Dynamics of Agricultural Value Chains and Sustainable Energy

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DYNAMICS OF AGRICULTURAL VALUE CHAINS AND SUSTAINABLE ENERGY

AUTHORS
Mohammed U.
Maimuna A. A
Adeoye Adebayo SAMSON
Oyewo Isaac. O. JERRY
IPU Michael OGWUMA
Jonathan. A. OGWUCHE
Edache Ernest EKOJA
Idikwu Onwe UGBEM

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PREFACE

This volume brings together a collection of scholarly contributions that explore key issues related to sustainable development, agricultural innovation, and economic empowerment in contemporary societies. In an era marked by increasing global challenges such as food security, environmental sustainability, and inclusive development, the role of targeted interventions and resource management has become increasingly significant.

The chapters in this book address critical themes such as the impact of international development funds on women's empowerment within agricultural value chains and the potential of alternative bioenergy sources for sustainable development. These studies highlight the importance of integrating economic, environmental, and social perspectives in addressing development challenges, particularly in emerging and resource-dependent regions.

By adopting an interdisciplinary perspective, this volume integrates insights from development studies, agricultural economics, and sustainability research. It not only contributes to academic discourse but also provides practical implications for policymakers, development practitioners, and researchers working on sustainable growth and inclusive development strategies.

It is hoped that this book will serve as a valuable resource for researchers, students, and practitioners interested in agriculture, sustainability, and development, while encouraging further research on innovative and inclusive approaches to global development challenges.

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Editorial Team
April 8, 2026
Türkiye

CHAPTER 1

EFFICACY OF INTERNATIONAL FUNDS FOR AGRICULTURAL DEVELOPMENT –(VCDPs) ON WOMEN EMPOWERMENT ON RICE VALUE ADDITION IN NORTH CENTRAL NIGERIA

[1] Mohammed U.

[2] Maimuna A. A

[1]Department of Agricultural Economics and Extension Services, Ibrahim Badamasi Babangida University, Lapai, usmanmohammed.usmanou@gmail.com

[2]IFAD Assisted Value Chain Development Programme (VCDP) Niger State

INTRODUCTION

Women in Nigeria are a diverse group of individuals who have a wide range of experiences and backgrounds. They are mothers, daughters, sisters, wives, entrepreneurs, professionals, and activists. Women in Nigeria face numerous challenges, including gender inequality, poverty, and a lack of access to education and healthcare. According to NBS (2022). The overall performance of female in the project was enhanced putting their performance at 74.5% from the study, 70% of females said that the programme services and benefits such as tools, inputs, capacity building, mentoring and networking platforms are readily available and are also accessible by all members of their clustered groups especially those who have paid their matching grants for inputs and equipment. Women involvement in agriculture can extend beyond traditional farming to agribusiness and entrepreneurship. They are engaged in value addition, processing, marketing, and distribution of agricultural products. Government policies and initiatives that promote women participation in agriculture, such as funding schemes, training programs and access to land, productive assets can encourage more women to enter the sector. Access to affordable financing options is crucial for women to start or expand agricultural ventures. Microfinance institutions and government-backed loan programs can help address this challenge. Providing relevant education and training in modern farming, processing techniques, agribusiness management, and marketing is essential to equip women with the necessary skills. It's important to acknowledge and address challenges such as access to land, productive asset for value addition and market volatility that can deter women from entering or staying in agriculture. Involving women in agriculture in Nigeria can be a viable strategy for reducing gender inequality, unemployment, boosting food security, and driving economic growth, reducing vulnerability, raising their status. However, it requires a multi-faceted approach involving government support, education, access to resources, and a focus on innovation and sustainability.

Despite these challenges, Nigerian women are making strides in all areas of life and are becoming increasingly empowered to take control of their lives and their futures. In Nigeria, a woman has few rights within her home and family, even though it may be her sole world and environment.

All over the country, a woman is considered to have no legal right to her own children, all property of the house is considered to belong to the man, even if it is paid for by the woman (Lucas, 2024**).** Women participation in Income-Generating Activities (IGAs) is a crucial mechanism for ensuring the rural development of developing countries. Consequently, over the past four decades, women's entrepreneurship has gained popularity around the world with a growing number of females to starting and running their own businesses Daniel, (2025). Women play different roles and perform different responsibilities concerning the livelihood of their households, men have the primary responsibility for income-earning and women have the primary responsibility for the utilization of food and home management in rural households Abera *et al.,* (2022).

For years, the International Fund for Agricultural Development (IFAD) has been financing projects that seek to develop value chain with the specific aim of improving smallholder livelihoods and seeking to achieve gender equality, youth and women empowerment. Value chain development programme (VCDP) is one of such projects by the Federal Government of Nigeria (FGN) and IFAD which aims at enhancing productivity, promotion of agro-processing, access to markets and opportunities to facilitate improved engagement of the private sector and farmers organization in the development of effort. This programme takes a holistic and demand-driven approach to addressing constraints along the cassava and rice value chains, also aiming at poverty alleviation in the rural areas focusing more on the vulnerable group of which youths and women are part and in order to lift these set out of the poverty line, entrepreneurs trainings become important components in IFAD programmes National Bureau of Statistics, (2022).

While the FGN/IFAD assisted VCDP programme has continued to invest in rural people, most programmes benefits have always skewed in favor of men with the men being more visible than the females. This is because empowering women and girls can lead to the health and social development of families, communities, and countries as well as achieving gender equality. Value Chain Development Programmne (VCDP) has earmarked thirty-five percent of the matching grants for women, enabling them to upgrade their production and processing technologies and capacities.

In addition, the programme has applied the Gender Action Learning System, a community-led methodology for rural livelihood development and gender equality VCDP supervision report (2024).

Aim and Objectives of the study: The aim of this study is to critically examine the efficacy of the programme in improving the income-generation of the women in study area.

Specifically, objectives of the study are to:

i. describe the socio-economic characteristics of the women in the study area.
ii. determine the income-generating activities carried out by women in the study area.
iii. examine the efficacy of IFAD-VCDP on income and welfare of the beneficiaries
iv. Identify the constraints faced and the strategies put in place that influence women participation in programme at the study area.

1. METHODOLOGY

Study Area

The study was conducted in two States, namely: Benue and Niger in north central, Nigeria, concentrating on cassava and rice value chains including rural infrastructure, capacity building, advisory services. Benue state lies between latitudes 6^0 25'and 8^0 8'N and longitudes 7^0 47' and 10^0 0'E. it occupies an area of 33,955 km^2. Having a population of 4,253,641 people in 2006 while the projected population is 6,141300 (National Bureau of Statistics, 2022). Niger state is a state in the North Central region of Nigeria and the largest state in the country by area, it lies between latitude 09°61', 09°37' north of the equator and longitude 06°56', 06°32' east of the Greenwich meridian. The town shares boundary with the Federal Capital Territory from the north-west direction (Mohammed et al., 2025). The population was 201,429 at the 2006 while the projected population is 6,783,300 (National Bureau of Statistics, 2022).

Sampling Procedure and Sample Size

The primary data was obtained through the use of pre-tested structured interview schedule. The instrument was designed to gather relevant information on the socio-economic characteristics of the women that participated in the Programme, identified the income-generating activities of the respondents, determined the specific agribusiness women were involved before the programme and identified the constraint faced by women and strategies put in place that influenced women participation in the study area. Multistage sampling procedure was used to obtain sample from the study area. Other stages involved. Purposive sampling technics was used in selection of beneficiaries which depends on high population of women in production, processing and marketing along rice value chains.

First stage, Benue and Niger States was purposively selected in the zone.

Second stage, women (producers, processors and marketers of rice) beneficiaries in the programme was purposively selected from three (2) LGAs from each of the state making a total of 4 LGAs, based on high population of women into production, processing and marketing along rice value addition. This gave a total of 4 LGAs selected.

Third stage, Gboko, and Katsina-Ala were selected from Benue. Those from Niger State were Katcha and Kontagora**.**

Fourth stage involved a purposive selection of communities in each State respectively.

Fifth stage, Random sampling technics was used to select women respondents that is programme beneficiaries based on percentage and interviewed. Giving a total of 243 women respondents as the sample size for the study. The list of the beneficiaries was obtained from the IFAD-VCDP office.

Table 1: Sampling procedure and sample size

S/N	STATE	LGA	VILLAGES SELECTED	NUMBER OF WOMEN SELECTED @ 15%
1	Benue	Gboko	Achin	12
			Agbel	8
			Chia	14
			Gboko	13
			Mbadim	13
			Pika	13
				11
		Katsina-Ala	Katsina- ala	12
			Yooyo	12
			Iwaar	11
			Mbajir	5
			Mberev	4
2	Niger	Katcha	Katcha	15
			Edotsu	11
			Dzwafu	15
			Essa	16
			Gbakogi	5
		Kontagora	Alala	12
			Buda	4
			Ganawa	15
			Kamuka	18
			Maje	4
			TOTAL	**243**

Source: Field survey, 2025

2. RESULTS AND DISCUSSIONS

The socio-economic characteristics of the respondents under consideration include age, contact with extension agent, marital status, house hold size and level of education.

The result in table 2 revealed that the average age of women participating in the Value Chain Development Programme (VCDP) was 49 years in Benue State with 45.5% and 40 years in Niger State with 46.0%. This implies that a majority of the respondents are in their economically active and productive years. This finding is in line with the research conducted by Zakari *et al.* (2023), which reported a mean age of 42 years among women involved in rice processing under the IFAD-VCDP in Kogi State, Nigeria. The distribution of marital status for Benue State, as presented in Table 2, indicates that a significant proportion (64.1%) of the respondents were married, (25.0%) were single, while a smaller percentage of (10.9%) were widows. In Niger State, the marital status distribution revealed that the majority of the respondents, (67.8%), were married, followed by a smaller percentage of (7.8%) who were widowed, while (24.4%) were single. This finding agrees with the study by Mahmud & Hafsat, (2025), which stated that active involvement in such programmes leads to increased productivity, creativity, self-worth, and empowerment among women. The results on household size in Benue State revealed that a significant proportion (45.1%) of the respondents had a family size ranging from 1 to 5 persons while only a very small proportion, (0.7%), reported having 16 persons or more in their households. In Niger State, the distribution followed a slightly different pattern. The majority of respondents (59.3%) had a household size between 6 and 10 persons, indicating a tendency towards moderately large families. A minimal (0.6%) had households of 16 persons and above. The findings further showed that the average household size in Benue State was 8 persons, while in Niger State, it was 13 persons. This suggests that, on average, respondents in both states had fairly large household sizes. This finding aligns with the results of Daniel, (2025), who stressed that large family sizes can serve as a source of unpaid or family labour, reducing the cost of hiring external labour and increasing the capacity for farming and processing activities. Also, table 2 below reveals that in Benue State, the educational distribution indicates that (48.5%) of the respondents had secondary education, while (16.4%) of the women had tertiary education, and (11.7%) reported receiving Qur'anic education. In Niger State, findings show that only (17.4%) of the respondents had secondary education, while (21.7%) had only primary education.

Interestingly, the highest proportion of respondents in this state, (51.3%), reported Qur'anic education, which reflects the socio-cultural and religious context of the region. This agrees with the assertion by Abubakar, *et, al.*, (2024) that when women lack sufficient educational background, it can hinder their comprehension of technical information and restrict their entrepreneurial growth. However, the overall educational level of respondents in both states remains relatively low. This could cause a limitation in their ability to maximise the benefits of training and capacity-building programmes provided under VCDP. The results in Table 2 below show that the majority (86.7%) of the respondents in Benue State had access to extension agents, while (13.3%) reported having no contact with extension agents. Similarly, in Niger State, the majority of respondents (72.2%) had access to extension services, while (27.8%) had no contact with extension agents. The findings imply that agricultural extension services are well established and relatively effective in delivering critical support to women farmers involved in VCDP activities in both Benue and Niger States. This result aligns with the findings of Mathew *et al.* (2024), who stated that the high frequency of contact with extension agents shows a strong indication of the active presence of extension services in the study areas.

Table 2: Socioeconomic Characteristics of Respondents in Niger and Benue States

Variables	Niger (n=115**) Freq (%)**	Benue (n=128**) Freq (%)**
Age (years)		
20-30	5 (2.3)	6 (3.0)
31-40	50 (46.0)	43 (35.3)
41-50	42 (40.7)	52 (45.5)
51-60	15 (9.8)	25 (15.2)
60 and above	3(1.2)	2 (1.0)
Mean	40	49
Marital Status		
Married	78 (67.8)	82 (64.1)
Single	28 (24.4)	32 (25.0)

Widow	9 (7.8)	14 (10.9)
Household Size (number)		
1 – 5	22 (19.0)	44 (34.4)
6 – 10	38 (33.0)	65 (50.8)
11 – 15	46 (40.0)	12 (9.4)
16 – 20	6 (5.1)	6 (4.7)
21 and above	3 (2.6)	1 (0.7)
Mean	13	8
Contact with Extension Agent		
Yes	83 (72.2%)	111 (86.7%)
No	32 (27.8%)	17 (13.3%)
Primary education	25 (21.7)	30 (23.4)
Qur'anic education	59 (51.3)	15 (11.7)
Secondary education	20 (17.4)	62 (48.5)
Tertiary education	11 (9.6)	21 (16.4)

Source: Field survey, 2025

Income-generating activities carried out by women in the study area

Table 4.4 below shows the distribution according to Income-generating activities carried out by women in the study area, The VCDP activities mostly carried out by women in Benue and Niger States. The results show that: rice production (69.3%); rice processing (59.5%); rice marketing (62.7%); were the VCDP activities mostly involved by women in Benue State. In Niger State, the results show that: rice production (72.5%); %); rice marketing (71.0%); rice processing (63.9%) were the VCDP activities mostly patronized by women. This findings implies that women in the study area were involved in rice value chains but at varying degree of their interest. This result is in line with (Ebuka, *et, al.,* 2024) who stated that agriculture has huge and diverse opportunities and potentials that cannot only create employment and transform the national economy but also tremendously impact the personal lives of the women.

The VCDP activities that were also involved by women in Benue state, for additional income include: weeding (12.4%,) harvesting (11.1%), threshing (11.1%), cleaning (12.5%), sorting (9.2%), rice parboiling (17.6%) , drying (16.3%), winnowing (13.7%), de-stoning (12.4%), grinding (12.4%), nutrient dense recipes (39.2%), petty trading (49.0%), Hair dressing (3.9%), food vendor (25.5%), stone crushing (0.7%) and tailoring (3.9%) and in Niger States for additional income also include: weeding (17.5%), harvesting (22.0%), threshing (25.4%), cleaning (26.6%), sorting (25.4%), rice parboiling (39.0%) , drying (41.8%), winnowing (54.2%), de-stoning (39.5%), grinding (35.6%), nutrient dense recipes (5.6%), petty trading (32.2%), food vending (2.8%), stone crushing (0.6%) and tailoring (3.4%).This is in line with (Malik and Jerry,2023) who reported from their study that one way to increase income while decreasing household vulnerability to shocks is to take advantage of different, diversified sources of income.

Table 3: Income-generating activities carried out by women after the programme in the study area

Income-Generating Activities	Niger (n=115)	Benue (n=128)
Rice Production	64 (36.2%)	106 (69.3%)
Rice Processing	103 (58.2%)	91 (59.5%)
Rice Marketing	12 (6.8%)	96 (62.7%)
Weeding	31 (17.5%)	19 (12.4%)
Harvesting	39 (22.0%)	17 (11.1%)
Threshing	45 (25.4%)	17 (11.1%)
Cleaning	47 (26.6%)	16 (10.5%)
Sorting	45 (25.4%)	14 (9.2%)
Rice Parboiling	69 (39.0%)	27 (17.6%)
Drying	74 (41.8%)	25 (16.3%)
Winnowing	96 (54.2%)	21 (13.7%)
Rice De-stoning	70 (39.5%)	19 (12.4%)
Rice Grinding	63 (35.6%)	19 (12.4%)

Nutrient-dense Recipe	10 (5.6%)	60 (39.2%)
Petty Trading	57 (32.2%)	75 (49.0%)
Hair Dressing	0 (0.0%)	6 (3.9%)
Food Vendor	5 (2.8%)	39 (25.5%)
Stone Crushing	1 (0.6%)	1 (0.7%)
Tailoring	6 (3.4%)	6 (3.9%)

Source: Field survey, 2025

Efficacy of IFAD-VCDP on income and welfare of the beneficiaries in the study areas

Women participating in Value Chain Development Programme (VCDP) activities in Niger and Benue states have shown improvements in their welfare, including increased income, better living conditions, and access to resources. The result in Table 4 revealed that in Benue State, the majority of the women (89.8%) were able to employ more labourers to work for them in their various enterprises. This outcome was largely due to the increased income generated through their participation in VCDP activities. Furthermore, (92.2%) of the women in Benue State confirmed they could now pay off their medical bills with ease, showing improved access to healthcare services, while (83.6%) reported being able to settle their house rent and utility bills, which indicates better housing security. About (85.2%) of the respondents also acknowledged that they were now able to pay their children's school fees, ensuring continuity in education for their families. High percentage of women (82.8%) reported an increase in their annual income. These findings are consistent with the report by David *et al.* (2024) in the study on the "Impact of Value Chain Development Programme (VCDP) on the Farmers in Bassa Local Government Area of Kogi State", which established that VCDP had positively influenced the livelihoods of (75.0%) of the farmers in the study area. In Niger State, the results from Table 4 revealed that majority of the women (78.3%) reported they were now able to pay their children's school fees, a critical indicator of improved household welfare and investment in future generations.

Furthermore, (65.2%) of the women confirmed they could afford to pay their medical bills, which points to enhanced health outcomes and improved access to healthcare services. About (89.5%) were also able to employ additional labourers for their enterprises due to the increased income generated from participation in the VCDP. This research agrees with Daniel *et al,* (2025) on "Effect of Women's Development Projects in Improving the Social Welfare of the Beneficiaries.

Table: 4 Income & Welfare Status of Respondents in Niger and Benue States

Variables	Niger (n=115) Freq (%)	Benue (n=128) Freq (%)
Increase in Income Annually	92 (80.0)	106 (82.8)
Purchase of Additional Land for Rice Farm	65 (56.5)	60 (46.8)
Employing of More Laborers	103 (89.5)	115 (89.8)
Increase in Laborer Wages/Salaries	58 (50.4)	74 (57.8)
Savings for Future Occurrence	75 (65.2)	96 (75.0)
Participation in Family Programmes	87 (75.6)	110 (86.0)
Adoption of Innovative Crop Practices	64 (55.7)	79 (61.7)
Access to Clean Water	88 (76.5)	98 (76.6)
Payment of Children's School Fees	90 (78.3)	109 (85.2)
Access to Modern Education	89 (77.4)	90 (70.3)
Payment of House Rent and Bills	83 (72.3)	107 (83.6)
Purchase of Mobility	57 (50.0)	106 (82.8)
Purchase of Household Equipment	62 (54.0)	94 (73.4)
Payment of Medical Bills	75 (65.2)	118 (92.2)
Change of Residence	43 (37.4)	58 (45.3)

Source: Field Survey, 2025

Constraints faced and the possible solutions

The distribution of Strategies and factors influencing participation in income-generating activities in VCDP activities in the study area is shown in Table 5 below.

In Benue State, results shows that very serious factors influencing participation of women in the VCDP activities show that majority (95.3%) of the women said Prioritizing women participation, (83.6%) Regular and prompt training, (94.5%) Capacity building, (79.7%) Form and strengthen more women-only groups were some of the factors that influenced the participation of women in the VCDP. This is in line with Marcel and Suleiman (2024) whom stated that women training and development have a number of positive effects on the social welfare of the beneficiaries, programme can help women to improve their economic status, health and empowerment, which can lead to a number of benefits for families and communities. In Niger State, results shows that very serious factors influencing participation of women in income generating activities in the VCDP activities show that majority (86.1%) of the women said Regular and prompt training, (74.0%) Prioritizing women participation, (61.7%) Forming and strengthen more women-only groups, (81.7%) Capacity building, (80.9%) Taking cognizance of women in various roles as actors in the rice value chains, (84.3%) Empower women to leverage on opportunities were among some of the factors that influenced the participation of women in the VCDP. This is in line with Marcel and Suleiman (2024) who posited that Women training and development have a number of positive effects on the social welfare of the beneficiaries, programme can help women to improve their economic status, health and empowerment, which can lead to a number of benefits for families and communities. This implies that women in the study area had high level of participation in a lot of VCDP activities but at varying degree of interest to them.

Table 5: Distribution of constraints faced and the strategies put in place that influence women participation in programme at the study area.

Variable	**B/VS (Freq)**	**B/S (Freq)**	**B/NS (Freq)**	**N/VS (Freq)**	**N/S (Freq)**	**N/NS (Freq)**
Taking cognizance of women in various roles as actors in the rice value chains	110(86.0)	44(28.8)	0(0.0)	93(80.9)	44(24.9)	0(0.0)
Access to land	48(37.5)	112(73.2)	5(3.3)	76(66.1)	53(29.9)	4(2.3)

Access to production and processing machines/equipment	85(66.4)	60(39.2)	1(0.7)	81(70.4)	45(25.4)	11(6.2)
Access to financial services/credit	55(43.0)	84(54.9)	13(8.5)	99(86.1)	45(25.4)	33(18.6)
Access to water	71(55.5)	77(50.3)	15(9.8)	111(96.2)	51(28.8)	7(4.0)
Access to processing center	86(67.2)	34(22.2)	23(15.0)	80(69.5)	22(12.4)	45(25.4)
Access to market stalls and store	56(43.8)	41(26.8)	58(37.9)	94(81.7)	26(14.7)	57(32.2)
Empower women to leverage on opportunities	102(79.7)	39(25.5)	2(1.3)	97(84.3)	42(23.7)	8(4.5)
Capacity building	121(94.5)	37(24.2)	0(0.0)	94(81.7)	42(23.7)	1(0.6)
Price subsidy (Input, equipment)	100(78.1)	45(29.4)	0(0.0)	70(61.0)	49(27.7)	8(4.5)
Prioritizing women participation	122(95.3)	30(19.6)	1(0.7)	85(74.0)	29(16.4)	3(1.7)
Regular and prompt training	107(83.6)	36(23.5)	0(0.0)	99(86.1)	29(16.4)	0(0.0)
Form and strengthen more women-only groups	102(79.7)	41(26.8)	0(0.0)	71(61.7)	36(20.3)	0(0.0)

Source: Field Survey, 2025

B= Benue, N=Niger, VS=very serious S= serious, NS=not serious, WS=weighted sum, WM=weighted Mean

CONCLUSION AND RECOMMENDATIONS

The study revealed that there is high level of participation of women in VCDP agricultural activities. The majority (83.3%) of the respondents were better- off after participating in the project as it evidently improved their welfare status. To achieve a desired national transformation, the platform for women's involvement in leadership where gender sensitive interests can be expressed as critical because this will reduce their vulnerability. The need to view political participation as a continuous process will help to steady the rate of women's participation against a decline level.

This is possible with a resilient political will and democratic leadership spirit, which is not limited to political parties but inclusive of trade unions, educational sector, employment, social institutions and with the growing recognition of the need to incorporate women into mainstream development projects in order to promote accountability and yield results, a conscious effort is needed to encourage women involvement in nation building. It is therefore recommended that women should be given more opportunities they needed; it will lead to full development of their roles. Women lack the training and the means to bloom and this is needed for advancing the position of women, strengthening their capacities and skills and expanding the opportunities for women to more fully develop their roles.

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CHAPTER 2
UNLOCKING POTENTIAL UTILIZATION OF JATROPHA CURCAS FOR A SUSTAINABLE BIOENERGY IN SELECTED AREAS OF OYO STATE, NIGERIA

[1] Adeoye Adebayo SAMSON
[2]Oyewo Isaac. O. JERRY

[1]Department of Agricultural Extension and Management, Federal College of Forestry, Nigeria, saadeoye06@gmail.com, ORCID ID: 0000-0003-0909-5168
[2]Department of Agribusiness Management Federal College of Forestry, Forestry Research Institute of Nigeria (FRIN), Ibadan, Nigeria, ojerry2@gmail.com, ORCID ID: 0000-0003-0544-9918

INTRODUCTION

Environmental degradation sets in as a result of human activities through greater use of energy (Ulucak *et al*., 2020). The greater consumption and generation of energy induced a greenhouse effect which has led to the deterioration of the environment through the depletion of air, water, and soil, and the destruction of ecosystem and the extinction of wildlife (Bolan *et al*., 2024). When the environment becomes less valuable or damaged, environmental degradation has occurred. There are many forms of environmental degradation which ranges from destroyed habitat, biodiversity loss, or depletion of natural resources (Xiong *et al*., 2023). There are negative impacts on the environment arising from the activities of man through utilization of pesticides for agricultural purpose which has caused pollution of the atmosphere. Other activities which cause environmental pollution include thermal power station, burning of fossil fuel, gas flaring, and cement manufacturer plant (Lala *et al*., 2023). All these emit harmful pollutants like sulphur(iv)oxide, carbon(iv)oxide, that cause acid rain, global warming, and malfunctioning of human hemoglobin. In Nigeria, like many developing nations the environmental problems are massive; aggravated soil erosion, flood disasters, and desertification due to the effect of shifting cultivation on fragile soils, forest clearing, bush burning, animal over-grazing, pollution of water, air, and land due to improper disposal of industrial and domestic waste, and pollution through consumption of fossil fuel with great effect on human wellbeing (Aruleba *et al*., 2023).

Environmental degradation arising from fossil fuel consumption and unsustainable agricultural practices poses a significant threat to the attainment of the 2030 Agenda for Sustainable Development, particularly SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 15 (Life on Land). In developing economies such as Nigeria, these challenges are compounded by energy poverty, land degradation, and weak institutional frameworks, which collectively hinder sustainable development outcomes. The transition toward renewable bioenergy crops represents a strategic opportunity to simultaneously address energy access, climate mitigation, and land restoration objectives.

Energy crops such as *Jatropha curcas* are increasingly recognized within global sustainability discourse as instruments capable of delivering co-benefits across environmental, economic, and social dimensions of sustainability, aligning with SDG 8 (Decent Work and Economic Growth) and SDG 12 (Responsible Consumption and Production), while reducing pressure on forest ecosystems and biodiversity.

Consequently, in Nigeria focus still hinges on fundamental issues of food security and sustainable agriculture which has devoted large hectares of land to cultivation of arable crops with militating factors like the use of obsolete cultural practices, scanty plants stand, poor weed control, usage of inorganic fertilizers, with poor management accounting for low productivity of the farmers (Onwe et al., 2024). However, it is worthy of note that the European farmers have diversified into the production of renewable energy crops due to the surplus of human and livestock food for income generation from biofuel with its variant environmental mitigation as erosion prevention, improvement of micro-climate and cleaning of greenhouse gases (Ali *et al.*, 2025). While there has been shift to production of renewable energy crops around the world, the Nigeria focus is yet based on how to increase the level of food production. The misery of sustainable environment in this part of the world could be as a result of lack of adequate awareness and environmental information among farmers.

In view of these environmental problems, studies have been carried out on the impact of energy crops for environmental sustainability. Development of sustainable bioenergy from energy crops is considered an important factor in reducing greenhouse emission, acid deposition in soil and chemical runoff, and improvement of the environment for both man and wildlife through deliberate afforestation project (Maishanu *et al*., 2019). Sustainable environment according to Anil *et al*. (2024) is possible based on the production of biodiesel which considerably reduce non-renewable energy requirement and greenhouse gas emissions due to fossil fuel consumption, and the pressure on the ozone layer is also abated. *Jatropha curcas* as a potential bioenergy crop is a perennial crop known for its invasive growth, fertility, and adaptability to all soil types. This energy crop is relatively drought resistant with soil erosion control potential, and provides better habitat for man and wildlife.

Jatropha curcas has many potential contributions to sustainable environment in the area of wind and soil erosion, serves as good source of organic fertilizer for the soils, facilitates water erosion control, and help in solving deforestation problems in the developing countries (Yu and Zhang, 2025).

Therefore, the increasing demand for sustainable and locally available energy alternatives underscores the need to explore non-food bioenergy crops with high adaptive potential in Nigeria. *Jatropha curcas* presents a viable option for bioenergy development due to its ability to thrive on marginal lands, its high oil yield, and its compatibility with environmental sustainability goals. However, the successful integration of *Jatropha curcas* into Nigeria's bioenergy landscape largely depends on the level of awareness, perceptions, and actual utilization among local stakeholders. In Southwest Nigeria, particularly in selected areas of Oyo State, limited empirical evidence exists on how communities understand, perceive, and engage with *Jatropha curcas* for bioenergy production. Addressing this gap is essential for informing policy, guiding extension services, and promoting community-driven bioenergy initiatives. Hence, this study examines the awareness, perception, and utilization of *Jatropha curcas* for bioenergy production in Southwest Nigeria, with the aim of generating evidence-based insights that can support sustainable energy planning, rural livelihood enhancement, and environmental conservation in the region.

1. Literature Review

The Global situation of Jatropha cultivation

Yu and Zhang (2025) exemplified that a global assessment of the ecological suitability for Jatropha cultivation under present and future climatic conditions indicate that high yields should be attainable in both tropical and hot temperate areas. Climate change is estimated to reduce average global yield levels by about 10% with higher variation at local scale (Li *et al*., 2025). According to Our World in Data (2025) areas in Africa, South America and Northern part of South and East Asia (Northern India, Nepal and China) are expected to become more suitable for Jatropha cultivation in the future due to expected reduced frequency of frost events and cold days and nights.

Figure 1. Plantation of Jatropha and Jatropha seeds.
Source: Ogunwole (2014); Kabe Hinlibe *et al*., (2020).

Moreover, based on the perspective of water, Jatropha cultivation could provide feedstock for biodiesel or biofuel production in India which is considered an option for making productive use of wastelands and for downstream environmental flow requirements. Using wastelands for cultivating Jatropha could help in strengthening local livelihoods, income diversification among smallholders and germane for a land development (Ogunwole *et al*., 2019). Jatropha cultivation is projected to yield 4.72 million hectares by 2010 and 12.8 million hectares by 2015, and as at that time, Indonesia is expected to be the largest producer in Asia with 5.2 million hectares, Ghana and Madagascar together will have the area in Africa with 1.1 million hectare and Brazil is projected to be the largest producer in Latin America with 1.3 million hectares (FAO, 2020).

Figure 2. Processed Jatropha oil from Jatropha seeds
Source: Kabe Hinlibe *et al*., (2020)

Zhang (2024) point out that the world's energy supply has relied heavily on non-renewable crude oil derived from fossil fuel, out of which 90% is estimated as being consumed for energy generation and transportation and which has led to crisis of fossil fuel depletion and environmental degradation. These realities have a boost to the search for renewable and sustainable alternatives to fossil fuels which is biodiesel from the Jatropha crop. The non-inflammable characteristics, biodegradability, non-toxicity and non-explosiveness makes it more environmentally friendly compared to petroleum diesel (Sharma and Bhende, 2024).

Jatropha Biofuel as a Renewable Energy Source in Developing Countries

In developing countries, biofuel energy production serves a better alternative to both fossil fuels and solar energy system and the Jatropha biofuel have advantage in replacing the diesel engines and in neutralizing the carbon emissions from the combustion of hydrocarbon (Dar and SheerGojree, 2025). According to Decoding Biosphere (2025), the world is facing a big challenge to prevent environmental damage which is a result of the use of fossil energy and global warming with the evident increase in greenhouse gas concentration in the atmosphere.

One of the primary justifications for a shift to the Jatropha biofuel as alternative energy source has to do with the climatic benefits that are anticipated to occur from the substitution of fossil fuels, whose combustion results in large net CO_2 emissions to fuels whose combustion releases gases sequestered through cultivation and which are therefore considered greenhouse gas (GHG) neutralizer (Yu and Zhang, 2025). Also, to address the problems of gradual depletion of the world's petroleum reserves, steep price hikes and the effects of exhaust emissions on environmental pollution, which prove that there is an urgent need for suitable alternative fuels for use in diesel engine (Wang and Azam, 2024). The Jatropha plant can yield about 1000 barrels of oil per year per square miles on a degraded soil with little or no carbon debts which offers immediate and sustained greenhouse gas advantage (Gerrard, 2022).

Figure 3. Jatropha Cooking Stove
Source: Kabe Hinlibe *et al*., (2020)

Greenhouse gas emissions from fossil fuel combustion are the main reason for climate change. Most biofuels on the other hand, have a much lower net emission of greenhouse gases when used for energy (Filonchyk *et al*., 2024). Jatropha plant for biofuel absorbs carbon as it grows, and when harvested release only the amount of carbon they absorbed thus mitigating the effect of climate (Yu and Zhang, 2025). The biofuel does not have to possess zero greenhouse gas emissions to be of benefit, though they must show lower emissions overall than the alternative (Chowhury *et al*., 2025).

Figure 4. Jatropha Lantern
Source: Kabe Hinlibe *et al*., (2020)

Biofuels represent a promising pathway for advancing national energy security while delivering substantial environmental benefits, including reduced carbon emissions and lower sulfur content relative to conventional petroleum-based fuels (Nahar *et al*., 2011). Climate change poses significant challenges to agricultural systems, particularly in climate-vulnerable countries such as Bangladesh, where agriculture remains the primary livelihood for a large proportion of the population. Seasonal water scarcity, especially during summer and winter, constrains crop productivity; although winter is generally considered climatically stable for cultivation, drought conditions frequently limit yields. These challenges are further compounded by intense population pressure over 162 million people within a land area of approximately 147,570 km^2 of which only a limited proportion is arable. Ongoing land degradation driven by erosion, deforestation, and other anthropogenic activities continues to reduce the availability of productive farmland.

Enhancing agricultural productivity under these conditions requires either improved water availability or the adoption of drought-tolerant plant species. In this context, crops with low water requirements or deep root systems capable of accessing subsurface moisture are particularly valuable. Such crops also offer opportunities to diversify rural livelihoods and reduce dependence on fossil fuels in both developed and developing economies, including Bangladesh. Among these, *Jatropha curcas* has attracted considerable attention due to its drought resistance, ease of propagation, and ability to thrive on marginal and degraded lands without competing with food crops (Heller, 1996; Grimm, 1996).

The species can be cultivated on wastelands and infertile soils, has a productive lifespan of up to 50 years, and is well suited to a wide range of agro-ecological conditions, including low to high rainfall zones and areas experiencing short-duration frost (Henning, 2010).

In recent years, *Jatropha curcas* has gained prominence as a feedstock for biodiesel production in both developed and developing countries. The plant produces seeds rich in non-edible oil that can be readily converted into biodiesel, a renewable and environmentally friendly alternative fuel. Its adaptability allows cultivation in drylands, shallow or rocky soils, marginal fields, boundary lands, and even flood-prone areas. Owing to its toxicity and inedibility to humans and livestock, *Jatropha curcas* is also widely used as a live fence, protecting food crops from animal intrusion. Moreover, its extensive root system contributes to soil stabilization and erosion control when planted along riverbanks and coastlines, while leaf litter enhances soil fertility (Nahar *et al*., 2011). Beyond energy applications, various parts of the plant possess documented medicinal value, underscoring its multifunctional role in sustainable agricultural and bioenergy systems (Openshaw, 2000; Gubitz *et al*., 1999). The seeds of *Jatropha curcas* contain approximately 30–35% non-edible oil (Heller, 1996; Deng, 2010; Gubitz *et al*., 1999; Henning, 2002). Depending on planting density and management practices, one hectare of land can yield between 158 and 396 gallons of oil (Chawla, 2010). On average, about 0.26 gallons of oil can be extracted from 8.8 lb of seeds (Achten, 2008) to approximately 11–12 lb of seeds (Jongschaap, 2007).

2. MATERIALS AND METHODS

Study Area

The study was carried out in Oyo State which is an inland State in the South-western Nigeria. It covers the land area of approximately 32,241.8 square kilometers. The total population in Oyo State according to the 2006 population census is 5,591,589. There are 2,809,840 males and 2,781,749 females in the state. It is bounded in the North by Kwara State, in the east by Osun State, in the South by Ogun State and in the west partly by Ogun State and partly by the Republic of Benin. Oyo State is homogenous mainly inhabited by the Yoruba ethnic group.

The state is made up of thirty-three (33) Local government areas. It covers approximately an area of 28,454square kilometers and is ranked 14th by size. Further, it contains a number of natural features including the old Oyo National Park. The climate is equatorial, notably with dry and wet seasons with relatively high humidity. Average daily temperature ranges between 25^0c (77.0ºF) and 35ºc (95.0ºF), almost throughout the year. The occupation of Oyo State is mainly agrarian.

Figure 5. Map of the Study Area adapted from OCHA (2018)

Population of the study

The target population for this study includes trained Jatropha producers in Oyo State. These are trained bioenergy producers and exposed to Jatropha plant for its economic benefits. **Sampling procedure and sample size**

A multi-stage sampling was adopted for the study. In 1st stage 1, there was ten percent (10%) random selection of the 33 LGAs in Oyo State. Ido, Akinyele and Lagelu LGAs which represent the 10% of the thirty-three (33) LGAs in the State.

In 2nd stage, the list of trained Jatropha producers was obtained from the 3 LGAs, and they were 243 trained Jatropha producers in the study area. In 3rd stage, 30% of wards were selected from the LGAs. The 4th stage showcased selection of three (3) villages from wards in Ido, 4 villages from wards in Akinyele, and 5 villages from wards in Lagelu LGAs were randomly selected respectively. Finally, the 5th stage employed random selection of ten (10) trained Jatropha producers in each village from which a total number of one hundred and twenty (120) respondents were selected as a sample size (Table 1).

Table 1. Summary of sampling procedure and sample size

Number of LGAs in Oyo State	10% of LGAs	Trained Jatropha producers in each LGA	Number of wards in the LGAs	30% of wards in the selected LGAs	Selected villages	Randomly selected biofuel producers from each village	Total sample size
Thirty-three (33)	Ido	68	10	3	3	10	30
	Akinyele	76	12	4	4	10	40
	Lagelu	99	14	4	5	10	50
Total		243					**120**

Source: Field survey, 2024

Method of data collection

Primary sources were used for data collection. A structured questionnaire containing both open and closed ended questions based on the objectives and the hypotheses of this study was developed for the purpose of primary data collection, whereas secondary data was developed from the review of relevant literatures.

Data Analysis

The data collected was analyzed with the aid of descriptive. The descriptive statistical tools used are frequencies and percentages. The study adopted survey method for the analysis of data collected.

3. RESULTS AND DISCUSSION

Jatropha curcas Potential Utilization for Sustainable Bioenergy

The result on Table 2 showed that most respondents (95.8%) are familiar with Jatropha as a source of biofuel. This indicates that respondents are fully aware of the importance of Jatropha for biofuel production. This concurs with Ntaribi and Paul (2018) that investment in Jatropha is common with its seeds yielding some volume of biodiesel from year to year depending on acre of cultivation. About 85.0% of respondents had knowledge of organizations promoting Jatropha for ethanol and oil as bioenergy products. This suggests existence of industrial companies in the southwest Nigeria responsible for biofuel production from Jatropha. This aligns with Adepoju and Oloyede (2018) that some industrial companies have extracted biodiesel from Jatropha as a springboard for reusable energy. Also, most respondents (91.7%) explained that bioenergy from Jatropha are integrated into existing energy infrastructure. This indicates that respondents are conversant of the use of biofuel as an alternative to hydrocarbon fuel. This corroborates Riayatsyah *et al*. (2022) that Jatropha-based biodiesel will be a viable alternative to fossil fuel. In addition, 86.7% of respondents confirmed Jatropha-based bioenergy could sustainably serve as replacement for fossil fuels was among. This suggests concerted efforts should be disposed towards harnessing production of biofuel as substitute to hydrocarbon fuels. This aligns Riayatsyah *et al*. (2022) that Jatropha-based biodiesel will be a viable alternative to fossil fuel. The findings reveal that 97.5% of respondents were confident that Jatropha could serve as a source of job creation and pollution reduction from combustion of hydrocarbon fuel. This implies industrial companies producing biodiesel could mop-up unemployed population and ensure safe environment. This corroborates Chilakamarry *et al*. (2023) that biodiesel production industry has contributed to enhancement of productivity and constant maintenance of the environment.

Furthermore, about 65.8% of respondents declared usefulness of oil from Jatropha enhance cleaning of injector pumps of motor vehicles. This indicates an effectiveness of Jatropha oil for injector cleaning in most vehicles. This agrees with Balaji *et al*. (2023) that Jatropha oil blend gives lower emissions with higher injection pressures and better performance of engines. Moreover, 64.2% of respondents observed that Jatropha bioenergy supports reduction of greenhouse gas emissions. This suggests that bioenergy enhances decimation of greenhouse gas emissions in the environment. This concurs with Reid *et al*. (2019) that energy from biomass creates significant contributions to reduce carbon emissions from hydrocarbon fuels.

Table 2. *Jatropha curcas'* Utilization for Bioenergy

Statements	**Yes**		**No**	
	F	**%**	**F**	**%**
Familiarity with Jatropha as a source of biofuel	115	95.8	5	4.2
There are organizations promoting Jatropha for ethanol and oil as bioenergy products	102	85.0	8	15.0
It can be integrated as complementary product with existing energy infrastructure	110	91.7	10	8.3
Jatropha-based bioenergy is useful for domestic and industrial purposes	65	54.2	55	45.8
Jatropha-based bioenergy has promising application as replacement for fossil fuels	104	86.7	16	13.3
It is a useful source of job creation and for reduction of pollution hydrocarbon fuel	117	97.5	3	2.5

It is useful in reducing energy poverty and scarcity	52	43.3	68	56.7
Oil produced from Jatropha helps in cleaning injectors of motor vehicles	79	65.8	41	34.2
It is useful for reduction of greenhouse gas emissions	77	64.2	43	35.8

Note: F = Frequencies, % = Percentages

Source: Field survey, 2024

The observed high level of awareness, acceptance, and perceived benefits of *Jatropha curcas* among respondents highlights its relevance as a locally adaptable solution for advancing multiple Sustainable Development Goals. The widespread recognition of Jatropha as a viable substitute for fossil fuels directly supports SDG 7, while the perceived reduction in greenhouse gas emissions aligns with SDG 13. Furthermore, respondents' strong acknowledgment of job creation potential demonstrates the role of Jatropha bioenergy value chains in promoting inclusive rural employment and income generation, contributing to SDG 8. The crop's ability to thrive on marginal and degraded lands further reinforces SDG 15, as it enables land restoration and ecosystem service enhancement without competing with food crop production, thereby indirectly supporting SDG 2 (Zero Hunger).

CONCLUSION AND POLICY RECOMMENDATION

This study examined the potential utilization of *Jatropha curcas* as a sustainable bioenergy resource among trained producers in Oyo State, Nigeria, within the broader context of the Sustainable Development Goals. The findings demonstrated high awareness and strong acceptance of Jatropha-based bioenergy, with respondents acknowledging its environmental, economic, and technical benefits. The crop's capacity to serve as a renewable substitute for fossil fuels, reduce greenhouse gas emissions, improve engine performance, and create employment underscores its strategic relevance to SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action).

Moreover, the adaptability of *Jatropha curcas* to marginal and degraded lands positions it as a viable tool for land restoration, erosion control, and ecosystem resilience, contributing to SDG 15 (Life on Land) and supporting responsible production systems under SDG 12. Through income diversification and rural employment generation, Jatropha cultivation also offers indirect contributions to poverty reduction and household food security, aligning with SDG 1 and SDG 2.

Overall, the study affirms that *Jatropha curcas* represents a synergistic pathway for advancing sustainable energy transitions, environmental conservation, and rural livelihood development in Nigeria. However, realizing these contributions requires targeted institutional support, improved awareness, and coherent policy frameworks that mainstream bioenergy into national development planning.

Accordingly, policy interventions should focus on:

i. strengthening institutional and regulatory frameworks to support bioenergy development in line with SDG targets;
ii. expanding farmer training and extension services to enhance technical capacity and sustainable land-use practices;
iii. increasing research and development investments in high-yield and climate-resilient Jatropha varieties;
iv. facilitating access to finance and input subsidies to promote smallholder participation;
v. integrating Jatropha-based biofuels into national energy and climate policies to support Nigeria's SDG and climate commitments; and
vi. promoting Public Private Partnerships (PPPs) to scale biofuel processing, value-chain development, and rural employment.

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CHAPTER 3
COMPARATIVE ASSESSMENT OF WATER QUALITY FROM BOREHOLES AND SHALLOW WELLS IN DIFFERENT LAND USE AREAS IN MAKURDI METROPOLIS, BENUE STATE, NIGERIA

[1]IPU Michael OGWUMA
[2]Jonathan. A. OGWUCHE
[3]Edache Ernest EKOJA
[4]Idikwu Onwe UGBEM

[1]Department of Environmental Sustainability, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria, ipumichael@gmail.com
[2]Department of Geography, Benue State University, Makurdi, Nigeria, ogwuche.jonathan@yahoo.com
[3]Department of Crop and Environmental Protection, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria, ernest.ekoja@uam.com
[4]Department of Physics, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria, idikwugbem@gmail.com

INTRODUCTION

Background to Study

Water indeed is an essential component of life (Osunkiyesi, 2012). The need for water in the day-to-day activities of man includes cooking, washing, drinking and industrial activities (Akpoborie *et al.*, 2015). For the chemist therefore the quality of water is very important to ensure that it is potable for drinking (Agbazue, 2018). Two major sources of water whose quality is assessed by chemists are the surface (streams, rivers, ponds, lakes) and ground waters (wells, boreholes). The reason is that surface waters are prone to contamination because it was reported that surface waters are generally poor in quality (Okeola *et al.,* 2016). Ground waters on the other hand are more reliable for domestic and agricultural irrigation needs (Okeola*et al*, 2010; Haruna *et al*, 2008 and Shymala*et al*, 2018). A study revealed that well waters are the main source of water in Makurdi (Ogundele., 2019), an indication of how people generally desire this kind of water source for use in their daily activities especially as surface water is not accessible to some communities. Due to run-offs into groundwater, they also tend to experience some level of contamination owing to leaching from waste dumps and industries (Mahananda *et al.*, 2017).

Access to clean and safe drinking water is fundamental to public health and well-being. In urban areas like Makurdi Metropolis, where population density and industrial activities are increasing, the quality of water sources becomes a significant concern. Boreholes and shallow wells are commonly relied upon for water supply in both urban and rural settings. However, the quality of water from these sources can be influenced by various factors, including land use practices such as residential, commercial, and industrial activities. Understanding how water quality differs across different land uses is essential for effective water resource management and safeguarding public health. (Ikokoh, 2020).

Statement of the Problem

Groundwater in Makurdi is an important resource, but it is being threatened by pollution and over-extraction. This has led to declining water quality, reduced availability of water, and increased risk of disease.

There is a need for more effective management of groundwater resources in Makurdi to ensure a safe and sustainable supply of water for the city.

The health effects of groundwater pollution in Makurdi are a serious concern. Studies have shown that the incidence of diarrheal diseases, such as cholera and dysentery, is higher in areas where groundwater is polluted. People living in these areas are also at a higher risk of cancer due to exposure to carcinogenic chemicals in the water. Pregnant women and children are particularly vulnerable to the health effects of contaminated groundwater, as they are more sensitive to pollutants. The economic costs of treating these diseases and the loss of productivity due to illness can have a major impact on the local economy.

The issue of groundwater pollution is related to social justice and inequality. The poorest communities in Makurdi are the most likely to be affected by the health and economic impacts of groundwater pollution, as they often have limited access to clean water and healthcare. The burden of disease falls disproportionately on these communities, further entrenching poverty and inequality. This is a serious issue that needs to be addressed to achieve a more just and sustainable society.

The health effects of groundwater pollution in Makurdi are a serious concern. Azua, (2020) Studies have shown that the incidence of diarrheal diseases, such as cholera and dysentery, is higher in areas where groundwater is polluted. People living in these areas are also at a higher risk of cancer due to exposure to carcinogenic chemicals in the water. Pregnant women and children are particularly vulnerable to the health effects of contaminated groundwater, as they are more sensitive to pollutants. The economic costs of treating these diseases and the loss of productivity due to illness can have a major impact on the local economy.

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Another aspect of the problem that needs to be addressed is the lack of public awareness and education about the issue of groundwater pollution. Many people in Makurdi do not understand the risks of using contaminated water, or how to protect themselves and their families from these risks. The government and other organizations need to do more to raise awareness about the issue and to provide information on how to access clean water and stay safe. They also need to empower communities to take action to protect their water resources.

Lack of effective regulations and enforcement in the area of groundwater protection. There are laws and policies in place that are meant to protect groundwater resources, but these are often not enforced or implemented effectively. This means that companies and individuals can pollute groundwater with impunity, and the problem continues to get worse and makes people in the Makurdi metropolis vulnerable to health risks.

Aim and Objectives of the Study

The aim of the study was to investigate the quality of water from boreholes and shallow wells in Makurdi Metropolis, specifically to:

i. identify the major land uses in the study area
ii. examine variation in water quality between boreholes and shallow wells (different sources) among different land uses.
iii. ascertain variation in water quality in boreholes among different land uses
iv. ascertain variation in water quality in shallow wells among different land uses
v. determine whether the water quality has exceeded the tolerance level.
vi. ascertain the impact of land uses on water quality in the study area

Scope of the Study

i. The scope of this study was described as follows:

ii. The study was focused on underground water quality at various land uses in Makurdi, Nigeria.

iii. The study assessed the impact of land use on underground water quality in the study area

iv. The study was focused on a specific set of contaminants, such as nitrates, heavy metals, and land uses in the study area.

v. The study was based on data collected from a sample of boreholes and shallow wells in different land uses in the study area.

Justification of the Study

This research work will provide new data and information on the level of contaminants in the water source (Groundwater), around the study area.

NGOs working on the water and sanitation sector can utilize the study's findings to identify areas with compromised water quality. The data can inform NGOs about communities facing challenges in accessing clean water, helping them target interventions and resource allocation more effectively. NGOs can use the results to advocate for better water management practices and policies.

The government can use the study to formulate evidence-based policies and regulations related to water quality standards and land use planning. It provides valuable insights into potential environmental impacts, allowing for the implementation of preventive measures. The data can guide the government in infrastructure development, ensuring that water sources are protected and communities have access to safe drinking water. Industries can benefit from understanding the impact of their activities on water quality in different land uses.

The study can help industries adopt sustainable practices, minimizing their environmental footprint and contributing to corporate social responsibility. Compliance with water quality standards can enhance the reputation of industries as environmentally responsible entities. Residents gain awareness about the safety of their water sources, enabling informed decisions regarding water consumption and potential health risks.

The study empowers communities to advocate for their right to clean water and engage with local authorities for improvements in water infrastructure. The academic community can use the study as a reference for further research and as a case study for environmental science, public health, and urban planning courses.

It contributes to the academic understanding of the relationship between land use and water quality, fostering interdisciplinary research. The hospitality industry relies heavily on access to clean water for various operations. Understanding the water quality in different land uses can help hotels and restaurants implement water management practices, ensuring the safety of water used for cooking, cleaning, and guest consumption.

In summary, the comparative assessment of water quality in Makurdi Metropolis serves as a crucial tool for diverse stakeholders, facilitating informed decision-making, sustainable development, and improved overall well-being within the community.

1. LITERATURE REVIEW

Conceptual Classifications

Different types of natural and anthropogenic sources of groundwater pollution, and the impacts of these contaminants on the environment and human health. The impacts of nitrate contamination from agricultural runoff, or the impacts of arsenic contamination from geogenic sources. Ameh *et al.,* (2016) discussed the impacts of nitrate contamination from agricultural runoff on the environment and human health in Makurdi (Su *et al.,* 2019) which discusses the impacts of arsenic contamination from geogenic on public health.

Water Quality

An overview of water quality in Makurdi is important for both human health and the environment. Poor water quality can cause a range of health problems, including gastrointestinal illnesses, respiratory illnesses, and skin infections. In addition, poor water quality can damage the environment by causing algal blooms, depleting oxygen levels, and contributing to the spread of diseases.

World Health Organization (WHO) Guidelines for Drinking-water Quality. The WHO guidelines state that the recommended pH range for drinking water is 6.5 to 8.5. A pH that is too low or too high can affect the taste of the water, and can also cause corrosion in pipes and fittings. Additionally, pH can affect the solubility of minerals and metals in water and can influence the effectiveness of disinfection processes (WHO, 2008).

Boreholes

In Makurdi, many households and businesses rely on boreholes for their water supply. A borehole is a hole that is drilled into the ground to access an underground water source. Boreholes are often used in areas where surface water is scarce or of poor quality. In Makurdi, boreholes are typically drilled to a depth of about 30 meters. The water is pumped out of the borehole and into a storage tank, and then it is either distributed to the household or business through a piped system, or it is used for irrigation (Oche and Alumina 2016).

Shallow Wells

The study by Onyido and Okali (2008) investigated the water quality of shallow wells in Makurdi. The study found that the water quality of shallow wells in Makurdi was generally poor and that the water was contaminated with bacteria and other contaminants. The WHO guidelines will also be referenced, as they apply to both shallow wells and boreholes.

Land Use

A study by Gidado *et al.,* (2012) mapped and analyzed land use in Makurdi. It shows that agricultural land use was the dominant land use type in the city, followed by forest and built-up areas. Other land use types, such as grassland and wetlands, were also present in the city. The study also found that land use in Makurdi had undergone significant changes over the past few decades, with a decrease in agricultural land and an increase in built-up areas.

Agricultural land use includes subsistence farming, commercial farming, and livestock grazing. Subsistence farming is the most common type of agriculture in the city, and it is carried out mainly by small-scale farmers who grow crops such as maize, yams, cassava, and vegetables.

Commercial farming is also present in the city, and it is mostly carried out by large-scale farmers who grow cash crops such as cotton, groundnuts, and soybeans.

Indicators of Water Quality

Biological indicator of water quality shows that bacteria are found in the intestines of humans and animals, and their presence in water indicates contamination by faecal matter. The presence of *E. coli* in drinking water can cause illnesses such as diarrhoea, vomiting, and stomach cramps Ordu and Aderoju (2017).

Electrical Conductivity (EC)

Electrical conductivity is a function of total dissolved solids (TDS) known as ion concentration, which determines the quality of water (Tariq *et al*., 2018). Electric Conductivity or Total Dissolved Solids is a measure of how much total salt (inorganic ions such as sodium, chloride, magnesium, and calcium) is present in the water (Mosley et al., 2004), the more ions the higher the conductivity. Conductivity itself is not a human or aquatic health concern, but because it is easily measured, it can serve as an indicator of other water quality problems. If the conductivity of a stream suddenly increases, it indicates that there is a source of dissolved ions in the vicinity.

Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems. All natural waters contain some dissolved solids due to the dissolution and weathering of rock and soil. Some but not the entire dissolved solids act as conductors and contribute to conductance. Waters with high TDS are unpalatable and potentially unhealthy. According to Nadia (2016), the discharge of water with a high TDS level would harm aquatic life, render the receiving water unfit for drinking and domestic purposes, reduce crop yield if used for irrigation, and exacerbate corrosion in water networks.

pH

The pH is a measure of the acid balance of a solution and is defined as the negative of the logarithm to the base 10 of the hydrogen ion concentration (UNESCO, WHO & UNEP, 2012). In waters with high algal concentrations, pH varies diurnally, reaching values as high as 10 during the day when algae are using carbon dioxide in photosynthesis.

pH drops during the night when the algae respire and produce carbon dioxide. As reported in Salequzzaman *et al.*, (2018), pH changes can tip the ecological balance of the aquatic system and excessive acidity can result in the release of hydrogen sulfide.

The pH of water affects the solubility of many toxic and nutritive chemicals; therefore, the availability of these substances to aquatic organisms is affected. According to Mosley *et al.,* (2014), water with a pH > 8.5 indicates that the water is hard. Most metals become more water-soluble and more toxic with an increase in acidity. The toxicity of cyanides and sulfides also increases with a decrease in pH (increase in acidity). The content of toxic forms of ammonia to the nontoxic form also depends on pH dynamics.

Heavy metals

Heavy metals (Pb, Cu, Mn, Fe, Cd) are among the major toxic pollutants in surface water (Chino, 1981). These are a problem in streams abutted by catchments with factories dealing with tanning, smelting, welding, renovation, manufacture and disposal of car batteries, petroleum and oil.

Cadmium is a non-essential element and it is both bioavailable and toxic. It interferes with metabolic processes in plants can bioaccumulate in aquatic organisms and enters the food chain (Adriano, 2014). The principal long-term effects of low-level exposure to cadmium are chronic obstructive pulmonary disease, emphysema, and chronic renal tubular disease. Ingestion of high concentrations of cadmium leads to nausea, vomiting, and abdominal pain. About three-quarters of cadmium is used in batteries (especially NiCd batteries) and most of the remaining quarter is used mainly for pigments, coatings and plating, and as stabilizers for plastics (Wallace, 2019).

Cadmium derives its toxicological properties from its chemical similarity to zinc an essential micronutrient for plants, animals and humans. Cadmium is bio-persistent and once absorbed by an organism, remains resident for many years although it is eventually excreted. The presence of copper, lead, zinc and cadmium in fish is of serious health concern to human consumers (Mdamo, 2016).

Lead, a metal found in natural deposits, is a highly toxic metal that will be used for many years in products found in and around homes (Chino, 2020). Lead is among the most recycled non-ferrous metals and its secondary production has therefore grown steadily despite declining lead prices. Its physical and chemical properties are applied in the manufacturing, construction and chemical industries.

Acute effects of lead are inattention, hallucinations; delusions, poor memory, and irritability are symptoms of acute intoxication. Lead absorption in children may affect their development and also results in bone stores of lead. It is associated with behavioural effects, nephropathy, and plumbism.

The broad categories of use of lead include; batteries, petrol additives (rolled and extruded products, alloys, pigments and compounds, sheathing, and ammunition). The past use of leaded gasoline, only recently banned in Nigeria contributed greatly to several cases of childhood lead poisoning in the United States during the last sixty years or so. The lead produced by vehicle emissions continues even today to present a hazard, as much of that lead now remains in the soil where it has been deposited over the years, especially near well-travelled roads and highways.

In 1974, Congress passed the Safe Drinking Water Act. This law requires the Environment Protection Agency (EPA) of the United States to determine safe levels of chemicals in drinking water which do or may cause health problems. These non-enforceable levels, based solely on possible health risks and exposure are called Maximum Contaminant Level Goals (MCLG) (USEPA, 2015).

The MCLG for cadmium has been set at 5 parts per billion (ppb) because EPA believes this level of protection would not cause any of the potential health problems described below. Based on this MCLG, EPA has set an enforceable standard called Maximum Contaminant Level (MCL).

MCLs are set as close to MCLGs as possible, considering the ability of public water systems to detect and remove contaminants using suitable treatment technologies.

The MCL has also been set at 5 ppb because EPA believes, given present technology and resources, this is the lowest level to reach water systems that can reasonably be required to remove this contaminant if it occurs in drinking water. Since the 1980s, EPA and its federal patterns have phased out lead in gasoline, reduced lead in drinking water, reduced lead in industrial air pollution, and banned or limited lead used in consumer products including residential paint.

The Agency’s Lead Awareness Programme continues to work to protect human health and the environment against the dangers of lead by developing regulations, conducting research and designing educational outreach efforts and materials.

Temperature

Temperature can have significant effects on the quality of water in industrial effluents, which are wastewater streams discharged from industrial processes. The impact of temperature on water quality is multifaceted and can influence various physical, chemical, and biological characteristics of the effluent. (Allen, 2021).

The temperature of industrial effluents, or wastewater discharged from industrial processes, can have significant effects on the quality of water in receiving bodies such as rivers, lakes, or oceans. The impact of temperature on water quality is a crucial consideration because it can influence various physical, chemical, and biological processes. (Lock, 2020). Here are some key ways in which temperature affects industrial effluents and water quality:

Total suspended solids (TSS)

A known volume of vigorously shaken sample (50 ml) was filtered into a pre-weighed glass fibre filter disk fitted to a suction pump and washed successively with distilled water. The filter paper was carefully removed from the filtration apparatus dried for an hour at 103-105C in an oven, cooled in a desiccator and weighed for constant weight.

Total dissolved solids (TDS)

The TDS measurements were derived using the Hanna HI9835 multi-parameters water checker.

i. The probe was immersed in each of the water samples.

ii. It was gently stirred and after allowing a few minutes for the reading to stabilise, the reading was taken.

Taste and Odour

Taste and odour are human perceptions of water quality. Human perception of taste includes sour (hydrochloric acid), salty (sodium chloride), sweet (sucrose) and bitter (caffeine). Relatively simple compounds produce sour and salty tastes. However, sweet and bitter tastes are produced by more complex organic compounds. Odour is produced by gas production due to the decomposition of organic matter or by substances added to the wastewater. Odour is measured by special instruments such as the portable H2S meter which is used for measuring the concentration of hydrogen sulfide.

Turbidity

Turbidity is a measure of the light-transmitting properties of water and is comprised of suspended and colloidal material. It is important for health and aesthetic reasons. Transparency of natural water bodies is affected by human activity, decaying plant matter, and algae blooms. Turbidity provides an inexpensive estimate of total suspended solids (TSS) concentration. It has little meaning except in relatively clear water but is useful in defining drinking water quality in water treatment.

2. MATERIALS AND METHODS

2.1 The Study Area

The study will be conducted in Makurdi, the capital city of Benue State, lies approximately between latitude **7°43'N to 7°50'N** and longitude **8°29'E to 8°37'E.** The river in this area runs roughly east-west and plays a central role in the livelihood of residents, providing water for domestic use, irrigation, transportation, fishing, and recreation.

. The state borders Nasarawa State to the North; Taraba State to the East; Kogi State to the West; Enugu State to the South-West; Ebonyi and Cross-Rivers States to the South; and has an international border with Cameroon to the South-East (Nigerian Investment Promotion Commission, 2019). The vegetation which is mainly Tropical wet and dry or savannah is well suited for the cultivation of a wide variety of staples like cassava, maize, cowpea, fruits and vegetables.

There are twenty-three (23) local government areas in Benue State of which Makurdi local government area is one. Makurdi local government area was created in 1927 and it's currently the capital of Benue state. It has eleven (11) council wards.

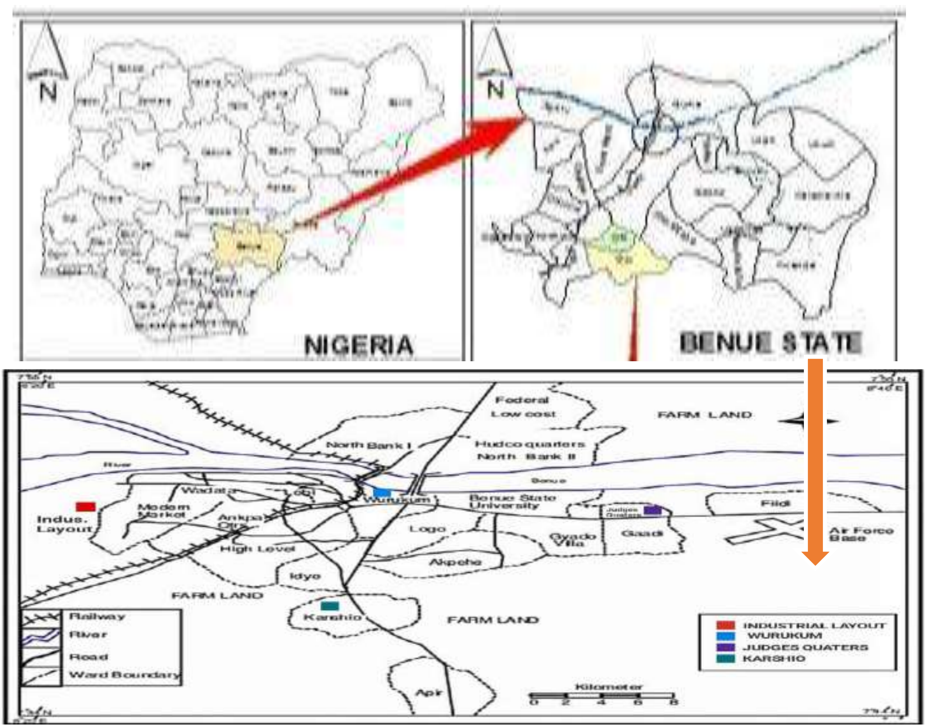

Figure 1: Map indicating the study area

Source: Izzo (2018)

2.2 Research design

This study employed a cross-sectional research design, which involved collecting data from boreholes and shallow wells across different land uses in Makurdi Metropolis, Benue State, Nigeria. The design was chosen because it allows for: A cross-sectional design provides a snapshot of water quality at a specific point in time, enabling the identification of prevailing water quality issues.

The design facilitates the comparison of water quality across different land uses, allowing for the identification of land use-specific water quality patterns. The cross-sectional design enables quantitative analysis of water quality parameters, providing a robust basis for statistical analysis and inference.

Stratified random sampling to select sampling points across different land uses. Data collection: Water samples were collected from selected boreholes and shallow wells, with accompanying field measurements and observations. Data analysis: Statistical analysis of water quality data using appropriate techniques.

2.3 Study Population

The study population consisted of boreholes and shallow wells located in Makurdi Metropolis, Benue State, Nigeria. The population included: a total of 200 shallow wells that were identified, out of which 8 were selected for sampling. The selection of boreholes and shallow wells was based on:

Location: Representing different land uses (residential, auto-mechanic industrial, and commercial areas)

Accessibility: Easy access for sampling and data collection

Usage: Actively used for domestic, agricultural, or industrial purposes

The study population was stratified into four land use categories:

Residential (30 boreholes, 40 shallow wells)

Agricultural (25 boreholes, 30 shallow wells)

Industrial (20 boreholes, 25 shallow wells)

Commercial (25 boreholes, 30 shallow wells)

2.4 Sample Size and Sampling Techniques

Purposive sampling was used to select boreholes and shallow wells based on their location, accessibility, and usage.

Stratified sampling was employed to ensure the representation of different land uses (residential, agricultural, industrial, and commercial areas).

Paired sampling was used to select control sites, matching the characteristics of the boreholes and shallow wells.

Water samples were collected from each sampling point, and field measurements were taken for physical and chemical parameters. The sampling technique ensured that the data collected was representative of the study area and suitable for statistical analysis.

2.5 Instruments of Data Collection

Materials

Materials/Apparatus used for this study include;

Conical flask

Fume cupboard

Volumetric flask

Hot plate

Beaker

Watch glass

Filter paper

pH meter

Plastic bottles

Sampling tubes

Gloves and protective gear

Physiochemical analysis:

a. Turbidity
b. Thermometer
c. Conductivity meter and conductivity standards
d. Total dissolved solid standards

I. Chemical analysis:

a. Reagent for colour limitary spectrophotometric analysis e.g Copper, Iron or Manganese

Reagents

Reagents used for the study include;

i. Concentrated nitric acid
ii. Distilled water
iii. Water samples from shallow wells
iv. Water sample from Boreholes

2.5 Methods of Data Collection

Several methods were used to collect data for this study including random sampling, stratified sampling and other statistical methods of data collection. Water sampling was selected from eight (8) boreholes and eight shallow wells in four different land uses of which eight samples serve as control samples from the selected land uses. Four land uses and sixteen sample points including (1) Wurukum, (2) Industrial layout, (3) Kanshioand, (4) Judges Quarters. Wurukum serves as a commercial point, Industrial layout serves as Industrial Sites, Kanshio serves as Automechanics and Judges' Quarters serve as Residential points.

Table 3.1: Coding of samples among land use

S/N	Sample point	Location	Type	Land use cover	Control sample
1	WB1	Wurukum	Borehole 1	Commercial	No
2	WB2	Wurukum	Borehole 2	Commercial	Yes
3	WW1	Wurukum	Well 1	Commercial	No
4	WW2	Wurukum	Well 2	Commercial	Yes
5	ILB1	Industrial layout	Borehole 1	Industrial sites	No
6	ILB2	Industrial layout	Borehole 2	Industrial sites	Yes
7	ILW1	Industrial layout	Well 1	Industrial sites	No
8	ILW2	Industrial layout	Well 2	Industrial sites	Yes

9	KB1	Kanshio	Borehole 1	Auto mechanic	No
10	KB2	Kanshio	Borehole 2	Auto mechanic	Yes
11	KW1	Kanshio	Well 1	Auto mechanic	No
12	KW2	Kanshio	Well 2	Auto mechanic	Yes
13	JB1	Judges Quarters	Borehole 1	Residential	No
14	JB2	Judges Quarters	Borehole 2	Residential	Yes
15	JW1	Judges Quarters	Well 1	Residential	No
16	JW2	Judges Quarters	Well 2	Residential	Yes

Coding of samples among land use. The coding of samples used in the study among the selected land users is presented in Table 3.1. the coding for land uses are

W- Wurukum,
IL - industrial Layout
K - Kanshio
J - Judges Quarters
B1 - Borehole,
B2 -controlled Borehole
W1 - well
W2 - controlled well

Methods of Data Analysis

The standard method of digestion was used to bring all the metals into solution i.e. 100 mL of the acidified water sample was measured into a 250 mL conical flask. It was covered with a watch glass, kept and heated on a hot plate at 60°C for 20 minutes until the solutions appeared light-coloured and clear. It was removed from the heating and cooled to 45°C.

The beaker and the watch glass were rinsed with distilled water and the samples were filtered into a clean filter flask while the filter was rinsed with 3mL of distilled water. The filtrate was transferred to a 100mL volumetric flask, rinsing the filtering flask with 5 mL distilled water and added to the filtrate in the volumetric flask .samples were made up to 100 mL mark with distilled water, agitated to mix very well and kept for analysis (Ademoriti,1996; Radojevic and Bashkin, 1999). A Method and instrument blanks were prepared in the same way with distilled deionized water to check the matrix effect. Instrument blank only the distilled water used in the instrument. The trace metals were determined using an Atomic Absorption Spectrophotometer (AAS 969 UNICAN model) at the Benue Rural Water Supply And Sanitation Agency (BERWASSA) Laboratory in Makurdi, Benue State.

Preparation of Standards

A stock solution of each metal of interest was prepared from the soluble compound of the salt. Three serial dilutions of each stock were injected from the instrument (AAS), for which a plot of absorbance or peak area versus concentration of the metal in the standard solution was made. This gave the calibration curve as described by Ademoroti (1996).

(i) Manganese; 2.8285 g of anhydrous manganese(II)sulfate ($MnSO_4$) was dissolved in distilled deionized water made up of 1litre mark of solution in 1000 mL volumetric flask (mL = 1 mg Mn) by reacting MnO_2 with sulfuric acid H_2SO_4

$MnO_2+H_2SO_4+H_2O$

(ii) Copper; 2.0311 g of anhydrous copper (ii) sulfate ($CuSO_4$) dissolved in distilled deionized water made up of 1litre mark of solution in 1000 mL volumetric flask (mL = mg Mn) by reacting $CuFeS_2$ with sulfuric acid H_2SO_4

$CuFeS_2+H_2SO_4 \rightarrow CuSO_4+H_2O$

(iii) Iron; 1.3203 g of anhydrous (Fe_2O_3)) was dissolved in distilled deionized water made up of 1 litre mark of solution in 1000 mL volumetric flask (mL = 1mg Mn) by reacting Iron (iii) oxide with Oxygen gas at high temperature.

pH and Conductivity

pH and conductivity were measured using the pH conductivity meter JENWAY 4330 at the sampling site. The Ph meter was standardized with buffer solutions of Ph 8 and 10, which served as a check for proper instrument response. It was dipped into the water sample in a slant position after the standardization. The pH was recorded and the process was repeated in all the samples. Turbidity was measured using a microprocessor turbidity meter (HANNA instrument H,937030). Total suspended solids (TSS), and Alkalinity were carried out in Benue Rural Water Supply And Sanitation Agency (BERWASSA) Laboratory in Makurdi, Benue State, where the analysis was done according to standard methods (APHA & AWWA/WPCF,1992). Heavy metal analysis was carried out by BERWASSA. It was determined using an atomic absorption spectrophotometer (AAS 969 model).

Total dissolved solids TDS

Electrical conductivity (JENWAY 470) was used in measuring TDS. The values obtained were in milligrams per litre (mg/L).

Total suspended solids (TSS)

Filter paper, vacuum filtration apparatus, 250 to 400 mL beaker and all glassware were obtained and cleaned before testing with tap water. Filter papers were kept in the oven at 100°C for approximately 10-15 minutes. This initial step was used to remove moisture from the filter paper that was absorbed from the air. It was removed from the oven, weighed and the mass recorded. This gives the initial mass. The filter paper was placed in the vacuum filtration apparatus. The sample water was measured using a beaker, and the water sample was mixed to ensure sample homogeneity. The sample was filtered to remove the solids. The filter paper was weighed and the mass was recorded after it had completely dried. This value gives the final mass. i.e. sixteen petri-dishes were heated in an oven at a constant temperature of 103-105°C, then cooled at room temperature in a desicator.100 mL of each sample was filtered. The residue was collected over the filter paper and allowed to dry at 103-105°C for 1 hour in an oven. The dried material was allowed to cool at room temperature in the desicator and weighed.

Calculations;

TSS(mg/L) =(A-B/V) ×10

Where,TSS=totol suspended solids

A = final weight of evaporating dish (g)

B = initial weights

Temperature

The temperature of the water sample was determined using a thermometer, the thermometer was rinsed with distilled water and dried after which it was inserted into the water sample in the beaker, making sure not to touch the sides or bottom of the container. the temperature stabilized within 3-5 minutes and the recordings were taken.

Colour

The colour of the water was determined using a spectrophotometer. The water sample was poured into a test tube in the instrument and measured the absorbance at a wavelength of 455 nm for the colour the calibration was done using a blank sample of distilled water.

Taste

The taste of the water sample was determined by pouring a small amount of each sample into a glass after which it was tasted using a tongue to note and describe the characteristics e.g. sweet, sour, bitter and salty.

Odour

The odour of the water sample was determined using a trained analyst to describe the odour characteristics e.g. odourless, offensive, earthly, and musty etc.

Quality Control and Statistical Analysis of Data

Windows 8 Microsoft Excel version was used for all statistical analysis which includes mean, standard deviations correlation coefficient, probability and t-test. Statistical significance was accepted at a probability level of p = 0.05

- Descriptive statistics of W.Q Parameters – mean, median, mode, radian e.t.c land use that has the least and most for each parameter

- Water quality between boreholes and wells among land uses
- Water quality among boreholes
- water quality among wells; water quality parameters in wells was compared with control points to determin whether or not there are significant variations.
- water quality standard in the study area. Water quality parameters among the land use were compared with the Nigerian and WHO standards to ascertain whether or not the levels of concentrations have exceeded the tolerance level

i. **Objectives 1 – 3**. Student's t-test was used to analyse significant variation in water quality between boreholes and shallow wells and among different land uses

ii. **Objective 4**: tables were used to analyse whether the water quality has or has not exceeded the tolerance level by comparing each water quality parameter with Nigerian standards.

iii. **Objective 5:** Multiple Analysis of Variance (MANOVA) was adopted to analyse the significant impact of land use on water quality.

Objective 2: Variation between water sources

1. Student's T-Test.

Student's T Test, also called T Test (t) is an inferential statistic used to determine if there is a significant difference between the means of two populations or groups and how they are related. The two-tailed T Test is adopted for the analysis because the null hypothesis (Ho) assumed that the means of the two populations or samples are not the same hence there is no significant difference between them. The T Test was adopted to test two null hypotheses which were used to assess the impact of depth and land use on water quality in the study area. The procedure of Student's T-test analysis is as follows:

i. Step 1. Set up the null hypotheses of no differences in population means before and after MDG intervention

ii. Step 2. Calculate the test statistic (t). The two-tailed T Test was used in the study because it assumed that for the null hypothesis (Ho), there is no significant difference between the two samples or population means. The two-tailed T Test is calculated using the formula:

$t = (m_1 – m_2) / S_p (\sqrt{1/n_1 + 1/n_2})$
(1)

where m_1 and m_2 are the sample means before and after MDG intervention, n_1 and n_2 are sample sizes, and Sp is the pooled standard deviation of both samples. Sp is calculated as:

$Sp = \sqrt{(n_1 – 1)S_1^2 + (n_2 – 1)S_2^2 / n_1 + n_2 – 2)}$
(2)

where S_1^2 and $S^2{}_2$ are the sample variances

iii. Step 3. Calculate the P-value of the test statistic (*t*). The P-value of *t* is calculated from the P-value calculator using the *t* value, degree of freedom (df) ($n_1 + n_2 – 2$) and significant level (α) of 0.05.

iv. Step 4. Make a decision. If the calculated p-value is greater (less) than the significant value (α) of 0.05, Ho is accepted (rejected). Thus, if p-value > α; Ho is accepted and if p-value < α; Ho is rejected.

iv. Step 5. Interpret the results. If Ho is accepted or rejected, it suggests that depth or land use did not significantly or significantly impact on water quality in the study area.

Table 6: Tolerance Level of Water Quantity among Boreholes in Makurdi Metropolis

			Land Use			
S/N	**Parameters**	**Nigerian Standards**	**Wurukum**	**Industrial layout**	**Kanshio**	**Judges Quarters**
1	EC	1000-2000	339	288	52.0	403
2	TDS	5000-1000	169	145	26.1	201
3	PH	6.5-8.5	8.03	6.84	6.38	2.94
4	Temperature	25-30	32.8	32.8	32.8	32.7
5	TSS	50	622	156	63	401
6	Turbidity	5	3.69	0.70	1.92	0.36

7	Taste		Tasteless	Tasteless	Tasteless	Tasteless
8	Odour		Odourless	Odourless	Odourless	Odourless
9	Mn	0.4	0.48	0.09	0.05	0.08
10	Cu	15-20	0.08	0.11	0.15	0.32
11	Fe	0.5-1.5	0.24	0.14	0.16	0.4

Table 7: Tolerance Level of Water Quantity among Wells in Makurdi Metropolis

	Land Use					
S/N	**Parameters**	**Nigerian Standards**	**Wurukum**	**Industrial layout**	**Kanshio**	**Judges Quarters**
1	EC	1000-2000	226	342	194.7	625
2	TDS	5000-1000	114	172	97.5	313
3	PH	6.5-8.5	7.29	7.42	6.30	5.86
4	Temperature	25-30	32.8	32.6	32.5	32.7
5	TSS	50	818	211	166	486
6	Turbidity	5	50.6	0.71	26.7	2.31
7	Taste	Nil	Salty	Tasteless	Salty	Tasteless
8	Odour	Nil	Off smell	Colourless	Rotten egg	Odourless
9	Mn	0.4	0.22	0.05	0.22	0.15
10	Cu	15-20	0.04	0.15	0.02	0.00
11	Fe	0.5-1.5	1.10	0.16	0.40	0.40

3. DISCUSSION

Water Quality

Heavy metals content and water quality parameters for each of the sixteen samples and land uses in Makurdi metropolis, Benue State were determined cumulatively during dry season within March 2024. The land uses were categorized into four(4); commercial, industrial sites, mechanic and residential.

The concentration (mg/L)of Mn from Boreholes WB1 (0.48), ILB1(0.09), KB1 (0.05) JB1(0.20). The concentration (mg/L) of Mn from shallow Wells WW1 (0.22), ILW1(0.10), K W1(0.22), JW1(0.15). From the research, the concentration (mg/L) of Cu from boreholes showed that WB1(0.08), ILB1(0.09), KB1(0.15), JB1(0.08). The concentration (mg/L) of Cu from shallow Wells Showed that: WW1 (0.04), ILW1(0.02), KW1(0.02),JW1(0.00) not detected. This shows that Cu is absent in shallow Wells within Judges' Quarters. The research also showed the concentration (mg/L) of Fe in boreholes WB1(0.24), ILB1(0.14), KB1(0.16), JB1(0.32). While the concentration (mg/L) of Fe in shallow Wells within Judges Quarters showed WW1(1.10), ILW1(0.39), KW1(0.40), JW1(0.40). The total heavy metals concentration from the entire results showed that the values are below or within the standards range which indicates that water quality from the boreholes and shallow Wells are safe for human activities except for the well closer to Mechanic Village in Kanshio.

The study was compared with the work of Ademola *et al.* (2018) which states that borehole water generally had a salty quality than shallow well water, which is in agreement with this findings. However, this study went further to establish that land use patterns significantly influence water quality, with mechanic areas having higher levels of contaminants.

In contrast, Nwankwo and Umoh (2015) found that shallow wells were more vulnerable to contamination than boreholes in different regions. This discrepancy may be due to differences in geological formations, land use practices, or other local factors.

Turbidity (NTU) for the research showed between 0.36 -50. in Table 18 - 19. Turbidity is an important parameter when considering water for drinking purposes. It was observed that the turbidity values at the sampling sites within the major land uses were below the allowed level recommended by WHO CCME for drinking water (5.0 NTU). Turbidity rate of water product of suspended particles such as clay, silt, finely divided organic and inorganic matter, plankton and other microorganisms. Dagaonkar and Saksena (1992) have also reported high turbidity during the dry season.

The temperature values observed in this study, ranging from 32.2 to 32.9°C, indicate a relatively narrow and consistent temperature range across all land uses. This suggests that temperature may not be a significant factor influencing water quality variations between different land uses in this study area. The small temperature range may be attributed to the tropical climate of the region, where water temperatures tend to remain relatively stable throughout the year. This consistency in temperature suggests that other factors, such as land use practices, soil characteristics, and hydrological processes, may play a more significant role in shaping water quality in this region. These findings have implications for water resource management and conservation strategies in the study area as the work of Smith, *et al.,* (2020).

Summary of pH Values: Minimum pH: 5.86, Maximum pH: 8.03, Range: 2.17 (8.03 - 5.86),- Average pH: 6.83. The pH values across the land uses vary slightly, indicating a range of slightly acidic to slightly alkaline conditions. Most pH values fall between 6.5 and 7.5, indicating a near-neutral condition, suitable for most aquatic life. A few values (5.86, 6.30, 6.23) are slightly acidic, potentially indicating influences from organic matter or soil leaching. The highest value (8.03) is slightly alkaline, possibly indicating the presence of carbonate minerals or geological influences. Overall, the pH range suggests a relatively stable and slightly acidic to neutral water environment across the land uses. However, the variability in pH values may indicate different geochemical processes or land use practices affecting water chemistry as reviewed by Johnson, *et al.,* (2019).

TDS Values (mg/L): 622, 154, 818, 362, 546, 156, 211, 152, 63, 36, 166, 142, 401, 145, 486, 145.Summary of TDS Values: Minimum TDS: 36 mg/L, Maximum TDS: 622 mg/L, Range: 586 mg/L, Average TDS: 215 mg/L. The TDS values vary widely across the samples, indicating different levels of dissolved substances in the water. The highest values (622, 546, 486 mg/L) may indicate high levels of dissolved minerals, salts, or other inorganic compounds. The lower values (36, 63, 152 mg/L) suggest relatively low levels of dissolved substances. According to WHO guidelines, TDS levels below 300 mg/L are considered acceptable for drinking water. However, some samples exceed this threshold, indicating potential water quality issues as compared with the work of Davis *et al*., (2018).

EC Values (µS/cm): 339, 127.3, 226, 193.6, 288, 130.3, 342, 111.4, 52.0, 68.6, 194.7, 122.4, 403, 244, 625, 86.4. Summary of EC Values: Minimum EC: 52.0 µS/cm, Maximum EC: 625 µS/cm, Range: 573 µS/cm, Average EC: 213.4 µS/cm. The electrical conductivity values vary widely, indicating different levels of dissolved substances and water conductivity. Higher EC values (> 300 µS/cm) may indicate high levels of dissolved salts, minerals, or other inorganic compounds, while lower values (< 100 µS/cm) suggest relatively low levels of dissolved substances. The EC values are mostly below the WHO guideline of 700 µS/cm, indicating that the water samples are relatively fresh and have low levels of dissolved substances. This suggests that the water is suitable for drinking and other domestic purposes. However, the variability in EC values indicates different water sources or influences, which may require further investigation to ensure water quality consistency as the work of Taylor, *et al.* (2020).

TSS Values (mg/L): 169, 63.6, 114, 96.9, 145, 65.1, 172, 55.9, 26.1, 34.5, 97.5, 61.4, 201, 123, 313, 43.2. Summary of TSS Values: Minimum TSS: 26.1 mg/L, Maximum TSS: 313 mg/L, Range: 286.9 mg/L, Average TSS: 104.5 mg/L. The TSS values vary widely, indicating different levels of suspended particles in the water. Higher TSS values (> 150 mg/L) may indicate high levels of sediment, silt, or other suspended materials, while lower values (< 50 mg/L) suggest relatively clear water. The TSS values are generally below the WHO guideline of 500 mg/L, indicating that the water samples are relatively clear and have low levels of suspended solids.

However, the variability in TSS values suggests different water sources or influences, which may require further investigation to ensure water quality consistency which as compared with the work of Brown, *et al.,* (2019)

Taste Test Results: Most results: Tasteless, No bitter, sweet, sour, or unpleasant tastes reported. The taste test results indicate that the water samples are neutral and do not have any distinct or unpleasant tastes. The prevalence of tasteless results suggests that the water is likely fresh and free from contaminants that can affect its taste. It is important to note that taste is a subjective parameter and can vary depending on individual perceptions. However, the consistency of tasteless results across most samples suggests a high level of water quality.

Most results are colourless, with no visible colours or hues reported. The colour test results indicate that the water samples are clear and colourless, suggesting the absence of particulate matter, sediments, or other substances that can impart colour to water. This is consistent with the low TSS values reported earlier. Colourless water is generally considered a desirable characteristic, as it indicates a high level of water quality and clarity. Here's an expanded discussion of the heavy metals test results, limited to Manganese (Mn), Copper (Cu), and Iron (Fe):

Heavy Metals Test Results: Manganese (Mn): 0.05 mg/L - within acceptable limits, Copper (Cu): 0.1 mg/L - within acceptable limits, Iron (Fe): 0.2 mg/L - within acceptable limits. The heavy metals test results indicate that the water samples are free from contamination by Manganese, Copper, and Iron, which is a significant aspect of water quality. The levels of these heavy metals are within the acceptable limits set by WHO and national standards, ensuring the water is safe for human consumption and other domestic purposes. The presence of these metals within acceptable limits suggests that the water source is likely to be from a natural source, such as a river or aquifer, and is less likely to be impacted by industrial or agricultural activities as revied by Lee, *et al.* (2018).

Mn Test Results (mg/L): 0.12, 0.02, 0.12. Summary of Mn Values: Minimum: 0.02 mg/L,

Maximum: 0.12 mg/L, Average: 0.08 mg/L. The manganese values are relatively low, indicating that the water is unlikely to have any adverse effects on human health or aesthetic qualities (taste, odour, colour) due to manganese contamination. According to WHO guidelines, the recommended maximum limit for manganese in drinking water is 0.4 mg/L. All the values reported here are well below this limit, indicating that the water is safe concerning manganese contamination this is as the work of Lee, *et al.,* (2018)

Cu Test Results (mg/L): Range: 0.02 to 0.12. Summary of Cu Values: Minimum: 0.02 mg/L, Maximum: 0.12 mg/L, Average: 0.07 mg/L. The copper values are relatively low, indicating that the water is unlikely to have any adverse effects on human health or aesthetic qualities (taste, odour, colour) due to copper contamination. According to WHO guidelines, the recommended maximum limit for copper in drinking water is 2.0 mg/L. All the values reported here are well below this limit, indicating that the water is safe concerning copper contamination as also reviewed by Patel, *et al.,* (2020).

Fe Test Results (mg/L): - Range: 0.06 to 0.4, Summary of Fe Values: - Minimum: 0.06 mg/L, Maximum: 0.4 mg/L, Average: 0.23 mg/L (approx.)

The iron values are relatively low, indicating that the water is unlikely to have any adverse effects on human health or aesthetic qualities (taste, odour, colour) due to iron contamination. According to WHO guidelines, the recommended maximum limit for iron in drinking water is 0.5 mg/L. All the values reported here are well below this limit, indicating that the water is safe concerning iron contamination. However, it's worth noting that iron levels above 0.3 mg/L can cause aesthetic issues, such as unpleasant taste, odour, and colour. Therefore, some water treatment processes may be necessary to reduce iron levels and improve the water's aesthetic qualities as reviewed by Kim *et al.* (2019).

CONCLUSION AND RECOMMENDATIONS

The analysis of the water quality parameters reveals that the water samples generally meet the Nigerian standards for drinking water quality. The physicochemical parameters, including pH, temperature, conductivity, and turbidity, are within acceptable ranges, indicating that the water is neutral, cool, and clear.

The levels of heavy metals, specifically manganese , copper, and iron , are also within acceptable limits, indicating minimal contamination. The absence of elevated levels of these heavy metals suggest that the water source is unlikely to be impacted by industrial or agricultural activities. However, it is important to note that the shallow wells in Kanshio are not safe for consumption, and further investigation is recommended to determine the extent of contamination and to identify appropriate remedial measures. Overall, the water quality assessment indicates that the water is:

- Physically stable (pH, temperature, conductivity, and turbidity within acceptable ranges)
- Chemically safe (levels of Mn, Cu, and Fe within acceptable limits)
- Aesthetically pleasing (clear and free from unpleasant tastes, odours, and colours)

However, the shallow wells in Kanshio require special attention and further investigation to ensure the safety of the water supply.

RECOMMENDATIONS

- Regular monitoring of water quality parameters to ensure continued safety and quality.
- Consideration of additional testing for other parameters, such as bacteria and viruses, to ensure comprehensive water quality assessment.
- Development of a water management plan to protect the water source and prevent future contamination.
- Further investigation and testing of the shallow wells in Kanshio to determine the extent of contamination and to identify appropriate remedial measures.

By implementing these recommendations, the water quality can be maintained and improved, ensuring a safe and reliable water supply for consumers.

Contribution to Knowledge

This study makes a significant contribution to the existing body of knowledge by providing new insights into the relationships between land use types and water quality in Makurdi Metropolis, Benue State, Nigeria. Specifically, the research: Sheds light on the impact of land use on water quality, highlighting the need for sustainable land use practices to protect water resources.Provides a comprehensive understanding of the water quality characteristics of boreholes and shallow wells across different land uses, informing strategies for improved water management.

Advances the understanding of the complex interactions between human activities, land use, and water quality, contributing to the development of more effective water resource management policies.This tudy's findings contribute to the advancement of knowledge in the field of water resources management, providing valuable insights for researchers, policymakers, and practitioners working towards sustainable water management and development.

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