that conflict has no single cause, instead, it is context-specific, multi-causal, and multidimensional resulting from such factors as:

> *“political and institutional factors - weak state institutions, elite power struggles and political exclusion, breakdown in social contract and corruption, identity politics; socioeconomic factors - inequality, exclusion and marginalization, absence or weakening of social cohesion, poverty; and resource and environmental factors - greed, scarcity of national resources often due to population growth leading to environmental insecurity, unjust resource exploitation.*

A highlight of cases in point of gendered impacts of such armed conflicts in the continent. In Sudan, Brody, et al., (2008) observed as follows:

> *The effects of natural resource conflicts on women and men can be seen in existing conflicts. Take for example the case of Sudan. Both the conflicts between the north and the natural resource-rich south and the conflict in Darfur between nomadic and sedentary tribes are partly a result of quarrels over natural resources. The horrific levels of sexual violence in Darfur, particularly against women and girls, which occur in villages when men and boys are away fighting, in and around refugee and Internally Displaced People (IDP) camps, and outside the camps at times when scarce fuel and water is being collected, provide a stark example of the gendered effects of climate-change-related conflicts.* (p. 9).

In the case of Nigeria, the UN (2017) noted that:

> “*approximately 90 percent of those affected by conflict in northeast Nigeria do not have access to basic services. As a result, women and girls have been forced to exchange sex for food and other essential supplies, and early marriages of girls to older men are on the rise, as an ostensible protection mechanism and source of income for desperate families (p. 43).*

2.4 Recent Developments and Intensity of Gender Vulnerability in SSA

There are several developments in the SSA region in the recent past that show the intensity of gender vulnerability in the region. The increasing number and the dynamics of crises and climate change in the continent have pressured the vulnerability of the inhabitants of the region. The crises have increased and the cases of conflict-related sexual violence in the armed conflict-affected countries are shown in Table 1.

The upsurge in cases of conflicts in Africa induced vulnerability of women and girls. This has specifically caused an increase in violent extremism, mass migration as a result of mass displacement, and trafficking in persons for sexual exploitation. It has further made the perpetrators use the bodies of women and girls as a trading currency in the 'political economy of war'. Though an insignificant number of men and boys are victims of sexual violence, they are used as children soldiers or men in guerrilla warfare. A case in point is the Libyan armed conflict which started in 2011. Daw, El-Bouzedi, and Dau, (2015) provide statistical evidence which shows that a total of 21,490 lives were claimed, while 19,700 persons were injured and 435,000 persons were displaced. Also, cases of conflict-related sexual abuse and forced marriage were recorded in Northern Uganda against the Lord's Resistance Army, Cote d'Ivoire, and Southern Sudan against local and international actors like the UN peacekeeping forces (Kinoti, 2008). Women and girls were abused either in the form of forced marriage which involves not only forced or coerced sex but inclusive of other abuses.

Unfortunately, sexual violence against women is used as a weapon of war in most African countries as reported in the 2018 edition of Thompson Reuters Foundation's World Most Dangerous Countries for Women. The issue of the most dangerous country in the world for women in terms of sexual violence which includes rape as a weapon of war shows six African countries (DR Congo, Congo, South Africa, Somalia, Egypt, and Nigeria) making the list of the ten most dangerous for women in the world in 2018 (Thomson Reuters Foundation, 2018). Apart from South Africa and Egypt where most women suffer other forms of sexual violence such as domestic rape, the other countries which are in one crisis or other are most likely to have suffered gender-based sexual violence (GBSV) as a weapon of war.

The more recent dynamics of gender vulnerability in Africa shifts to gender-based violence (GBV) strategy as adopted by Boko Haram Islamic insurgents. There is a paradigm shift in insurgency strategy and tactical change by terrorist groups in Africa, for example, using girls and women as suicide bombers and boys and men for guerrilla war. The Nigerian Boko Haram is a case in point where 56% of the group's 238 suicide bombing cases between 2011 and 2017 were carried out by girls/women having graduated from learning phase to incremental improvement phase in their bombing strategy (see Warner & Matfess, 2017; and Pearson, 2018). Boko Haram deployed 434 bombers to 247 different targets during 238 suicide-bombing attacks and at least 56% of these bombers were women, (Warner & Matfess, 2017). Lamentably, attacks and abuses that Nigerians would have never thought possible in the country have become commonplace: girls are used as suicide bombers, the reinstitution of "slavery," mass immolation of students in their dormitories, for example, the abduction of 276 Chibok schoolgirls in 2014 and that of 111 Dapchi schoolgirls in February 2018. By and large, women and girls remain exposed to the risk of sexual violence and other crimes. The increase in election violence, extremism and terrorism, and other criminalities that have resulted in conflicts has exacerbated the vulnerability of women and girls in SSA.

2.5 Gender Vulnerability, Climate Change, and Armed Conflict: Theoretical and Empirical Links

2.5.1 Theory of Vulnerability

Martha Fineman in her classical work, *The Vulnerable Subject: Anchoring Equality in the Human Condition* propounded the theory of human vulnerability, in which she sees vulnerability as universal, inevitable, and an aspect of the human condition shared by all. According to Fineman (2008), vulnerability initially should be understood as arising from our embodiment, which carries with it the ever-present possibility of harm, injury, and misfortune from mildly adverse to catastrophically devastating events, whether accidental, intentional or otherwise. The theory is based on a recognition that we are all born defenseless, feeble, and must fear natural disasters (Cooper, 2015). The human condition is subject to continuous vulnerability (Fineman, 2017) because vulnerability is universal, constant, and inherent in the human condition. However, the position of different people "within a web of economic and institutional relationships" differs, the magnitude and the potential of an individual's or group's vulnerability varies too (Fineman 2008, p. 10). Hence, both women and men suffer violent-conflict-related abuses and traumas, disruptions, and loss of resources due to either violence or weather variability, but disproportionately.

Generally speaking, the two significant ways the negative impacts of armed conflict are felt are physically forced displacement (PFD) and gender-based violence (GBV) such as sexual violence and abuse, especially, against women and children. While forced displacement is a consequence of both climate change hazards, GBV is peculiar to only armed conflict. GBV against women can be traced back to WWII (Buchowska, 2016) and is a deliberate systematic weapon of warfare aimed at inflicting torture and humiliating victims to destabilize families and demoralize "enemy" communities (El Jack, 2003; and UN, 2017). Men are not spared from victimization and violence, but women do experience rape and forced pregnancy, forced sex work, and sexual slavery, either in the hands of the fighting men (combatants), aid workers, or other actors in the peace broker process. For instance, cases of forced marriages in Northern Uganda in the hands of the Lord's Resistance Army (Karlson & Mazurana, 2008), and Cote d'Ivoire, Haiti, and Southern Sudan where UN Peacekeepers among other aid workers are implicated as perpetrators of sexual abuse of women and children (Csaky, 2008). Women and children in Africa's conflict zones are often vulnerable to sexual violence (Arieff, 2010; Nordas, 2011).

Notwithstanding, the causes and dynamics of climate change and conflict differ but natural disasters often occur in areas affected by conflict. Kuo, (2016) documents that climate change increases the chances of war in Africa by 11%. In 2011, for example, conflict and drought led to famine in

Somalia. Conflicts, on the other hand, hinder government, and individuals from preparing adequately and responding to disasters emanating from climate change risks. Disasters resulting from climate change or conflict exacerbate impoverishment which can induce some women (not excluding men) to adopt negative coping strategies such as transactional sex that may result in HIV/AIDS and incontinence that are detrimental to the health of the victims. The Foregoing analysis shows that there is an interlink between climate change risk and armed conflict as well as their impacts on men and women. On the gender impact, women suffer more from the impacts of climate change than men due to social and cultural norms (Goh, 2012; UN, 2008). Similarly, the impacts of conflict on men and women are documented, but empirical evidence on gender differential assertion is contextual and nuanced. For example, while the core cause of gender vulnerability in Indonesia is the cultural practices and beliefs and inequality in the society (Yumarni, Amaratunga, & Haigh, 2014), in China, it is the social roles and access to resources and information (UN Women, 2016).

Schroeder's (1987) case study of Hausa households in the Sahel part of Africa shows that women are more vulnerable to climate risk of droughtPlümper and Neumayer (2006) quantitatively estimated the gender-specific effects of armed political conflicts analyzing the health impacts of armed conflicts on men and women. The study specifically focused on the gender gap in life expectancy. The authors showed that men suffered directly the impacts of armed conflicts as combatants or civilians singled out for massacre as the case in Rwanda, but women suffer more indirectly and in the long run on three channels "economic damage effect, the displacement effect, and the sexual violence effect". The sexual violence against women which manifests in the form of sex trafficking (enforced prostitution), rape, forced pregnancy, and sexual slavery is usually higher during the conflicts. Plümper and Neumayer (2006) found that on average, women are more vulnerable to the negative impacts of armed conflict in interstate and civil wars. The effect is more profound in an ethnic-based civil war and a failed state than in nonethnic armed conflict. Armed conflict has different stages which have different impacts on gender vulnerability. Byrne (1996) identified four stages of armed conflict, namely: run-up to conflict (pre-conflict); the conflict itself; peace process (or conflict resolution); reconstruction and reintegration (or post-conflict). The breakdown is not only critical to the impact assessment and gender response mechanism but also makes provision to hypothesize the likely impacts at a given stage on gender dimension (El Jack, 2003).

Gates et al., (2012,) argue that conflict has detrimental effects on the reduction of poverty and hunger, primary education, reduction of child mortality, and access to water. Their empirical evaluation shows that a medium-sized conflict is estimated to increase undernourishment by an additional 3.3%, reduce life expectancy by about 1 year, increase infant mortality by 10%, an additional 1.8% of the population are deprived access to potable water. The study further found a catch-up effect in the economic growth of post-conflict countries. Yumarni, et al., (2014) used both qualitative and quantitative methods in investigating the dimensions of gender vulnerability in a case study of post-earthquake reconstruction in

Indonesia. Their findings show physical, social, and economic factors as the most prominent determinant of the susceptibility of women to post-earthquake crises and they argued that culture and weak institutions are the main causes of gender vulnerability in Indonesia. Similarly, Nordas's (2011) pilot study on conflict-related sexual violence in 20 African countries, made up of 177 armed conflict actors shows that sexual violence is committed mostly indiscriminate, by some conflict actors such as the state armies, in years with low levels of killings and post-conflict time. IFRC (2015) explored the interaction between GBV, natural disaster, and conflict in a country-based study covering nine developing countries comprising Bangladesh, Bosnia-Herzegovina, El Salvador, Haiti, Malawi, Myanmar, Namibia, Romania, and Samoa. The study documents, among other findings, that displacement as a result of conflict can increase the incidence of GBV, and that disasters cause impoverishment that may result in indulging in transactional sex as a coping strategy. From the empirical evidence explored, it is glaring that the attention of authors has been on the nature of the impact of climate change risks and armed conflicts on women and men alike, but the level of their vulnerability to climate risk and conflict is nuance and needs further empirical insight.

3.0 Methodology

3.1 Data

Men and women are vulnerable to climate change and armed conflicts. However, relatively little is known about how that vulnerability differs between men and women, particularly in conflict-prone areas. This analysis focuses on understanding the influence of climate change and armed conflict on gender vulnerability in SSA – girls and women-, using annualized panel dataset that spans from 1997 to 2018. The time frame is influenced by data availability and the consciousness to minimize the number of missing observations. The selected sample consist of thirty-five (35) SSA countries, made-up of Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroun, Cape Verde, Central African Republic, Chad, Comoros, Congo Brazzaville, Democratic Republic of Congo, Cote D'Ivoire, Equatorial Guinea, Gabon, Gambia, Ghana, Kenya, Liberia, Madagascar, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, and Zambia.

The Gender Inequality Index (GII) is adopted as the proxy of gender vulnerability. According to UNDP (2019), GII "measures gender inequalities in three important aspects of girls and women human development—reproductive health, measured by maternal mortality ratio and adolescent birth rates; empowerment, measured by the proportion of parliamentary seats occupied by females and proportion of adult females and males aged 25 years and older with at least some secondary education; and economic status, expressed as labour market participation and measured by labour force participation rate of female and male populations aged 15 years and older". We consider this proxy as appropriate for measuring gender vulnerability because armed conflict and climate change constitute a major barrier to women and girls' reproductive health, empowerment, and economic life than men. GII is sourced from the UNDP database.

Armed conflict is defined in line with Armed Conflict Location and Event Data Project (ACLED) as "political violence on civil and communal conflicts, violence against civilians, militia interactions, rioting and protesting". The use of ACLED data following the tradition of prior authors such as Ezeoha and Ugwu, (2015); Ezoha, et al. (2018); Ujunwa, et al.(2018); and Afangideh, et al. (2018). We estimate armed conflict using the natural logarithm of the total number of fatalities arising from armed conflict. Armed conflict data is sourced from the ACLED database. Measures of climate change applied in empirical literature include relative rainfall (Crost et al., 2018), the intensity of extreme weather events (Berchin et al., 2017), CO2 emissions (Li et al., 2018), and GHG emissions and CO2 sequestration (Sahnoune & Imessad, 2017). We adopted the energy consumption approach, which is reflected in CO2 emissions as a measure of climate change. We take the natural logarithm of climate change and the data is sourced from World Development Indicators (WDI).

To make the findings comparable with previous empirics, we introduced some theoretically important control variables to the baseline model. For instance, Goh (2012) identified other drivers of gender vulnerability as natural capital, human natural capital, physical capital, human capital, financial capital, social capital, and political capital. We introduced natural rent, unemployment rate, population growth, GDP growth rate, exchange rate, and inflation rate, as control variables to capture some of the drivers outlined by Goh (2012).

3.2 Empirical Technique

To estimate the effect of climate change and armed conflict on gender vulnerability, we adopt the system-GMM model (Arellano & Bond, 1991 and Blundell & Bond, 1998). Gender vulnerability is defined as a function of climate change and armed conflict as follows:

GIIi,t=α+i=1jiLGIIi,t+i=1kiCi,ti=1Lixi,t+i=1M mix.xi,t+i,t

GII is the proxy of gender vulnerability, lag order of the series is represented by the sigma sign, while L is the lag operator (with LGIIi,t=GIIi,t-1), Ci,t represents armed conflict, xi,t representsixi,t climate change; and x.xi,t represents vectors of multiplicative and control variables (unemployment, GDP growth rate, population growth, natural rent, inflation rate, and exchange rate) and multiplicative variable (climate change x armed conflict); i, i, i and mi are the respective coefficients of the lagged *GII*, climate change and armed conflict variables, each of the control variables and multiplicative variables; and i,t are the error term and white noise, respectively. i represents the countries (i = 1…,35) and t represents the time periods (t= 1997…2018).

We consider the dynamic panel model more appropriate since previous studies have documented reverse causation among the variables (Fernandino et al., 2018; Sovacool; 2018; Baarsch et al., 2020; and Wang et al., 2020), which implies that static panel models may yield biased and inconsistent estimates. The system-GMM forms the basis of our analysis since the Blundell and Bond (1998) and Bond et al., (2001) approaches favour the system-GMM, over difference-GMM because of the presence of random-walk characteristics in macroeconomic variables.

4.0 Analysis of Empirical Results

4.1 Descriptive Results

Table 2 presents the variables definitions, data sources, and descriptive statistics. The Gender Inequality Index (GII) averaged 0.57 for the period under review, with a standard deviation of 0.58. SSA is the region with the highest GII in the world since the region's average is higher than the global average of 0.46, while Europe has the least GII of 0.29. The mean of climate change is 10093.70, while the standard deviation is18,133.07. The standard deviation of Carbon dioxide (CO2) emission exhibited the highest degree of variability across the variables, which is an indication of varying degrees of Carbon dioxide (CO2) emission in the region. The mean of armed conflict is 520 fatalities while the standard deviation is 3,860, which indicates that the data points are spread out over a large range of values. The mean of real GDP growth and population suggests that population is growing four times faster than output, as SSA economies are growing at 3.25% while the population is growing at 12.88%. This also justifies the inclusion of the variables as control variables, since such economic conditions increases competition for scarce resources, promotes conflicts and inequality. The combined effect of output growth and population would have accounted for the average unemployment rate of 10.46%, a major driver of inequality. Gender inequality is likely to increase in countries with slow growth rates, and high population growth and unemployment rates.

4.2 Static Panel Results

Table 3 presents the static panel results, which serve as the baseline estimation. The static models are Pooled Ordinary Least Square (Pooled OLS), Fixed-Effect (FE), Random-Effect (RE), and Least Square Dummy variable (LSDV) models. The baseline estimates provide strong confirmation for the direct impact of armed conflict and climate change on gender vulnerability in SSA, with the coefficients of armed conflict and climate change appearing positive and statistically significant at a 1% level. We also found the presence of a significant indirect effect of climate change on gender vulnerability using the interactive term. The result is consistent with theoretical projections and the findings of Durrania and Halai (2018), Daw et al., (2015), and Minoiu and Shemyakina (2014).

We found no statistically significant difference across the four static models. This implies, therefore, that in the absence of dynamic assumptions, armed conflict and climate change are direct significant determinants of gender vulnerability in SSA. However, interacting climate change with armed conflicts moderates the impact of climate change on gender vulnerability. This implies that the impact is more direct than indirect. This is to say that climate change could impact directly on gender vulnerability and indirectly through armed conflict, which is consistent with the positions of Gates et al., (2012), Buchowska (2016), and Chaney (2016).

The coefficients of unemployment, output growth, population growth, natural rent, inflation rate, and exchange rate were also positive and statistically significant, thus justifying their inclusion as control variables.

4.3 Difference-GMM results

Extant studies establish reverse causation between gender vulnerability, armed climate, and climate change (Fernandino et al.., 2018; Sovacool; 2018; Baarsch et al., 2020; and Wang et al., 2020). However, the Pooled OLS and FE results could not confirm the dynamic assumption because GII and the independent variables are correlated, and the error term is correlated with some of the vectors and endogenous variables to GII. Thus, the static models yield biased estimates. The results of the difference-GMM reported in Table 4 provide strong confirmation for the dynamic assumption since the coefficients of the lagged gender vulnerability are significant at a 1% level across the four models. The difference-GMM models, One-step and Two-step estimates are consistent with the static model results. The difference-GMM results also revealed that armed conflict and climate change have a positive and significant impact on gender vulnerability and that the impact of climate change is more direct than indirect. The control variables - unemployment, output growth, population growth, natural rent, inflation rate, and exchange rate - also exhibited a positive and statistically significant impact on gender vulnerability.

4.4 System GMM

The choice of the system-GMM over the difference GMM is usually linked to the problem of 'close to a random walk' in the variables. Most studies generally adopt Roodman's (2007) prescription that macroeconomic variables bear the characteristics of random walk (see: Ezeoha et al., 2015; and Ezeoha and Cattaneo, 2012). We departed from this tradition by adopting Blundell and Bond's (1998) and Bond et al (2001) approach to investigate the presence of random-walk in our variables. First, Blundell and Bond (1998) suggest that if the coefficients of the lagged dependent variables of Pooled-OLS and FE results are persistent and close to being random walk (ie., ϕ->1), the application of the difference-GMM yields to bias estimate. We found the presence of random walk characteristics in the variables since the coefficients of the lagged dependent variable (proxy of gender vulnerability) are 0.921 and 0.889 for the Pooled-OLS and FE results, respectively.

Bond et al., (2001) approach further argued that the Pooled-OLS estimate of the lagged dependent variable should be considered an upper-bound estimate, while the corresponding FE estimate should be considered a lower bound estimate, and if the lagged dependent variable of the difference-GMM is above the Pooled-OLS estimate, the result is upward biased and downward biased if close or below the FE estimate.

We found evidence that our variable bears the characteristics of a random walk since the coefficients of the lagged dependent variables derived from difference-GMM estimates for One-Step and Two-Step are below the lower band estimate (see: Table 5). This implies that the difference-GMM estimate is downward biased because of weak instrumentation and the system-GMM is preferred. System-GMM estimator is asymptotically efficient and robust to heteroskedasticity associated with serial correlation and autocorrelation since system-GMM assumes that differences are not correlated with the unobserved country effects (Ezeoha et al., 2015 and Coban and Topcu, 2013; Roodman, 2009a, 2009b; Bond, 2002). We also use Windmeijercorrected cluster robust errors to correct for the presence of cluster correlation.

The results of the system-GMM are reported in Table 6. We presented 5 different models of system-GMM broadly categorized into One-step and Two-step estimators. The difference between the models was explained in the footnote. We adopt model 5 because the post-estimation evidence indicates the absence of bias in the estimates because of the following reason. First, the Two-Step estimator yields a more asymptotically efficient estimate than the One-step estimator. Second, the null hypothesis for AR(1) is rejected and the null hypothesis for AR(2) is not rejected. The Sargan's test and Hansen's J test of over-identification of restrictions are not statistically significant, which implies the validity of the choice instruments. The validity of the instrument is further validated by the number of instruments (27), which is less than the number of selected countries.

Model 5 results of the system-GMM in Table 6 are consistent with the static and difference-GMM models. The results provide evidence of the dynamic assumption of the model with the coefficients of the lag dependent variables close to unitary and statistically significant at a 1% level. The result shows that the coefficients of armed conflict and climate change are positive and statistically significant. An increase in armed conflict by 1% will lead to an increase in gender vulnerability by 7.4%, while a 1% increase in climate change increases gender vulnerability by 14.9%. The coefficient of the interactive variable remained positive and statistically significant as a 1% increase in the interactive term increases gender vulnerability by 5.7%. The lower coefficient of the interactive term is an indication that the impact of climate change on gender vulnerability is more direct than indirect in SSA.

The results of the control variables are equally consistent with theoretical projections, except for real GDP growth, and provide strong justification for their inclusion in the models. We found that a 1% increase in unemployment promotes gender vulnerability by 6.9%, which is largely due to a cultural belief system that might lead to discrimination against girls and women in the workplace. A high rate of unemployment might exacerbate the segregation since employers of labour in SSA may have the incentive to segregate when there is a large pool of job seekers. The results also provide strong evidence that a 1% increase in RGDP growth increases gender vulnerability by 13.3%. This is counter-intuitive to extant theory, however, the findings could be attributed to the structure of SSA economies with non-inclusive growth and a large informal labour market. More importantly, some affluent homes do not encourage girls and women to take up official employment, in addition to the fact most activities of girls and women are not remunerated and not accounted for in the national accounts because they are mostly in the informal sector.

Again, a 1% increase in population growth increases gender vulnerability by 7.5%. This is essential because increasing population increases competition for diminishing resources, employment opportunities and in most cases promotes armed conflicts. Girls and women become the most vulnerable group amid these dynamics. The coefficient of natural rent also provides evidence that re-enforces the resource-curse hypothesis since a 1% increase in natural rent increases gender vulnerability by 6.9%. (evidence of resource-curse theory). The result further provides evidence that inflationary pressure and exchange rate depreciation induces gender vulnerability since we found that a 1% increase in inflation and exchange rate (depreciation) would increase gender inequality by 4.3% and 6.1%, respectively. This could be explained by the import-dependent nature of the economies and exchange rate pass-through to inflation. As prices increases, girls and women are more likely to switch expenditure, which may adversely affect maternal health due to poor nutrition, empowerment due to poor savings, and active labour market participation due to drop out of school or inability to acquire the necessary skills that make them competitive in the labour market.

5.0 Conclusion and Policy Implication

This study is motivated by the increasing incidences of climate change and armed conflict, and the increasing vulnerability of girls and women in SSA, which is now compounded by the impact of the COVID-19 pandemic. The results of the system-GMM estimation confirm the existence of a significant positive direct impact of armed conflict and climate change on gender vulnerability in SSA, which is one of the research objectives. Our second objective is to establish the presence of indirect impact of climate change on gender vulnerability inline the theoretical projection that climate change promotes armed conflict, and armed conflict induces gender vulnerability. The outcome of our analysis also found evidence of the presence of indirect impact of climate change on gender vulnerability when interacting with armed conflict. However, the impact is more direct than indirect, which indicates that climate change could drive gender vulnerability through multiple channels such as loss of livelihood, poverty, widening inequality, increasing dependency rate, among others. The outcome of this study clarifies our understanding of the impact of armed conflict and climate change on gender vulnerability in SSA. This is in addition to resolving the debate on the direct and indirect impact of climate on gender vulnerability.

The findings of the study are extremely important for policy formulation. While effective policy response might be to focus on reversing the trend of climate change, deescalating armed conflicts, and insurgence, it is also important to address other factors identified as drivers of gender vulnerability in SSA. Mainstreaming a mutually beneficial and inclusive economic structure that provides social safety nets for vulnerable girls and women is highlighted as essential. Also, reforming traditional ownership rights that allow women rights to own and inherit properties, investing massively in infrastructure, especially in the rural areas while offering strong protection against rape, violence, child labour, child soldier and child abuse such as the use of women as a shield during war or insurgency; are also crucial. Policy credibility in these directions and firm commitment and sustainability of investment in reversing climate change, deescalating conflict, pro-poor economic policies are extremely critical for stabilizing girls and women from future hazards (Yumarni, et al., 2014) and in achieving sustainable development (UNDP, 2011; UN Women, 2016). By implication, sustained disaster management and sustainable economic reforms together with the provision of sexual and reproductive health services and interventions as post-COVID1-19 measures are strategic to mitigating climate change, resolving conflicts, and promoting economic inclusion in SSA.

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CLIMATE CHANGE AND WATER RESOURCE MANAGEMENT: TREATED MUNICIPAL WASTEWATER REUSE PERCEPTION IN THE FEDERAL CAPITAL CITY OF NIGERIA

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***Abstract*:** If well managed, municipal wastewater can be an alternative source of water supply for agricultural, industrial, and domestic purposes especially at a time when climate change and rising population is exerting so much pressure on available freshwater sources. However, the success of such an idea is largely dependent on the perception and acceptability of reclaimed municipal wastewater by the public. This study examined the perception of the residents of the Federal Capital City of Nigeria towards the acceptability and utilization of municipal wastewater. The results reveal that in general, the people have a positive perception of the use of treated municipal wastewater in the study area. Under the domestic category, respondents had the most positive perception of using treated wastewater to flush toilets (3.57). Dust control during construction (3.59), watering of parks (3.54), fire fighting (3.47), watering of golf courses (3.40), and lawn (3.41) were the top options of choice. For industrial use, the use of treated wastewater for block production, paper mills, and paint production were tops with 3.5, 3.41, and 3.39 respectively. Commercial car wash with a mean of 3.32 topped commercial use of treated municipal wastewater. The respondents also consented to use treated municipal wastewater to improve agriculture. However, analysis between the groups showed that the positive perception is more inclined to outdoor use and industrial use. The result showed respondents had the least positive perception of domestic use and commercial use of treated municipal wastewater. Meanwhile, they rejected that treated municipal wastewater should be used to boost water supply in the FCT. Wastewater reuse is becoming imperative. The effluent discharge will be resourceful in improving agriculture and for industrial use as more respondents have no objection to its application in agriculture and industry. Wastewater reuse should be considered as an alternative source for non-potable water use whenever there is a case of water crisis or as a means to the prevention of water stress in the study area and Nigeria at large. Public knowledge and acceptance are crucial in wastewater reuse, as such, whenever a reuse programme is to be implemented, public consultation and confidence-building should be embarked on.

Keywords: Municipal Wastewater, Treated Wastewater Reuse, Wastewater Reuse Perception, Wastewater Reuse Options.

INTRODUCTION

Wastewater is any water that has been adversely affected in quality by anthropogenic influence (Chukwu, and Oranu, 2018). Iheukwumere et al (2019) defined wastewater as water that has been altered chemically, physically, or biologically and as a result, is no longer needed or useable (disposed or about to be disposed). Municipal wastewater is wastewater which origin is from a metropolitan or urban area. Municipal wastewater generally is known to contain either physical, biological, or chemical contaminants which render it harmful or unfit for human consumption or agricultural and industrial applications. However, wastewater can be an important resource when properly managed (Iheukwumere, Nwabudike, Nkwocha, and Phil-Eze, 2019).

In the late 19th century large and advanced cities realized that they had to reduce the number of pollutants they were discharging into the environment via the discharge of untreated wastewater. Wastewater treatment then emerged to remove contaminants and render them less harmful to the environment. Over time, the need for freshwater management arising from issues including climate change and scarcity gave rise to the treatment of wastewater for reuse purposes. Current technology allows municipal wastewater treatment systems to produce effluent that satisfies various regulations at a competitive cost; thus it may be possible to utilize treated wastewater as an alternative water supply (Ma, 2003). Population growth and climate change are two factors that at the moment has led to water stress and water supply deficit, not just for domestic purpose but as well as for agricultural and industrial uses.

In arid and semi-arid areas of Nigeria rainfall is experienced for less than four months throughout the year. The short duration of rainfall makes rainwater harvesting unattractive, coupled with the high evaporation rate in the region caused by intense and prolonged solar radiation. Also, agriculture which is a primary occupation in most rural communities in Nigeria is chiefly small-scale operations that rely on rain for production. On the other hand, large-scale agricultural operations which involve irrigation, impact heavily on the availability of freshwater resources for potable use. Such water stress with the possibility of high quality of treated effluent has made treated municipal wastewater an option to be explored mostly for agricultural purposes as well as industrial and domestic purposes.

Unfortunately, the systems for the management and useful integration of treated municipal wastewater into the urban water cycle are grossly neglected or lacking in Nigerian cities. Adesogan (2013) revealed the abysmal lack of wastewater treatment facilities in Nigerian cities, which would be a clog in the sustainable use of treated wastewater in combating population pressure on freshwater. Municipal wastewater reuse is practiced in a lot of countries as exhibited by the works of Adewumi, and Oguntuase (2016). However, there seems to be a dichotomy in the acceptability of treated municipal wastewater.

Ma (2003) assessed public attitude towards wastewater and discovered that respondents were positive to applications not involving close personal contact (such as fire fighting, car washing, lawn irrigation, and agricultural uses), while uses of wastewater for possible consumption (released into potable surface supply or groundwater supplies) or applications involving close personal contact (laundry) were unfavourable.

Lamnisos, Anastasiou, Grafias, Panayi, Larkou, Georgiou, and Middleton (2013) investigated public awareness, attitudes, and health risk perceptions of water reuse among the general public in Cyprus using a questionnaire-type survey of 800 participants. As many as half of the participants did not know where recycled water comes from, 35% were unaware of the existence of treatment plants while the vast majority did not declare certainly or know if they have ever consumed products produced with recycled water. While as many as half are unsure whether to agree that coming to contact with recycled water can be harmful to health, a large majority accept recycled water for landscape irrigation and report that they would visit parks or send their children to a school that practices it. Acceptance drops sharply to 58% for crop irrigation and as many as 70% agree or are unsure whether consuming fruit and vegetables produced with recycled water can cause disease and 90% believe that products produced with recycled water should be labeled. Only 20% believe that there is adequate quality control, paralleling the fact that only 30% trust the authorities.

A comparative analysis by Dolnicar and Schafer (2009) on knowledge, perceptions, and acceptability of wastewater reuse was carried out in Australia. This was to determine segments of residents who are more open-minded than the general population toward the use of recycled and desalinated water. Their findings revealed that the Australian population once perceived desalinated water as environmentally unfriendly, and recycled water as a public health hazard. The general level of knowledge about these two concepts as potential water sources has historically been low. After nearly five years of serious drought, accompanied by severe water restrictions across most of the country, and subsequent media attention on solutions to water scarcity, Australians now show more acceptance of desalinated water for close-to-body uses, and less resistance to recycled water for garden watering and cleaning uses.

Chen, Bai, Zhang, Lyu, and Jiao (2015) undertook a study on the attitudes of the stakeholders who are involved in reclaimed water reuse in Beijing, China. Results showed that the general public's knowledge of water resources was poor, while their awareness of reclaimed water reuse was high. The general public showed a strong acceptance of non-contact and non-potable reclaimed water reuse, but their acceptance of the three major water reuse types of river water supplement, park water supplement, and agriculture irrigation was not high. The beneficial use of reclaimed water was admired by water resource managers, industrial sectors, and researchers, and these stakeholders strongly supported the advancement of reclaimed water reuse. However, some of the stakeholders showed concerns about the potential risks from reclaimed wastewater reuse.

Alhumoud and Madzikanda's (2010) research result shows that the overwhelming majority of the respondents (77.91 percent) objected to using reclaimed water for drinking and only 16.83 percent said they might consider drinking it. The majority of respondents (75.28 percent, 66.80 percent, and 55.60 percent) did not object to using the reclaimed water for agricultural irrigation, car-washing, and house washing respectively. In addition, the research result of Alhumoud and Madzikanda (2010) shows that most of the respondents, even the ones that possessed enough knowledge about wastewater reuse, strongly opposed using reclaimed wastewater for human use (showering/bathing - 60.03 percent, clothes washing - 52.40 percent and cooking - 78 percent), regardless of its quality and cost.

Despite the accruing advantages of municipal wastewater reuse on climate change impacted water resources, public acceptance is key to any wastewater reuse scheme. Dolnicar and Schafer (2009) reiterated that many countries' water resources are limited in both quantity and quality. While measures are being taken to ameliorate this problem through engineering solutions from wastewater recycling and desalinating water from non-potable sources at a relatively low cost, the general public is skeptical about adopting these alternative water sources.

The federal capital city of Nigeria, known as Abuja is one of the few Nigerian cities with a functional wastewater treatment facility. The city has experienced a heavy upsurge in population between the years 1990 to 2020, this has placed enormous stress on water supply facilities. The city also lies in what could be called the transition zone of northern (arid and semi-arid) and southern (tropical monsoon) climates. The northern region of the country is not adverse to water scarcity and is therefore necessary that steps are taken to combat the issue of negative impact on freshwater resources in the light of sustainability. It is on this premise that this research set out to study the acceptability of treated municipal wastewater reuse in the FCT.

Materials and Method

Study Area

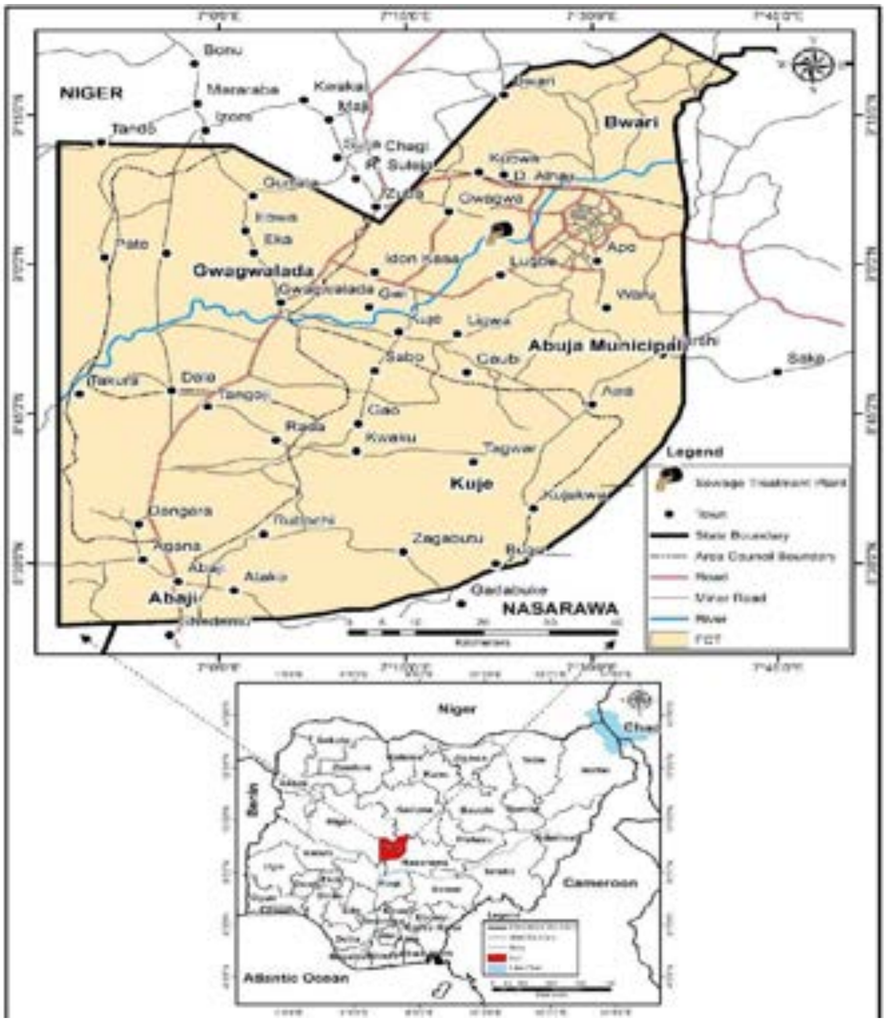

Figure 1: Federal Capital Territory Abuja
Source: Audu (2016)

The Federal Capital City of Nigeria, known as Abuja was created in 1976 after a committee on the location of the Federal Capital of Nigeria carried out an extensive examination of the dual government role of Lagos, its suitability as a National Capital, and the possibility of an alternative new capital city elsewhere in the country accessible to all and spacious (Oluwabadamisi, 2013). Its inception was planned in phases according to the regional master plan prepared by Doxiadis Associates Ltd in a joint venture with Wallace, Roberts, and Todd (WRT) (Abubakar, 2014). Abuja is located on Latitudes 8°21′N to 9°18′N and longitude 6°46′E to 7°37′E. Abuja has a total landmass of about 8000km². Abuja is bounded in the east by Nasarawa State, north by Kaduna State, west by Niger State, and south by Kogi State. The city is divided into six area councils which are Abuja Municipal, Gwagwalada, Kuje, Abaji, Kwali, and Bwari Area Councils. Amoo, et al (2017) revealed that the Abuja Master Plan is projected to cater to 3.1 million people in the land of about 8,000 square kilometers when fully developed.

The city experiences two seasons, the rainy and dry seasons which begin from April to October and from November to March respectively. The area records its highest temperature of about 34 °C during the dry season, during the rainy season the maximum temperature drops to about 24°C (Dan-Hassan, Olasehinde, Amadi, Yisa, and Jacob, 2012). The annual total rainfall is in the range of 1100mm to 1600mm (Dan-Hassan et al, 2012).

The soils of Abuja are Alluvial and Luvisols, which support the growth of tree species such as *Khaya spp., Azadirachta indica, and Gmelina arborea* (Agbelade, Onyekwelu, and Oyun, 2017). The soils of the capital city are also said to be shallow and sandy making them highly erodible. Soils on the Gwagwa plain are however deep and clayey thus fertile and productive (https://www.nigeriaonline.com/abuja). The indigenous people of Abuja are originally known to be farmers and hunters. The fertile soils of the area have supported the cultivation of crops such as Yam, Maize, Millet, Sorghum, Plantain, and Banana. With adequate treatment of municipal wastewater and a well-integrated system of Urban Water Cycle, treated effluent can be used amongst other things for agricultural irrigation and specific industrial purposes.

Research Design

The data for the study were compiled and presented in frequency tables and percentages for easy understanding and interpretation. The researcher distributed a total of six hundred (600) copies of a well-structured questionnaire. Out of the 600 copies of the questionnaire distributed, four hundred and ninety-two (492) copies representing 82% were correctly filled and returned. The returned copies of the questionnaire were collated and analyzed using appropriate statistical tools: descriptive statistics such as simple percentages and proportions, frequency tables and charts, weighted mean, and standard deviations.

Result and Discussion

Socio-Demographic Characteristics of the Respondents

The socio-demographic characteristics captured by the researcher include the respondent's gender, age group (or range), level of education, occupation, and years of residence in the study area.

Table 1 ***Sex Distribution of the Respondents***

Sex	Frequency	Percentage
Male	222	45.1%
Female	270	54.9%
Total	**492**	**100.0%**

Source: Author's Field survey result

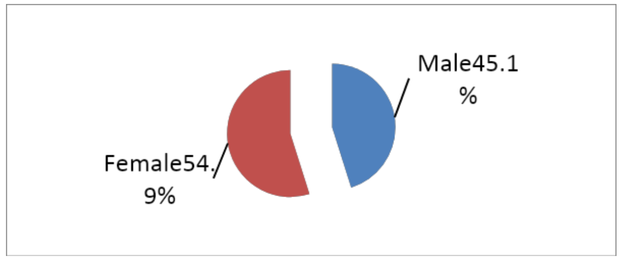

Fig. 2: Pie chart of the gender distribution of the respondents
Source: Author's Field survey result

The frequency distribution of the gender of the respondents shows an almost equitable percentage of gender representation. Particularly, the females are slightly higher (54.9%) compared to the male counterpart (45.1%). Fig. 1 is a graphical representation.

Table 2 ***Age Range of the Respondents***

Age group	Frequency	Percentage
15-19yrs	12	2.4%
20-24yrs	96	19.5%
25-29yrs	108	22.0%
30-34yrs	108	22.0%
35-39yrs	96	19.5%
40-44yrs	48	9.8%
45-49yrs	11	2.2%
≥50yrs	13	2.6%
Total	**492**	**100.0%**

Source: Author's Field survey result

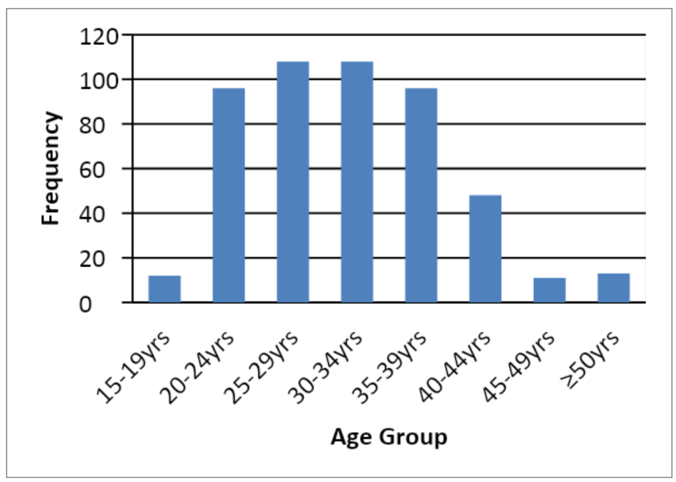

Fig. 3: Bar chart of the Age range of the Respondents
Source: Author's Field survey result

The frequency distribution result shows that the majority (44.0%) of the respondents are within the age group of 25-34years. 19.5% are of ages 20-24years and 35-39years respectively. About 2.4% of the total respondents are of age group 15-19 years; 2.2% are between 45-49 years while only about 2.6% of fifty years and above. A clearer view is presented in **figure 3**.

Table 3 ***Educational Attainment of the Respondents***

Education	Frequency	%age
No formal education	24	4.9%
FSLC	0	0.0%
SSCE	48	9.8%
Diploma/NCE	36	7.3%
B.Sc.	312	63.4%
PGD	5	1.0%
M.Sc.	62	12.6%
Ph.D.	5	1.0%
Total	**492**	**100.0%**

Source: Author's Field survey result

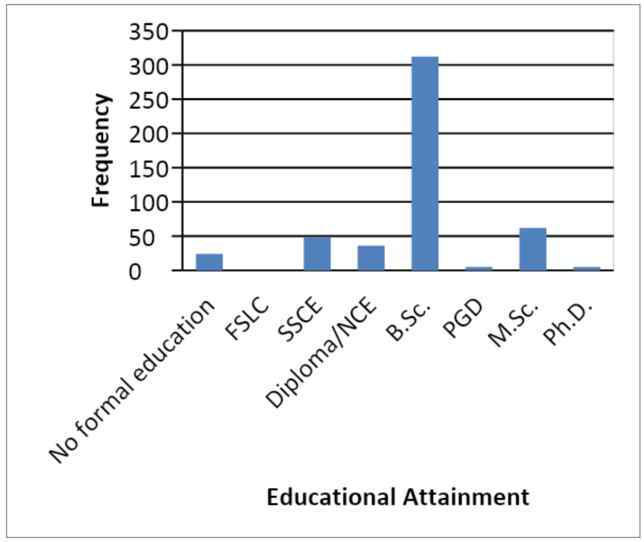

Fig. 4: Bar chart of Educational Attainment of the Respondents
Source: Author's Field survey result

The distribution of educational qualifications of the respondents are shown in Table 3 shows that about 63.4% of the total respondents are B.Sc. holders, 12.6% are M.Sc. holders, 9.8% are SSCE holders, 7.3% are Diploma/NCE holders, 1.0% each have PGD and Ph.D. respectively, while only about 4.9% have no formal education. A graphical representation is shown in **figure 4**.

Table 4 ***Occupation of the Respondents***

Occupation	Frequency	Percentage
Student	101	20.5%
Artisan	0	0.0%
Trader/Business	60	12.2%
Civil servant	228	46.3%
Private	48	9.8%
Corper	19	3.9%
Others	36	7.3%
Total	**492**	**100.0%**

Source: Author's Field survey result

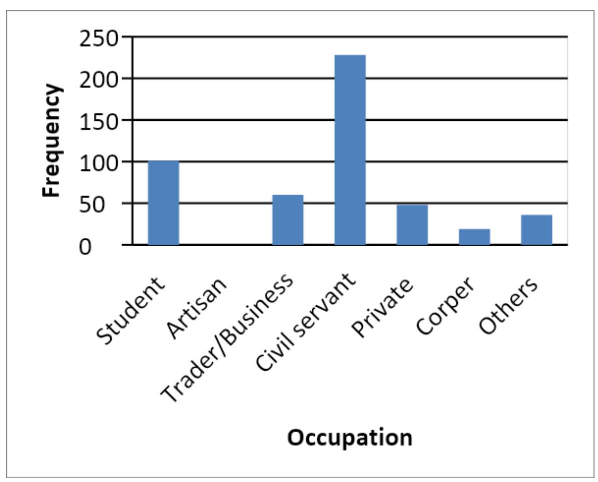

Fig. 5*:* Bar chart of Occupation of the Respondents
Source: Author's Field survey result

The occupational distribution of the respondents revealed that a total of 228 representing 46.3% of the total respondents are Civil Servants, 101(20.5%) are Students, 60(12.2%) are Traders/businessmen and women, 48(9.8%) are Self-employed, 19(3.9%) are Corpers, while 36(7.3%) are into other employment sections/engagements not mentioned in this study. See **figure 5** for more clarification.

Table 5 ***Respondents' Resident Years in FCT***

Years of Resident	Frequency	Percentage
1-3yrs	138	28.0%
4-6yrs	42	8.5%
7-9yrs	66	13.4%
10yrs and above	246	50.0%
Total	**492**	**100.0%**

Source: Author's Field survey result

The distribution of years of residents of the respondents shows that the majority (50.0%) have lived in the area for 10years and above. 138(28.0%) have lived in the area for 1-3years, 66(13.4%) have stayed in the area for 7-9years, while 42(8.5%) have lived in the area for 4-6years. The implication is that the respondents have stayed for a long time in the area; however, the information provided by them can be highly relied upon.

Table 6 ***Respondents' awareness of the existence of wastewater treatment plant in FCT***

Aware	Frequency	Percentage
Yes	294	59.8%
No	198	40.2%
Total	**492**	**100.0%**

Source: Author's Field survey result

The respondents' level of awareness of the existence of wastewater treatment plants in FCT cannot be boldly ticked 'yes' as about 59.8% are aware while 40.2% are not.

Table 7 ***Respondents' awareness of treated municipal wastewater reuse***

Aware	Frequency	Percentage
Yes	246	50.0%
No	246	50.0%
Total	**492**	**100.0%**

Source: Author's Field survey result

Table 7 shows that the proportion of those who are aware of treated municipal wastewater reuse is equal to the proportion of those who are not aware (50.0% each).

4.2 Data Analysis

4.2.1 Public perception on utilization of treated municipal wastewater in the FCT

Table 8a Respondents' perception on utilization of treated municipal wastewater in the FCT

QUESTION ITEMS	SA	A	D	SD	Mean	Perception
DOMESTIC USE						
Treated municipal wastewater should be used for drinking purpose	30	192	144	126	2.26	Negative
Treated municipal wastewater can be safely used for bathing	168	216	72	36	3.05	Positive
Treated municipal wastewater should be used for house cleaning	225	243	10	10	3.40	Positive
Treated municipal wastewater should be used in flushing toilets	325	134	23	11	3.57	Positive
Treated municipal wastewater can be safely used in cooking food	60	240	132	60	2.61	Positive
Treated municipal wastewater can be safely used for utensil/plate washing	95	300	73	24	2.95	Positive
Treated municipal wastewater can be safely used for laundry	204	252	12	12	3.35	Positive
OUTDOOR USE						
Treated municipal wastewater should be used for watering golf courses in the FCT	265	168	48	11	3.40	Positive
Treated municipal wastewater can be used for watering Parks in the FCT.	300	132	23	13	3.54	Positive
Treated municipal wastewater should be used for watering the lawn	276	168	24	24	3.41	Positive
Treated municipal wastewater can be safely used for vehicle washing	252	156	36	29	3.33	Positive
Treated municipal wastewater can be safely used in swimming pools	103	170	154	65	2.63	Positive
Treated municipal wastewater can be safely used for fire fighting	300	137	23	25	3.47	Positive
Water fountains in the FCT should make use of treated municipal wastewater.	168	240	48	12	3.21	Positive
Treated municipal wastewater can be used for dust control during road and other kinds of construction	348	96	36	12	3.59	Positive
Street cleaning requiring water should involve treated municipal wastewater	288	110	60	24	3.37	Positive
INDUSTRIAL USE						
Treated municipal wastewater should be used for cooling of machines in industries	276	144	48	24	3.37	Positive

Paint making industries in the FCT should make use of treated municipal wastewater for Paint production	264	168	48	12	3.39	Positive
Paper mills in the FCT should employ the use of treated municipal wastewater	276	156	48	12	3.41	Positive
Treated municipal wastewater should be used for construction block production	337	96	59	0	3.57	Positive
Detergent and soap making industries in the FCT should make use of treated municipal wastewater for the production	185	233	72	0	3.23	Positive
Food and pharmaceutical companies can use treated municipal wastewater as an alternative source of water	100	125	144	123	2.41	Negative
Treated municipal wastewater will be a better option for the production of plastic products	172	265	35	12	3.23	Positive
Treated municipal wastewater should be used for the production of insecticides, pesticides, herbicides, and other chemicals	204	228	38	10	3.30	Positive
Production of the textile, tie and dying activities should make use of treated municipal wastewater	228	192	48	17	3.30	Positive
COMMERCIAL USE						
Treated municipal wastewater should be used in hotels	48	216	144	84	2.46	Negative
Treated municipal wastewater should be used in commercial car wash centers	228	216	27	21	3.32	Positive
Treated municipal wastewater should be used in commercial laundry centers	204	228	24	36	3.22	Positive

Source: Field Survey 2019

The result in table 8a shows the respondents' perception of the utilization of treated municipal wastewater in the FCT. From the result, the respondents have a positive perception of the domestic use of treated municipal wastewater in the FCT. They specifically agreed that treated municipal wastewater can be safely used for bathing, house cleaning, flushing toilets, cooking food, utensil/plate washing, and laundry (with strata means >2.50). Meanwhile, they have a negative perception that treated municipal wastewater can be used for drinking purposes (with strata means <2.50).

On the outdoor use, the respondents were of the full positive view that treated municipal wastewater should be considered for outdoor usages, including: for watering golf courses in the FCT, for watering Parks in the FCT, for watering lawn, for vehicle washing in swimming pools, for fire fighting and water fountains, for dust control during road and other kinds of construction, and for street cleaning (with strata means >2.50).

On the industrial usage, the respondents' nod in agreement that: treated municipal wastewater should be used for cooling of machines in industries (mean=3.37>2.50), Paint manufacturing industries in FCT should make use of treated municipal wastewater for Paint production (mean=3.39>2.50), Paper mills in the FCT should employ the use of treated municipal wastewater (mean=3.41>2.50), Treated municipal wastewater should be used for construction block production (mean=3.57>2.50), Detergent and soap making industries in the FCT should make use of treated municipal wastewater for production (mean=3.23>2.50), Treated municipal wastewater will be a better option for the production of plastic products (mean=3.23>2.50), Treated municipal wastewater should be used for the production of insecticides, pesticides, herbicides and other chemicals (mean=3.30>2.50), and that Production of textile, tie and dying activities should make use of treated municipal wastewater (mean=3.30>2.50). Meanwhile, they disagreed that Food and pharmaceutical companies can use treated municipal wastewater as an alternative source of water (mean=2.41<2.50).

On the commercial use, the respondents opined that: Treated municipal wastewater should be used in commercial car wash centers (mean=3.32>2.50), and in commercial laundry centers (mean=3.22>2.50), and thus disagrees that treated municipal wastewater should be used in hotels (mean=2.46<2.50).

In general, the people have a positive perception of the use of treated municipal wastewater in the FCT (cluster mean = 3.17>2.50, 95% C. I. = 2.63‾3.98). This evidence is statistically significant (t* = 10.387, p=0.000<0.05). Under the domestic category, respondents had the most positive perception of using treated wastewater to flush toilets (3.57). Dust control during construction (3.59), watering of parks (3.54), fire fighting (3.47), watering of golf courses (3.40), and lawn (3.41) were the top options of choice. For industrial use of treated wastewater for block production, paper mills and paint production were tops with 3.5, 3.41, and 3.39 respectively. Commercial car wash with a mean of 3.32 topped commercial use of treated municipal wastewater. However, analysis between the groups showed that the positive perception is more inclined to outdoor use and industrial use (Group means = 3.33 and 3.25 respectively). The result showed respondents had the least positive perception of domestic use (Group means = 3.03) and commercial use (Group means = 3.0) of treated municipal wastewater.

These results are in line with the findings of the study conducted in South Africa by Bungu (2014) that the majority of respondents are willing to use treated wastewater for industry use (80%), fire fighting (86.8%), washing cars (73.5%), watering lawns and golf courses (80.2%) and flushing toilets (82.8%). The acceptance levels decrease as the human contact increases; this is seen by the decrease in acceptance levels of the following options: watering vegetable gardens (65.6%), washing clothes (60%), swimming pools (42.2%), cooking food (28.3%) and drinking (28%) as reported by Bungu (2014). Robinson *et al*., (2005); Hartley, (2006), and Bungu (2014) states that public acceptance of water reuse is higher when the degree of human contact is minimal. This is also evident in the work of Alhumoud and Madzikanda (2010). Regardless of its quality and cost Alhumoud and Madzikanda (2010) stated that respondents opposed human use of treated municipal wastewater.

Table 8b: OTHERS

	SA	A	D	SD	Mean	Inference
Treated municipal wastewater should be used to boost the water supply in the FCT.	19	101	192	156	1.96	Reject
Treated municipal wastewater should be pumped into the ground.	37	143	252	36	2.39	Reject
Treated municipal wastewater should be discharged into streams and Rivers.	140	148	156	48	2.77	Accept
Treated municipal wastewater should be used for all purposes.	45	171	144	132	2.26	Reject

Source: Author’s field survey, 2019.

In a wider sense, the respondents accepted that treated municipal wastewater should be discharged into streams and Rivers (mean = 2.77>2.50). Meanwhile, they rejected that treated municipal wastewater should be used to boost water supply in the FCT (mean = 1.96<2.50), that treated municipal wastewater should be pumped into the ground (mean = 2.39<2.50), and that treated municipal wastewater should be used for all purposes (mean = 2.26<2.50) (see table 8b). This rejection despite the positive perception underscores the fact that respondents will prefer to use treated wastewater by choice rather than integrating it into the urban water supply system without general knowledge and acceptance. The respondents rejected that the treated wastewater be used for all-purpose. Rather accepted discharging the treated municipal wastewater into the river from which extractions can be made by those who intend to utilize it. Respondents are mindful of the standard of treatment, as such a low level of treatment will affect the use of treated municipal wastewater.

Wastewater reuse has been identified worldwide as a viable option to augment water supplies. While technologies are available to ensure proper treatment of wastewater to even potable standards, many countries have experienced public resistance to wastewater reuse due to negative perceptions of consumers. For wastewater reuse initiatives to be successful public acceptance is imperative.

4.2.2 Perception on the patronage of agricultural products irrigated from treated municipal wastewater

Table 9 Respondents’ perception of the patronage of agricultural products irrigated from treated municipal wastewater.

AGRICULTURAL USE	SA	A	D	SD	Mean	Perception
Treated municipal wastewater can be used to improve crop production in the FCT.	240	192	47	13	3.34	Positive
Treated municipal wastewater can be used for watering personal farm crops/gardens.	228	192	48	24	3.27	Positive

Treated municipal wastewater should be used for irrigation of large-scale plantations in the FCT.	264	180	37	11	3.42	Positive
Crops irrigated with treated municipal wastewater will be highly patronized by residents of FCT.	127	138	109	118	2.56	Positive
Treated municipal wastewater should be used for animal rearing and aquaculture in the FCT.	109	203	124	56	2.74	Positive
Cluster result	**39.3%**	**36.8%**	**14.8%**	**9.0%**	**3.07**	**Positive**

Source: Field Survey 2019

From the survey result in table 9, about 39.3% of the total respondents strongly agreed to the positive agricultural use of treated municipal wastewater in FCT, 36.8% submitted to ordinary agree, 14.8% disagreed while 9.0% disagreed. The positive perception of the respondents was ascertained to be statistically strong ($t^* = 3.256$, $p=0.031<0.05$).

The respondents' consent that treated municipal wastewater should be used to improve crop production in the FCT (mean=3.34>2.50), for watering personal farm crops/gardens (mean=3.27>2.50), for irrigation of large scale plantations in the FCT (mean=3.42>2.50), for animal rearing and aquaculture in the FCT (mean=2.74>2.50), and that crops irrigated with treated municipal wastewater will be patronized by residents of FCT (mean=2.56>2.50). Alhumoud and Madzikanda's (2010) research result showed that the majority of their respondents in Kuwait did not object to using reclaimed water for agricultural irrigation. In contrast, Kantanoleon, Zampetakis, and Manios (2006) revealed that respondents had negative perceptions and objected to using treated municipal wastewater for food-related applications like animal rearing, crops, and greenhouse vegetable cultivations.

Mcheik, Toufaily, Hassan, Hamieh, Abi Saab, Rouphael, Ferracin, Berardo da shio, and Al Hadidi (2017), presented results of scenarios where secondary-treated municipal wastewater was used for table grapes irrigation in the region of Ablah, Bekaa valley in Lebanon, and fodder crops irrigation (vetch and barley) in the region of Ramtha in Jordan. Based on the production and quality components, table grapes were successfully grown on plots that are supplied with treated wastewater. Fodder crops were successfully grown using treated wastewater with a remarkable increase in biomass and grained yield production for the irrigated treatments. Aiello, Cirelli, Consoli, Giuffrida, Leonardi, and Licciardello (2012) evaluated the long-term effects of treated wastewater reuse on crops intended for human consumption. The levels of faecal contamination of eggplants and tomatoes irrigated by surface and subsurface drip irrigation with urban treated wastewater were analyzed and compared in 2008 and 2009 at

the experiment site (in Eastern Sicily, Italy). The study found that Salmonella and helminth eggs were never detected in treated wastewater or on fruit samples. Only two eggplant samples, irrigated by surface drip irrigation, contained 102 CFU/100 g of faecal coliform and faecal streptococci. Based on the production and quality components, the tomato crops were successfully grown on treated wastewater supplied plots, with higher yields (approximately 20%) than on plots supplied with fresh water.
The analysis of the reuse scenarios confirms that under controlled conditions, treated wastewater can be used as an additional water resource to increase agricultural production in water-scarce environments without health or environmental effects.

Conclusion
Lamnisos, et al (2013) stated that wastewater reuse is becoming imperative in water-scarce regions, in addition to evaluation of the extent of potential health risks involved, an assessment of public acceptance is necessary for a sustainable water reuse scheme to be successful. It is recommended that effluent discharge will be resourceful in improving agriculture and for industrial use in the study area. Hence, it should be channeled for that purpose as more respondents have no objection to its application in agriculture (including urban greening) and industry. Wastewater reuse should be considered as an alternative source for non-potable water use whenever there is a case of water crisis or as a means to the prevention of water stress in the study area and Nigeria at large. Public knowledge and acceptance are crucial in wastewater reuse, as such, whenever a reuse programme is to be implemented, public consultation and confidence-building should be embarked on.

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ASSESSMENT OF CLIMATE CHANGE AWARENESS AND SUSTAINABLE DEVELOPMENT IN RWANDA

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***Abstract**:* Climate action is a key Sustainable Development Goal (SDG 13) which also underpins other SDGs since climate action facilitates clean energy access, sustainable agriculture, clean water and sanitation, health and well-being, gender equality, and other related SDG objectives. This study assessed climate change awareness on sustainable development in Rwanda. A total number of 1003 filled questionnaires were collected from all provinces across Rwanda through online and offline means using the multistage sampling method. Descriptive statistics were used to analyze the data. Person's correlation was used to examine the relationship between climate change awareness and sustainable development in Rwanda. The result of a person's correlation between climate change awareness and sustainable development is 0.89. The null hypotheses were tested using a one-sample t-test. The hypothesis was rejected for the fact that in the result of 1 sample, the t-test is greater than the p-value, the mean value is greater than zero and the lower and upper interval of confidence is greater than 5%. Six climate change mitigation strategies were presented but in the respondent's opinion, a decrease of greenhouse gas emission with 32.8% has the biggest share of the distribution while protection of biodiversity with 6.48% has the least share of distribution. Based on the findings, the best approach to mitigate climate change in Rwanda includes: increasing the use of renewable energy sources to abate emissions, an increase of awareness of climate change causes and effects particularly concerning the management of biodiversity, and mobilization of citizens.

***Keywords**: Climate Change, Awareness, Sustainable Development, Mitigation, Rwanda*.

1. INTRODUCTION

Climate action is a key sustainable development goal (SDG13) which also underpins other SDGs since climate action facilitates clean energy, sustainable agriculture, clean water, sanitation, health and wellbeing, gender equality, and other related SDG objectives. Climate change is one of the most persistent challenges confronting the world today (Pachauri & Reisinger, 2007). It has a lot of implications for both human survival and natural systems (Valliammai, 2015).

In response to the impact and possible effects of climate change, national, supranational, as well as local initiatives are being developed and implemented to limit and mitigate greenhouse gases concentration in the earth's atmosphere (Raghuvanshi, et al 2008). According to the definition adopted by the Intergovernmental Panel on Climate Change (IPCC), "climate change" refers to any significant changes in global temperature, precipitation, wind patterns, and other measures of climate that occur over several decades or longer.

Studies have shown that the burden of the adverse effects of climate change is mostly borne by poor and low-income communities; especially women and children because they have much higher levels of vulnerability to climate change impacts (Khan, 2012). Impacts of climate change include an increase in global temperature, melting of snow and ice caps in the northern hemisphere, rising sea levels, more frequent extreme weather conditions - storms and heavy rains, droughts, floods, and hurricanes (Khan, 2012). All these impacts are mostly attributable to anthropogenic activities such as burning fossil fuel energy and other sectors which release carbon dioxide, (Fulton, 2017).

The impact of these adverse climate changes on the socio-economic life of the people is exacerbated by the lack of adapting strategies, which are increasingly limited due to the lack of institutional, economic, and financial capacity to support such actions. A good percentage of the population of Rwanda is not aware of the causes and effects of climate change. Climate change affects everyone, but those without other sources of income, and dependent only on land, water, and forests for their livelihoods and to meet domestic energy needs are relatively more affected by climatic change and environmental degradation (Women, 2015).

The impacts of climate change in Rwanda present increasing challenges like extreme weather conditions ranging from changing precipitation patterns, flooding, and other different disasters that occur as a result of climate change (Bimenyimana, et al, 2018). As reported by National Environment and Climate Change Policy (2019), Rwanda was considered as one of the world's lowest per capita emitters of greenhouse gases, but the country is highly vulnerable to the impacts of climate change - heavy rainfall, flooding, landslides, cropland damage, and famine.

Poor air quality is considered one of the country's largest environmental health risks because, in Rwanda, 2,227 deaths were attributed to ambient air pollution in 2016. Different climate change impacts in Rwanda, between 1980 and 2017 are reported to have affected more than two million people due to flooding - some were killed, injured, or rendered homeless (Nahayo, et al 2019). And more than 15,000 hectares of cropland and 23,000 houses were destroyed. This impact of climate change also affects the approaches of sustainable development in the country as findings showed that the total economic loss due to flooding in Rwanda is about 1.4% of the overall Gross Domestic Product (GDP) of the 2014/2015 fiscal year (Harerimana et al, 2016).

Another report by Rwanda Environmental Management Authority (2015) indicates that pollution remains a critical and growing challenge that needs policy considerations. The concept of sustainable development was first discussed at the United Nations Conference on the Human Environment in Stockholm in 1972. In 1987, the Bruntland Commission published its report - Our Common Future -, and in an attempt to show the interconnection between economic development and environmental stability, they define sustainable development as" development that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations General Assembly, 1987).

Environmental and Development (Brundtland) Commission was formed to address the growing concern about climate change, especially concerning the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development.

In June 1992, the first United Nations Conference on Environment and Development was held. The event marked a very important landmark in the history of sustainable development and concern for the environment. As efforts to address the various impacts of climate change at various levels continue, this work aims to assess the level of citizens' awareness, as well as their understanding of climate change and sustainable development in a bid to propose ways of addressing different climate change impacts that can hinder the attainment of sustainable development in Rwanda.

2. LITERATURE REVIEW

Existing literature on climate change awareness and sustainable development was reviewed to establish a knowledge gap, and also to provide support for the methodology that was used in this work. They also served as sources of information for comparison and reference. Donatella et al, 2020 conducted research on Climate change awareness: Empirical evidence for the European Union. They found that climate change attitudes have involved various socio-economic and climatological factors. In particular, they found that environmental awareness is directly related to per capita income. Chun Kung et al (2018) worked on Sustainable energy development under climate change in China.

In their work, a broad array of papers in the areas of bioenergy, wind power, industrial innovation, and climate change mitigation were collected and analyzed. Mazimpaka (2014) studied Wood fuel in Rwanda: Impact on energy, poverty, environment, and policy instruments analysis. The research had the aim of contributing to the prevention of environmental abuse, and to also explain why environmental policy overlaps with and directs forest and energy policies in the matter of wood fuels.

This research collected data on wood fuels consumption from different places - industries, prisons, and schools. Millicent et al (2013) researched Climate change awareness and perception among primary school teachers in Kisumu Municipality, Kenya where the result indicated that there is a need to improve the teachers' quality knowledge on climate change as they are key actors in climate change awareness in Kenya. E. D. Oruonye, (2011) conducted a study on an assessment of the level of awareness of the effects of climate change among students of tertiary institutions in Jalingo Metropolis, Taraba State Nigeria.

The result of the findings showed that 18.2% of the students interviewed have not known what climate change is all about, its causes, effects, and possible adaptive or mitigation measures. For Timothy et al, (2019), their work was based on Climate change awareness and its determinants in a growing city in the southwest part of Nigeria using Multivariate Analysis.

The result showed that four factors predict awareness of change in climate bordering on availability and dissemination of issues associated with a change in climate and the perception of who tackles the impacts of climate change.

Ozor (2009) researched The Implication of Climate Change for National Development. The purposes of the work are: creating awareness and also having a better understanding of the issues of climate change in the area and to kick start the process of curriculum development, improve teaching, learning, and research in the area of climate change adaptation. It could be seen that are limited studies on climate change issues in Rwanda. This study tries to address the knowledge gap of the various impacts of climate change at various levels and assess the level of citizens' awareness, as well as their understanding of climate change and sustainable development in a bid to propose ways of addressing different climate change impacts that can hinder the attainment of sustainable development in Rwanda.

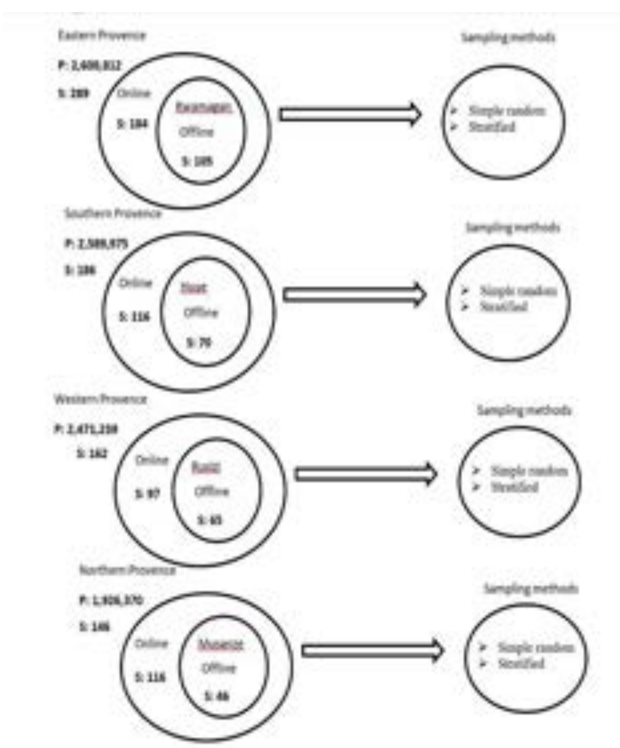
3.0 METHODOLOGY

Rwanda is a landlocked small nation located in East Africa, bounded by Uganda in the north, Burundi in the South, the Democratic Republic of Congo in the West, and the Republic of Tanzania in the East as shown in Figure 1. The land area is approximately 26,338 square kilometers with a population of about 11.63 million by 2018 estimate

Figure 1: The map of Rwanda.

3.1 Sources and type of data

The study relied on qualitative data from primary sources across the country - Rwanda. Primary data was collected through a well-designed questionnaire using two approaches - online and offline data collection. These comprised of information about climate change awareness and sustainable development. One thousand and three filled questionnaires were collected in total. The data collection is based on the personal characteristic of respondents, climate change awareness, and sustainable development. The study used a multi-stage sampling method for data collection involving the combination of a simple random sampling method and stratified sampling method to gather data needed for this study.



These two sampling methods were employed in this project as explained below: Online data used simple random sampling. This means that every person who was resident in Rwanda during the data collection was with equal probability of being a sample candidate. Offline data was collected using stratified sampling where the population was divided into five groups taken as strata by considering each province as a stratum and in each province, one district was chosen to be sampled - stratum. In the Eastern province, Rwamagana was a stratum. In the Southern province, Huye was chosen as a stratum. In the Western province, Rusizi was chosen as a stratum. In the Northern Province. Musanze was chosen as a stratum. The whole of Kigali capital was chosen as a stratum. This is well explained in Figure 2.

4.0 Result and discussion

4.1 Gender of respondents

The total number of respondents is 1003. As shown in Figure 3, 69% of the respondents are male while 31% are female as shown in Figure 3. The reason for the higher share of males in the distribution is that women appear to be less informed on the issues of climate change. This implies that males' opinion has more share in the study.

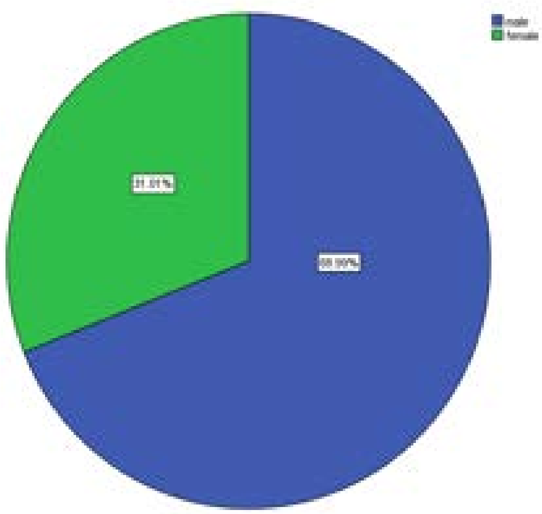


Figure 3: Distribution of respondents according to their gender

4.2 Age of respondents

The age bracket of the respondents is 14 years and above, and it follows range distribution for ease of analysis. Figure 4 shows the age range distribution of respondents. 55% of the respondents are within the age range of 26 - 40 years, 22.3% are within the age range of 41 - 60 years, 20.7% are within the age range of 14 – 25 years, while 1.9% is within the age range of 60 years and above. The age range of 26 – 40 years which constitutes 55% of the respondents has more percentage of respondents in the age distribution, implying that their opinions have a high share in this study.

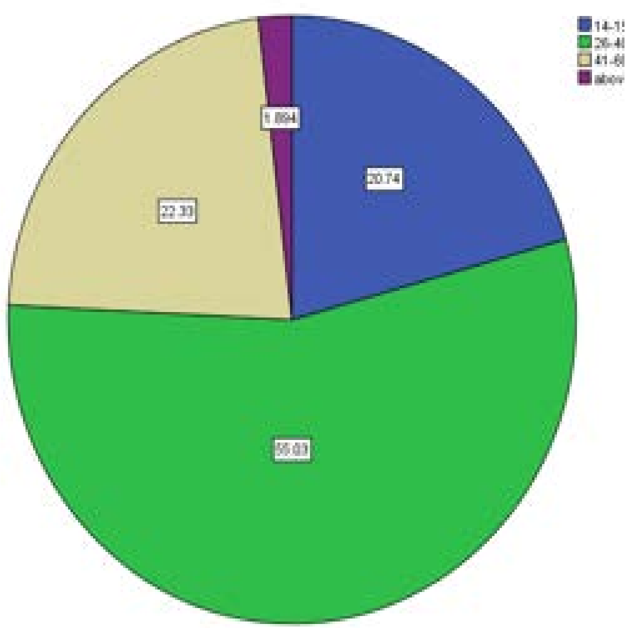


Figure 4: Distribution of respondents according to their age range

4.3 Knowledge of respondents on climate change

The purpose of this study is to evaluate the degree of knowledge the respondents have on climate change issues and sustainable development. From the output of the analysis, as shown in Figure 5, 91.03% of the respondents have heard about climate change before, while 8. 97% have not heard anything about climate change before. This shows that the majority of the respondents have heard of climate change.

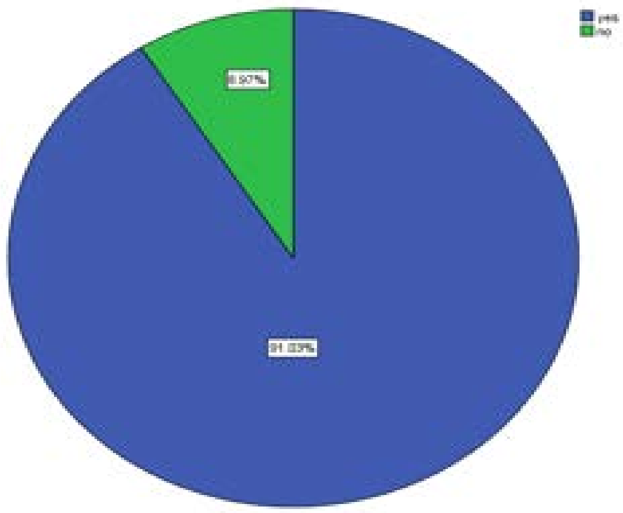


Figure 5: Distribution of respondents who have heard about climate change.

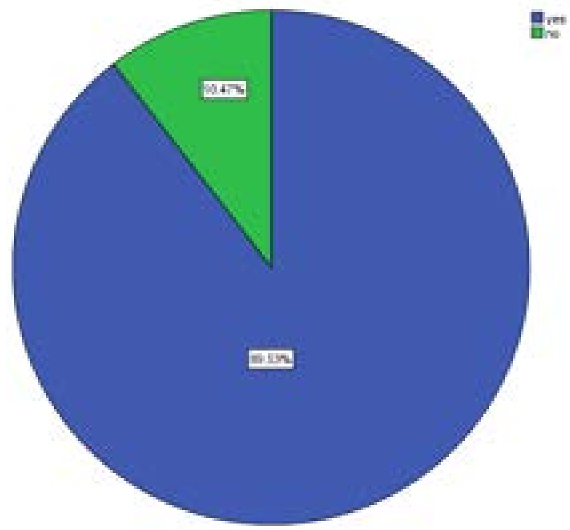


Figure 6: Distribution that showcases the awareness of respondents on climate change

Figure 6: show that 89.53% know something about climate change while 10.47 do not know anything about climate change.

4.4 Sources of information on climate change.

Here, we evaluated the sources of information on climate change. As shown in the level of frequency from Table 1, it can be seen that 41.6% of the respondents obtain their information on climate change from a government authority, 20.4% from television, 17.2% from social media, 15% from radio, and 3.9% from school while 1.9% have not heard any information about climate change.

Table 1: Respondents' sources of information on climate change.

Source of information	Respondents(Frequency)	Percentage (%)
No medium	19	1.9
Radio	150	15.0
Television	205	20.4
Social Media	173	17.2

School	39	3.9
Government authority	417	41.6
Total	**1003**	**100**

4.5 Respondent's opinions on how climate change impacts affect their careers

Figure 7 represents the respondent's opinions about the impacts of climate change on their career. The resulting output shows that 89.83% of the respondents agreed that climate change impact affects their career while 10.17% of respondents believe that a climate change impact does not affect their career.

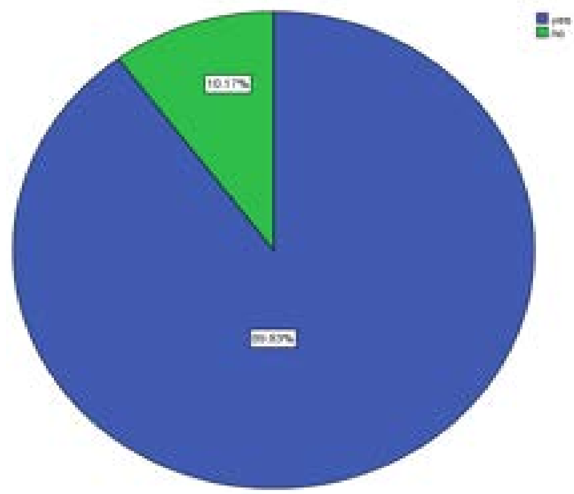


Figure 7: Distribution of climate change impacts on respondents' careers

4.6 Level of climate change awareness among the respondents

Unaware respondents are those who do not know about climate change, partially aware respondents are those who have knowledge about climate change but they do not have knowledge of the causes, effects, and mitigation of climate change, while aware are those who have substantial knowledge of the causes, effects, and mitigation and adaptation strategies of climate change. This distribution is shown in Figure 8.

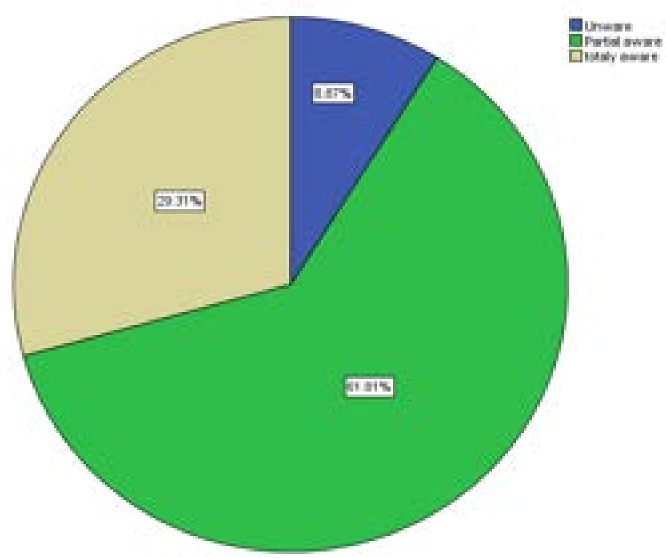


Figure 8: Distribution showing respondents' awareness of climate change

From the resulting output, 8.87% are unaware of climate change, 61.81% are partially aware of climate change, while those who are aware are 29.31% of the respondents.

4.7 Relationships between climate change awareness and sustainable development in Rwanda.

The study also examined the relationships between climate change awareness and sustainable development in Rwanda. To achieve this, the analysis was done by using Pearson's correlation in examining the relationship between climate change awareness with sustainable development in Rwanda. Pearson's correlation is a test statistic that measures the statistical relationship or association between two variables. The correlation information is summarized in Table 2.

Table 2: Correlations of climate change awareness and sustainable development.

	Climate change awareness	Sustainable development
Climate change awareness Pearson's correlation Sig. (2-tailed) **N**	1 1003	0.89 000 1003
Sustainable development Pearson's correlation Sig. (2-tailed) **N**	0.89 000 1003	1 1003

The result shows that the variables are related to one another. In Table 2, climate change awareness has Pearson's correlation of 0.89 with sustainable development which is a strong relationship. It also means that once there is an increase in climate change awareness in Rwanda, sustainable development will be affected positively.

4.8. Null hypothesis (Ho): "There is no significant impact of climate change awareness on sustainable development in Rwanda". Using sustainable development variables (poverty reduction, protection of biodiversity, and mobilization through leaders) which were used to determine if climate change awareness has significant impacts on sustainable development in Rwanda, the resulting output in Table 3 shows that the null hypotheses were rejected. The null hypothesis was rejected because the t-value is greater than zero, sig. (2-tail) is less than the mean value, and the lower and upper confidence is greater than 5%. For a null hypothesis to be accepted, the mean difference should be zero. Since all the necessary conditions to accept the null hypothesis failed, it was rejected; thus, the alternative hypothesis was accepted.

Table 3: Null hypothesis for Sustainable development.

One-Sample Statistics						
	N	Mean	Std. Deviation	Std. Error Mean		
Sustainable development	1003	1.11	.319	.010		
One-Sample Statistics						
Sustainable development	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	**Upper**
	110.744	1002	.000	1.115	1.09	1.13

4.9 Respondent's opinions on ways of addressing climate change impacts

Addressing climate change impacts will aid the achievement of sustainable development goals (SDGs13). Climate action is needed to adapt and mitigate climate change impacts in a bid to achieve sustainable development goals 13.

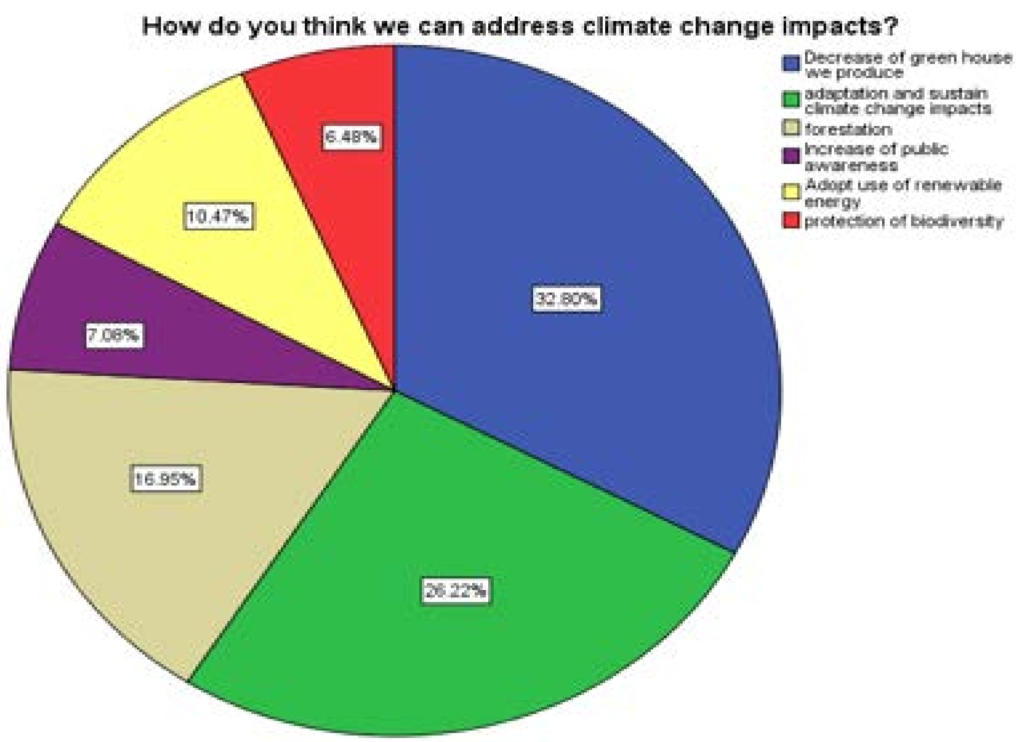


Figure 9: Respondents' opinion on ways of addressing climate change impacts

Figure 9 shows the opinions of the respondents opinions on the ways of addressing climate change impacts. From the Figure, 32.8% of the respondents are positive that “a decrease in greenhouse gases released in the atmosphere” will go a long way in addressing climate change impact. Whereas 26.22% of the respondents are positive that “sustainable climate change impacts” is a way of addressing the issues, 16.95% of the respondent are positive that “forestation” as a solution, 7.08% of respondents are positive on “public awareness” is the way forward, 10.47% of the respondents agreed on the use of “renewable energy” as a solution, and 6.48% of the respondents see “biodiversity” as a way of addressing climate change impacts. From these findings, a decrease in greenhouse gases released into the atmosphere is the best approach in addressing climate change impact.

5.0 Conclusion and Recommendation

The result shows that the level of awareness on climate change is still low in Rwanda. There is a need for an increase in an awareness campaign that can help adapt and mitigate climate change impacts. This study finds that there is a strong relationship between climate change awareness and sustainable development. This means that once there is an increase in climate change awareness, it will have a direct/positive impact on sustainable development in Rwanda. Based on the knowledge of respondents on climate change, we recommend an increase in awareness of climate change. This is because according to the respondents' output most of the citizens of Rwanda are not aware of climate change, its causes and effects, adaptation, and mitigation strategies of climate change. It is strongly recommended that the public and private sectors should increase awareness of climate change. This will involve the creation of climate change and environmental clubs in the schools, working places, and villages through basic leaders.

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