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# CONTENTS

	<b>PAPER TITLE/AUTHOR(S)</b>	<b>PAGE</b>
1	<b>Education Financing: An Impetus for Achieving Inclusive Growth and Sustainable Development in Nigeria</b> <sup>1</sup> Nuhu Musa, <sup>2</sup> Ali Maji & <sup>3</sup> Ibrahim Yusuf Ajogwu	1
2	<b>How to Prepare Floodplains for Climate Change</b> Jane Marsh	15
3	<b>Engineering the Built Indoor Environment; Strategies for Achieving Energy Efficiency and Sustainable Thermal Environment in Nigeria</b> <sup>1</sup> J. O. Abalum & <sup>2</sup> G. C. Alozie	18
4	<b>Solar Panels and their Effect on the Environment</b> Justin Myers	33
5	<b>Impact of Gully Erosion on the Residents of Kontagora, Niger State</b> <sup>1</sup> Iwalaiye Elizabeth Mayokun & <sup>2</sup> Arowolo Jacob Gbemiga	37
6	<b>Challenges and Prospects of Integrating Information and Communication Technology in Adult Education in Nigeria</b> Omosohwofa Felix Aredia	50
7	<b>The Effect of Military Internal Operations in Plateau State, Nigeria: Militating or Gravitating Insecurity?</b> <sup>1</sup> Sulaiman T. H., <sup>2</sup> Abalaka, J. N., & <sup>3</sup> Ajiteru, S. A. R.	58
8	<b>Towards Compliance Assurance with Data Protection Regulations in SAAS Applications</b> Hammajam Ahmed Adamu	73



## Education Financing: An Impetus for Achieving Inclusive Growth and Sustainable Development in Nigeria

<sup>1</sup>Nuhu Musa, <sup>2</sup>Ali Maji & <sup>3</sup>Ibrahim Yusuf Ajogwu

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### Abstract

The study seeks to examine the nexus between higher education financing, inclusive growth and sustainable development in Nigeria using annual time series data from 1990 to 2021 fiscal year. It employs auto-regressive distributed lag (ARDL) model and granger causality test to ascertain the long-run impact and causal relationship between higher education financing, and inclusive growth. GDP per capita was regressed on higher education expenditure (HEDU), unemployment rate (UNM), human capital proxy by gross tertiary education enrolment, population growth rate (POPGR) and corruption perception index (CORR). Results indicated that higher education expenditure exerted positive and insignificant impact on inclusive growth, but corruption perception index negatively influenced growth. The results of Granger causality test showed evidence of bi-directional causal relationship between GDPPC and HEDU. The study concludes that higher education financing is vital for the attainment of inclusive growth and sustainable development in Nigeria. The paper recommends that government in partnership with private organizations should remain committed to the funding of higher education and allocation to education sector be increased from the current less than 15 per cent to 26 per cent to meet the international standards stipulated by UNESCO.

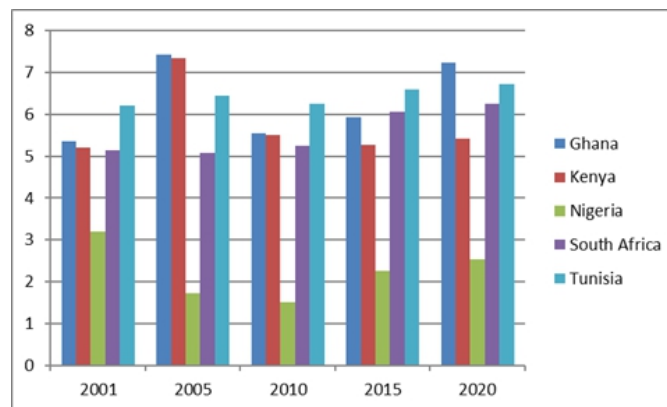
**Keywords:** *Higher Education Financing, Inclusive Growth, Sustainable Development, ARDL, Granger Causality*

*Corresponding Author:* Nuhu Musa

### Background to the Study

Higher education is the engine room of the country's development because it provides the needed manpower resources. Any country aspiring for development must make concerted efforts at developing her education sector, particularly university education by investing heavily in it so as to improve the quality of education (Ndubisi, 2013). Scholars like Aloysius and Augustine (2021) believe that this level of education equips human resources with the needed knowledge, skills and competencies, which would make citizens, contribute to economic development of the country. According to Todaro and Smith (2011), higher education helps to supply the essential human capital which is a necessary key to poverty reduction. Ndubisi (2013) posited that advanced and emerging economies such as China, India, Singapore, South Korea, Taiwan, Hong Kong and Malaysia that have achieved high level of global competitiveness was as a result of huge investment in education and human capital. It is however unfortunate that Nigeria despite her abundant human and material resources could not invest heavily in education which has serious implication on educational quality and infrastructural development.

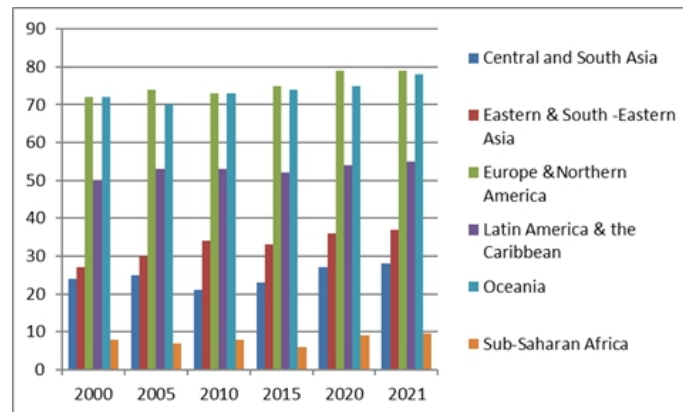
As part of effort to revamp education sector, United Nations Economic, Scientific and Cultural Organization (UNESCO) recommended that African countries must allocate at least 26 per cent of the national budget on education sector. Undoubtedly, education financing in Nigeria is far below her contemporaries in other countries.



**Figure 1: Allocation to Education (% of GDP) 2001-2020: A Comparative Analysis**

**Source:** Own Evaluation based on data from World Development Indicator.

Figure 1 shows allocation to education sector by five countries from 2001-2020. In 2001, government expenditure on education as a percentage of GDP was 3.2 per cent as against 5.35 per cent in Ghana, 5.15 per cent in South Africa, 5.21 in Kenya and 6.20 per cent in Tunisia. The percentage allocation to education was consistently higher in all countries than Nigeria. This indicates that tertiary education in Nigeria is grossly under-funded compared to her counterparts in other countries and this has posed serious challenges to growth prospect.



**Figure 2:** Tertiary Education Enrolment ratio by Region, 2000-2021

**Source:** UNESCO Institute for Statistics database, 2022

Figure 2 shows the trend of tertiary education enrolment across the regions from 2000-2021. From the graph, the highest gross enrolment rate was in Europe and Northern America (79 per cent) followed by Oceania (75 percentage point). In 2020, gross enrolment rate in higher education stood at 54 per cent in Latin America and the Caribbean and the lowest was in Sub-Saharan Africa estimated at 9 percentage points on the average.

Despite the tremendous increase in students' enrolments into the Nigerian universities, there is absolutely no corresponding improvement in the quality of education as a result of inadequate funding. Obviously, this has resulted to poor and dilapidated structure in our various institutions of learning, poor welfare packages for lecturers, inadequate research funding and incessant strike actions by academic and non-academic staff.

The main purpose of this study is to examine the impact of higher education financing on sustainable development in Nigeria using dataset from 1990-2021. Following this introductory part, the remainder of the paper is structured as follows. In section two, theoretical and empirical reviews are discussed. Section three and four present methodology used and regression results. The final section concludes and makes policy recommendations.

## Literature Review

### Conceptual Issues

Jhingan (2010), defines higher education financing as allocation to higher education by the federal government within a financial year. It refers to the amount expended on tertiary education by the federal government within a financial year. In other words, it refers to the outflow of resources from the federal government to the education sector. Higher education encompasses all formal post-secondary education including public and private universities, colleges of education, technical and training institutions and vocational schools. However, this study is restricted to public universities that fall within the ambit of the federal government in terms of funding.

Ndubisi (2013), defines inclusive growth as one in which all economic agents benefit. It refers to growth that helps in reducing absolute poverty; create employment opportunities and allowed citizen unfettered access to basic economic services like education, health etc. It is also referred to as pro-poor growth because it is meant to benefit the poor masses at the grass root. Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (Brunt land Commission,1987).

### **Theoretical and Empirical Literature**

Theoretically, the New Growth theory by Romer (1986) and Lucas (1988) appear to be germane to this study. The theory posited that economic growth and development depends on investment in human capital, through research, innovation and development in knowledge and skills. It emphasizes the strategic role of human capital in the development process. This theory asserted that increase in economic growth was made possible through direct and indirect investment in education by public and private sectors. The theory attributes growth process to key variables such as human capital accumulation, investment in education and number of educated labor force.

Cordelia and Kanalechi (2020), did a study on the impact of public expenditure on higher education in Nigeria. He did not find any significant impact of public expenditure on higher education. However, Ogungbenle and Edogiawerie (2016), use OLS múltiple regresión and found a positive and significant impact. Furthermore Japheth, Moses and Cyprian (2014), used data from 1990-2013 to examine how government expenditure on tertiary education affects growth. They find that public expenditure on tertiary education has significant effects on economic growth in Nigeria during the period of investigation. Ejiogu, Okezie and Chinedu (2013) in their study find supporting evidence of a positive relationship between tertiary education financing and economic growth. Ogungbenle and Edogiawerie (2016) discover similar results. Supporting this view, Odeleye (2012), carried out a study on the impact of education expenditure on economic growth of Nigeria using data from 1985-2007. The study employed Johansen co-integration and error correction model (ECM) techniques of analysis. It was discovered that only recurrent expenditure has significant effects on economic growth during the period of study.

Lawal and Wahab (2011), assessed the relationship between education expenditure and economic growth in Nigeria using time series data from 1980-2008. The study adopted ordinary least squares (OLS) technique and discovered that investments in education have direct and significant impact on economic growth in Nigeria. Omojimite (2010), also examined the impact of education expenditure in accelerating economic growth in Nigeria from 1980-2005. The study employed co-integration and granger causality test as technique of analysis. Results indicated the existence of long-run relationship between public expenditures on education and economic growth. The study also revealed uni-directional causality running from education expenditures to economic growth.



In South Asia, Hussaini (2020), conducted a study on the link between public expenditure on higher education and economic growth from 1990 to 2018. Using the multivariate causality test, the results revealed the existence of bi-directional causality between public expenditure on education and economic growth. Mallick, Das and Pradhan (2016), investigated the relationship between educational expenditure and economic growth in selected 14 major Asian countries (Bangladesh, China, Hong Kong, India, Japan, Nepal, Pakistan, Malaysia, The Philippines, Saudi Arabia, Singapore, Sri-Lanka, Thailand and Turkey) using panel data from 1973-2012. Employing Panel Vector error-correction model (PVECM), results revealed expenditure on education had significant effect on economic growth in all 14 major Asian countries.

Wasif and Idrees (2013), analyzed panel data for fourteen (14) countries using data set from 1990 to 2006. The authors find that the impact of public education expenditure on economic growth was stronger in developing countries than the developed countries. It concludes that public financing of education is an important determinant of economic growth in developing countries.

### Research Gap

Empirical evidence has shown that very few empirical works on the impact of higher education financing on economic growth have been carried out with divergent results, which may be as result of varying methodology used and variable measurement. Scholars like Cordelia and Kanalechi (2020) did not find any significant impact of higher education spending on economic growth. However other scholars (Lawal & Wahab,2011; Odeleye ,2012; Ejiogu, Okezie & Chinedu, 2013) discovered positive and significant impact of higher education expenditure on economic growth. More so, the direction of causality has not been comprehensively investigated by most scholars and this requires further empirical investigation. This is the major research gap that the current study is poised to address. Unlike prior research, in current paper, granger causality was employed to ascertain the direction of causation among the variables. In addition, diagnostic/robustness checks were carried out to avoid spurious regression results that are likely to be associated with time series data.

### Methodology

The theoretical link between education and sustained growth can be found in New Growth theory by Romer (1986) and Lucas (1988). The new growth theory posited that human capital is an important determinant in the growth process in addition to physical capital (K) and labour (L). The model is represented in equation [1].

$$Y = f(K^\alpha L^\beta H^\lambda) \quad [1]$$

The model in equation [1] can therefore be re-specified in a linear form as follows;

$$Y_t = \beta_0 \alpha K^{\beta_1} \beta L^{\beta_2} \lambda H^{\beta_3} \quad [2]$$

Estimating in logarithmic form, the model is re-specified as;

$$\ln Y_t = \beta_0 + \beta_1 \ln K + \beta_2 \ln L + \beta_3 \ln H + \varepsilon_{it} \quad [3]$$

Where Y is measured using real GDP as a proxy for economic growth, K denotes capital stock L represents labour supply measured by numbers of workers and H is human capital.  $\beta_1$ - $\beta_3$  represent elasticity of output with respect to labour, physical and human capital stock,  $\ln$  denotes the natural log and  $\varepsilon_{it}$  is stochastic error term.

This study employs Autoregressive Distributed Lag (ARDL) model and granger causality test to assess the impact of higher education financing on sustainable development. This technique was chosen because it yields consistent results irrespective of whether the variables are stationary at level I(0) or first difference I(1) or a combination of both. Granger causality was employed to test the direction of causation among variables, while bounds test was used to examine the long-run relationship. To ensure robustness of the results, the study employs some pre- and post-diagnostic checks.

### Model Specification

The model for this study was adopted from the work of Aloysius and Augustin (2021) but with some modifications in terms of variables employed and methodology used. These scholars used OLS estimation technique in their analysis. As a departure from prior studies, current study employed ARDL model and Granger causality test.

GDP per capita used as proxy for sustainable development was regressed on higher education expenditure (EDU), unemployment rate, and human capital proxy by gross tertiary education enrolment. Other control variables include population growth rate and corruption perception index. The extended version of model for the study is specified as follows:

$$GDPPC = f(\text{HEDU}, \text{UNM}, \text{HUK}, \text{POPGR}, \text{CORR}) \quad [1]$$

The model in Equation [1] is re-specified as in Equation [2]

$$RGDP = \beta_0 + \beta_1 \text{HEDU} + \beta_2 \text{UNM} + \beta_3 \text{HUK} + \beta_4 \text{POPGR} + \beta_5 \text{CORR} + \mu \quad [2]$$

The ARDL model specification is as follows:

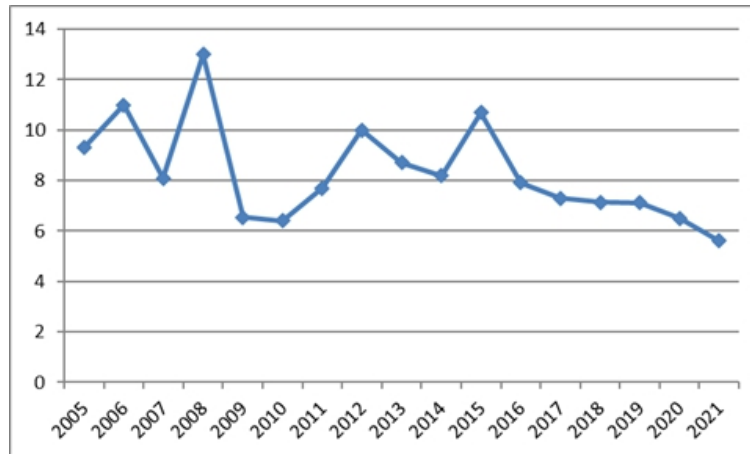
$$\begin{aligned} \Delta \ln GDPPC_t = & \alpha_0 + \sum_{j=n}^p \alpha_1 \Delta \text{HEDU}_{t-j} + \sum_{j=k}^p \alpha_2 \Delta \text{UNM}_{t-j} + \sum_{j=1}^p \alpha_3 \Delta \text{HUK}_{t-j} + \sum_{j=1}^p \alpha_4 \Delta \text{POPGR}_{t-j} \\ & + \sum_{j=1}^p \alpha_5 \text{CORR}_{t-j} + u_t \end{aligned} \quad [3]$$

where GDPPC is the annual growth rate of real GDP per capita. HEDU denotes higher education expenditure, UNM represents unemployment rate, HUK is human capital, POPGR and CORR denote population growth rate and corruption perception index.  $\alpha_0$  is constant parameter,  $\alpha_1$ - $\alpha_5$  are the coefficients while  $\alpha_0$  denotes constant intercept and  $\mu_t$  is the stochastic error term.

## Empirical Results and Discussion

### Trend Analysis

The trend of federal government allocation to education in Nigeria is presented in graphical form to show their growth pattern for various years.



**Source:** Own Evaluation based on data from CBN Statistical Bulletin

Figure 3 shows the trend of federal government allocation to education in Nigeria from 2005-2021. As shown above, in the year 2021, percentage allocation to education sector in Nigeria stood at **5.6 per cent**. In 2020, it was 6.5 per cent, and in 2019 percentage allocation to education increased to 7.12, In 2018, it rose slightly to 7.14 per cent and then in 2017 allocation to education sector was 7.3 per cent. In 2016, it rose to 8 per cent and then increased to 10.7 per cent in 2015. From all indications, the percentage allocation to education sector is far below 15- 26% recommended by United Nations Educational Scientific and Cultural Organization (UNESCO).

### Descriptive Statistics

Descriptive statistic test was conducted to ascertain if the variables in the model (i.e. GDPPC, HEDU, UNM, HUK, POPGR, and CORR) are normally distributed or not. The results are shown in Table 1.

**Table 1:** Results of Descriptive Statistics

Variables	GDPPC	HEDU	UNM	HUK	POPGR	CORR
Mean	22.63419	49.95516	14.59452	9.530645	18.26452	12.71161
Median	18.70000	50.42200	12.50000	9.010000	18.90000	12.68000
Std. Dev.	15.65612	3.186862	7.022089	4.265079	6.136044	1.578297
Skewness	-0.124448	0.136253	1.077575	1.045730	1.184300	1.073824
Kurtosis	3.457257	1.816045	4.402595	4.616682	5.491976	4.032421
Jarque-Bera	0.350085	1.906512	8.540425	9.025998	15.26777	7.334455
Probability	0.839421	0.385484	0.013979	0.010966	0.000484	0.025547

**Source:** Author's computation (2023)

The results indicate that the values for all the variables [HEDU, UNM, HUK, POPGR, and CORR] are positively skewed except GDPPC. This means that there is asymmetry in the distribution of the series.

### Stationarity Test

The paper conducted stationarity test using Augmented Dickey-Fuller (ADF) unit root test. The essence of conducting stationarity test was to avoid spurious regression. The results are presented in Table 2.

**Table 2:** Results of Stationarity  
ADF calculated in ( ) & ADF critical value

Variable	ADF @ Level	ADF @ First Difference	Order of integration	Decision
GDPPC	(-0.143) -2.963	(-6.786) -2.967	1(1)	Stationary
HEDU	(-2.113) -2.963	(-7.409) -2.971	1(1)	Stationary
UNM	(-5243) -2.963	NA	1(0)	Stationary
HUK	(-4271) -2.967	NA	1(0)	Stationary
POPGR	(-2.777) -2.963	(-5.145) -2.971	1(1)	Stationary
CORR	(-1.762) -2.971	(-9.025) -2.971	1(1)	Stationary

NA = Not applicable

**Source:** Author's computation (2023)

The analysis shows that the series UNM, HUK are stationary at level 1(0) while GDPPC, HEDU, POPGR and CORR are stationary at first difference 1(1). This implies that the variables exhibit mixed order of integration, thereby lending support for the use of ARDL model.

**Table 3:** Results of Bounds Test

Test	Critical val.	Sign.Level	I(0)	I(1)
F-Statistic	5.631018	10%	2.08	3.00
k	6	5%	2.56	3.49
		2.5%	2.70	3.73
		1%	3.06	4.15

**Source:** Author's computation (2023)

The results of bounds test indicated that the F-statistic is 5.631018 which is higher than the lower and upper bounds critical values of 2.56 and 3.49 at 5% level of significance. This indicates the variables have long run association.

**Table 4:** Long-Run Estimated Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-188064.3	141442.1	-1.329620	0.1940
HEDU	0.326954	0.293157	1.115289	0.2739
UNM	-34.79344	1636.070	-0.021266	0.9832
HUK	1.336951	0.315572	4.236593	0.0003
POPGR	-0.162944	0.350109	-0.465409	0.6462
CORR	-0.266750	0.140817	-1.894306	0.0714
R-squared	0.702542			
Adjusted R-squared	0.660048			
S Durbin-Watson stat	1.759782			

**Source:** Author's computation (2023)

The estimated long run results in Table 4 indicate that HEDU has positively impacted growth. This result shows that a unit change in HEDU would decrease GDP growth by approximately 0.32 per cent. The finding of this study is in keeping with previous studies by scholars like Cordelia and Kanalechi (2020).

Unemployment rate (UNM) was discovered to have inverse association with GDPPC. This means that a small increase in UNM would decrease GDPPC by approximately 34 per cent and this tends to stunt sustainable growth and development. This is in agreement with results obtained by several scholars (Odeleye, 2012; Ejiogu, Okezie & Chinedu, 2013).

In addition, the estimated coefficient of HUK is positive meaning that one percent increase in human capital accumulation would increase economic growth by about 1.33. However, corruption perception index and population growth rate exert negative impact. The implication of this finding is that corruption is detrimental to inclusive growth and development in Nigeria. R-square of 0.70 indicates that about 70% variations in the GDPPC were accounted for by changes in the explanatory variables. This indicates a good fit. The value of adjusted counterpart of 0.66 shows the result is robust. D-W statistic of 1.7 indicates complete absence of serial correlation problem.

**Table 5:** Short-Run Estimated Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
RGDP(-1)	0.733250	0.140817	5.207118	0.0000
HEDU	2.748254	1.048620	2.620829	0.0156
UNM(-1)	-1.444522	0.696764	-2.073186	0.0501
HUK	2.654196	0.713913	3.717813	0.0012
POPGR	-34.79344	1636.070	-0.021266	0.9832
CORR	-0.162944	0.350109	-0.465409	0.6462
CORR(-1)	-1.556472	0.386498	-4.027110	0.0006
ECM(-1)	-0.266750	0.041441	-6.436944	0.0000
R-squared	0.856200			
Adjusted R-squared	0.790837			
Durbin-Watson stat	2.983137			

**Source:** Author's computation (2023)

Table 5 shows the short-run estimated results of the impact of higher education financing. In the short-run, higher education expenditure exerts positive and significant impact. Similarly, human capital proxy by tertiary education enrolment had statistically significant impact on economic growth. *Ceteris paribus*, a unit increase in gross tertiary education enrolment rate results in 2.65% increase in GDP growth rate. However, the lagged value of unemployment rate and corruption perception index negatively influenced growth. This means that an increase in these macroeconomic variables strongly reduced GDPPC. This finding is consistent with studies conducted by Aloysius and Augustin (2021).

The R-square is 0.85 which indicates that about 85 per cent of the systematic variation in the dependent variable (GDPPC) is explained by the explanatory variables. After adjusting the degrees of freedom, the result still remains robust as shown by the adjusted coefficient of 0.79. The Durbin-Watson (D.W) statistic of 2.98 indicates absence of serial autocorrelation. The lagged error correction term (ECM) included in the model to capture the adjustment towards the long-run equilibrium is correctly signed (negative) and statistically significant. Thus, it will rightly act to correct any deviation from its long run equilibrium value. It shows that 26% disequilibrium in the dependent variable in previous years are corrected within a year.

**Table 6:** Diagnostic/Robustness Check

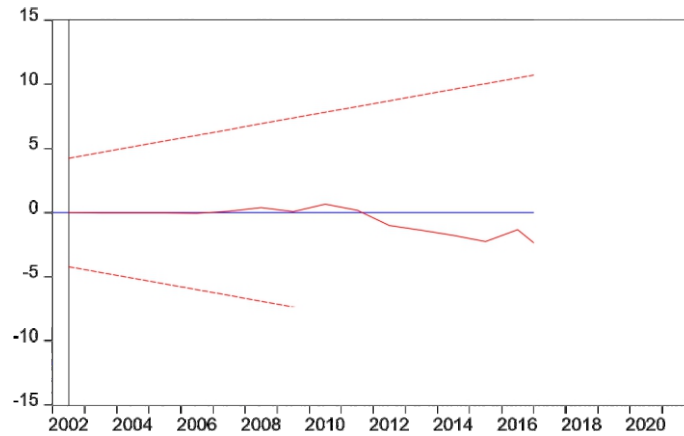
Tests Statistics	F-values	Probability val.
A. Serial-correlation	4.689883	0.017511
B. Heteroscedasticity	7.009140	0.0002
C. Ramsey Test	0.255292	0.617192

**Source:** Author's computation (2023)

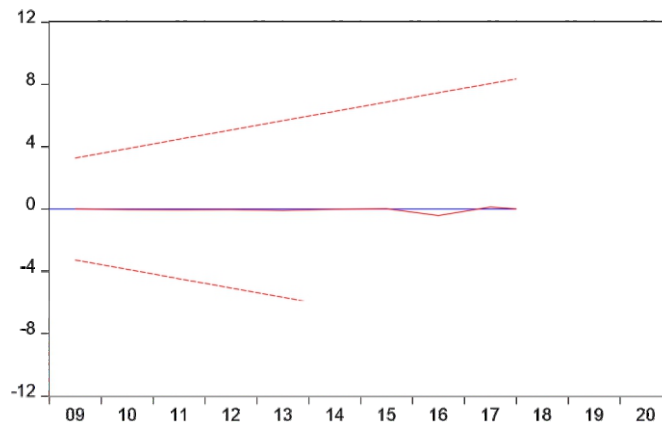
The results indicate that the model does not suffer serial correlation and heteroskedasticity problem because their corresponding F statistic and p- values are greater than 5%. Ramsey test

result also indicates that the model does not suffer misspecification bias.

Furthermore, CUSUM and CUSUM-SQ indicate the model passed stability test. The residuals are within the two critical lines, meaning that the model was stable as shown below.



**Figure 5a:** Results of CUSUMSQ  
**Source:** Author's computation (2023)



**Figure 5a:** Results of CUSUM  
**Source:** Authors' computation (2023)

**Table 7:** Pair-wise Granger Causality Test

Null Hypothesis:	F-Statistic	Prob.
HEDU does not Granger Cause GDPPC	10.0445	0.0005
GDPPC does not Granger Cause HEDU	6.25898	0.0057
UNM does not Granger Cause GDPPC	6.68535	0.0041
RGDP does not Granger Cause UNM	0.74394	0.4841
HUK does not Granger Cause GDPPC	2.63806	0.0886
GDPPC does not Granger Cause HUK	0.21235	0.8099
POPGR does not Granger Cause GDPPC	0.08284	0.9207
RGDP does not Granger Cause POPGR	1.62352	0.2146
CORR does not Granger Cause GDPPC	12.7955	0.0001
GDPPC does not Granger Cause CORR	1.82181	0.1798

**Source:** Author's computation (2023)

Table 7 shows the result of Pair-wise granger causality test. The result indicates the rejection of null hypotheses that HEDU, UNM and CORR do not granger cause GDPPC. The analysis indicates a uni-directional causality running from these three explanatory variables to the dependent variable GDPPC. However, a bi-directional causation was established between HEDU and GDPPC. This result supports submission of Hussaini (2020).

### Conclusion and Policy Implications

The paper investigated the impact of higher education financing on inclusive growth and sustainable development in Nigeria from 1990-2021. This study's contribution to knowledge is its findings of a positive and insignificant impact of educational financing on sustainable development in Nigeria. The possible explanation for the insignificant impact was an indication of low level of financial commitments to education sector which has contributed to the deplorable state of higher education in Nigeria. The policy implication is that higher education financing is vital for the achievement of inclusive growth and sustainable development in Nigeria. The paper recommends the following measures.

1. Tertiary education should be adequately funded by given priority attention in the national budget. In fact, government should increase her budgetary allocation to the education sector from the present less than 15 per cent to 26 per cent recommended by UNESCO. This will help in providing adequate resources for the maintenance of poor and dilapidated structures, building of libraries and laboratory, procurement of laboratory equipment, and procurement of relevant teaching and learning materials in tertiary institutions in Nigeria.
2. Government should ensure strict monitoring of funds allocated to the education sector to ensure effective utilization and to prevent misappropriation or diversion to private accounts.



3. In addition, all key stakeholders including private sectors and non-governmental organizations should be partners in funding of tertiary education. This will help mobilize resources for the development of the sector.

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## How to Prepare Floodplains for Climate Change

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### **Abstract**

**W**ith flooding expected to increase if action isn't taken, it's vital we act now. When considering the implications of climate change, you may wonder why someone would choose to live in a floodplain. However, people have called floodplains home for centuries. Enticed by recreational opportunities, fertile agricultural land and nearby water resources, the appeal should be no surprise. Yet, residents face severe damage to their homes and livelihoods when the rivers flood. As extreme weather events grow more frequent and intense, preparations become necessary.

**Keywords:** *Floodplains, Climate, Change*

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## **Background to the Study**

### **Worst Flooding Event in America**

The Great Flood of 1927 occurred in the Mississippi River and became recognized as the worst flooding event in U.S. history. Rushing water saturated 27,000 square miles approximately the size of New England killing nearly 1,000 people and displacing 700,000 more. The Great Flood cost nearly \$1 billion in damages and required the entire National Guard aircraft fleet to assist with rescue operations. Following 17 inches of rainfall in the Pearl River in 1983, the second most severe flood of the Mississippi destroyed 700 homes and led to 2,500 people evacuating the area. Events like these Mississippi River floods are bound to worsen in the coming years. Just as the 1983 flood prompted calls for levees, today's experts quickly seek strategic mitigation for floodplains.

### **The Floodplains at High Risk of Disaster**

According to satellite data from NASA, 24 percent of the global population is exposed to flooding disasters. Scientists found that 58 to 86 million people now live in flood-prone areas worldwide, while 255 million people experienced at least one flooding between 2000 and 2015. Calculations predict that 102,225 properties have a 26 percent higher risk of severe flooding in the next 30 years in New York City nearly 17 percent of all properties. More recently, Fort Lauderdale, Florida, saw over 20 inches of rain in six hours, sending a stream of water down roadways and shutting down businesses, schools and the airport. Scientists predict that U.S. flooding events will rise by 26 percent by 2050 if we fail to get climate change under control. Damages could also run nearly \$32.1 billion as communities struggle to repair their homes and businesses.

### **Five Climate Strategies for Floodplains**

Fortunately, climatologists aren't sitting down on the job strategic planning is underway to develop viable solutions against climate disasters in floodplains. As more people move to floodplain regions, protecting them and their communities is essential.

- 1. Develop comprehensive management.** A comprehensive management plan for floodplains assesses the risks and sets measurable goals to mitigate extreme weather effects. Outlining the procedures including preservation, resilience planning and emergency response allows residents and various organizations to better prepare for disaster and minimize the outcome.
- 2. Generate emergency preparedness.** Emergency preparedness is a crucial component of floodplain mitigation creating protocols should follow a risk assessment. For instance, people may have a split second to save themselves during flash flooding. An emergency preparedness plan outlines evacuation routes using road maps of the closest streets to main roadways.  
Other emergency planning could include pinpointing alternative energy sources in case of power outages, determining the equipment needed to protect infrastructure and implementing an ongoing training program for rescuers.
- 3. Upgrade dams.** Climate change has demonstrated its mercilessness and crumbling infrastructure risks greater devastation to an area. For example, older levees and other water-resisting structures can break, allowing large quantities of water to inundate a floodplain.

The American Society of Civil Engineers says it would cost a total of \$113.6 billion to upgrade U.S. dams about \$20 billion of that would go toward the 2,300 high-hazard dams. Meanwhile, U.S. dams are roughly 57 years old. It's time to invest where it counts the most.

4. **Utilize natural mitigation.** Engineered solutions for floodplain management are only so efficient that's why it's crucial to implement natural solutions, too.

Protecting wetlands can slow down and store water flow, preventing construction in open spaces like parks, decreasing coastal erosion and building up vegetation to the shoreline are all approaches we can take.

5. **Learn from history.** Of course, we should pay attention to lessons from historical flood events. History shows floodplain residents suffered great devastation due to poor planning and organization.

Ignoring climate change isn't going to stop it from bearing down on vulnerable communities, a reason why building climate-resilient areas is essential. Residents, governments, businesses and stakeholders must work together to implement floodplain mitigation and protect their futures.

### **Conclusion**

It's impossible to put off developing solutions for floodplains as climate change becomes increasingly unavoidable. Extreme and unexpected weather patterns pose too much risk for those living in floodplains, their communities, and the economy. Generating a plan to offset the damages will become dire in the coming years.

### **Reference**

<http://www2.eponline.com/Articles/2023/04/21/Prepare-Floodplains-for-Climate-Change.aspx>

## Engineering the Built Indoor Environment; Strategies for Achieving Energy Efficiency and Sustainable Thermal Environment in Nigeria

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### Abstract

This paper raised ideas in literature as anchor for the development of a sustainable energy-built environment. The paper focused on improving knowledge in an area the Authors consider trending and still evolving. It believes a Net -Zero Energy approach is ideal and a radical method in attracting results. It advocated for the promotion of passive engineering measures in overhauling the built environment into a clean sustainable one and encouraged reduction in energy through the use of energy collectors such as the photovoltaic systems, supported by batteries, charger controls, inverters and generators. The paper recommended the enforcement of energy ethics and code in Nigeria and that professionals in the built environment continuously update their knowledge. They should upgrade by acquiring trainings in new and evolving technologies, attend conferences and workshops, and must show concern over their environments by adhering to environmental ethics which calls for functionality in their designs, and for compliance with planning laws and building regulations as required by the local authorities. The knowledge of energy management which advocates for reduction in energy use should be introduced and practiced by all and environmental professionals and taught in schools, The easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy need, and this could be done through intelligent design solutions that get buildings to respond to climate.

**Keywords:** *Energy, Energy Efficiency, Energy Efficient Systems, Sustainable Indoor Environment.*

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### **Background to the Study**

Earth remains the only planet safe to anchor and promote life because the environmental composition supports life unlike other planets. However, over the years human activities have diminished this unique attribute to a degree of great concern. Man has brought this divine biotic endowment to its knees that he is now greatly in quest of what do to avoid a total collapse. A major agent of the dilapidating environment is the way and manner energy are used. Energy is used in transportation, building, construction industries, with most of them coming from electricity. According to Botkin and Keller (1998) more than 90% of energy from electricity is sourced from burning fossil which has a great damaging effect on our climate due to high carbon emission. Buildings have contributed more in fostering and creating intimate contact amongst inhabitants. The building in sync with local climate using resources efficiently for the future. Buildings account for 30% of the energy consumed in Nigeria, 45% of energy consumption in United States, and globally (Alozie, 2020, Botkin & Keller, 1998). Commercial buildings in Nigeria consume approximately 240 Kwh/m of electricity annually, with most of the energy and as much as 45% used in air-conditioning in cities, 25-30% in lighting, 20-30% in other systems and equipment (Alozie, 2019)

Accordingly, Alozie (2022), recorded an alarming growth rate in buildings in cities and rural environments to be at 10-15% annually and concluded that the pressure on the Nation's energy resources follows same magnitude, as recorded in buildings. This makes the call for an alternative energy solution which will not only alleviate the present issues in supply but take care of the future necessary. This calls for wholistic energy management strategies that will help develop energy efficient and sustainable indoor environment. It calls for a review of zero energy concept in buildings as an integrated means in engineering the built environment into an energy efficient environment. Knowledge of the macro climate of a region, in combination with qualitative understanding of local microclimate, allows Engineers, Architect, Builders and Landscape Architects to modify indoor and outdoor environments in ways that improve human comfort, reduce building energy consumption and optimize site resource use (McDonald, 2004), this is absolutely important in modern living because energy is scarce and expensive (Alozie, Eze, Ehibudu & Nnsewo 2018, Botkin Keller 1998).

Energy is needed to drive machines that provide cooling and heating in buildings (Alozie, 2019a) The need to keep the indoor temperature of buildings within acceptable comfort zone has become obvious because nearly all the activities of man happen inside buildings (Antonidaes, 1998). The concept of energy is somewhat abstract.; one cannot see it, yet pays for it, to understand energy, it is easiest to think about individuals when they say "am tired, I don't have energy to work ". Perhaps energy could be further easily understood through the lens of the idea of "force" because we all have had the experience of exerting force, of pushing or pulling. Any of these activities makes use of energy in one state or the other, which supports the first law of thermodynamics which states that energy is neither created nor destroyed but transformed from one form to another.

In order to keep this cycle of transition from one state to another and sustainable, energy management principles must be learned, this agrees with the erudite analysis by Means (2011)

which underscored that the easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy need. This Means (2011) suggested could be done through intelligent design solutions that get buildings to respond to climate. Intelligent building designs that respond to climate, consider heating and cooling factors, and find Net-Zero energy concepts needful.

Buildings have been repeatedly listed by scholars to account for more than 40% of total world energy usage. The implication therefore is that when buildings become energy efficient, the percentage of energy used in operating them will become small and perhaps insignificant especially in developing nations where energy is mostly nonrenewable. Energy sources in developing nations are mostly from burning fossil fuel. Burning of fossil fuel is an operation that increases global warming and causes climate change. When buildings in developing countries become energy efficient, green environment will begin to develop. This paper advocates for the professional in the built environment on whose shoulders the responsibilities of bringing man in harmony with his environment and the task of making this environment sustainable, is vested on, is expected to do so by reducing energy consumption through architecture and environmental engineering.

However, the paper further opines that energy reduction in the building sector, could be engineered through the combination of passive architecture strategies and active energy efficient devices such as Photovoltaics, Batteries, Charge Controllers, Inverters, and Generators. To justify the aim of the paper it became necessary to look into brief explanations of the following keywords: Energy, Energy- Efficient Design, Energy Efficiency, Energy Efficient Systems, Sustainable Indoor Environment and Thermal Comfort.

### **Energy**

Energy is the ability to do work (Egan 2000) There are two definite energy sources: nonrenewable and renewable,

### **Non-Renewable**

Approximately 90% of energy in United States and developed world come from oil, natural gas and coal because of their organic origin and they are referred as fossil (Botkin & Keller 1998) They are produced from plant and animal materials and are forms of stored energy that are part of our geological resource base. They are essentially non-renewable because they get exhausted with time and do not accumulate easily, sometimes may take centuries or may not accumulate at all.

### **Renewable Energy**

The second energy type, which include solar (sun), geothermal (soil), hydrothermal (water), wind, biomass (plants) among others, referred as alternative designates, are gradually being used as one to fossils. Solar and wind are not depleted by consumption and are described as renewable (Ikike & Alozie, 2022)



### **Energy- Efficient Design**

In popular imagination, energy efficient design has been understood to be a by-product of oil embargo initiated by the Organization of Petroleum Exporting Countries (OPEC) on October 1973, a date western consumers of fossil fuels became painfully aware of the energy intensive nature of their built environment and their fragile dependence on foreign energy sources (Moore, 2004). In most rigid form, energy – efficient design has been characterized as an attempt to reconstitute the practice of architecture as a purely instrumental science in its most expansive form. However, energy efficient design challenges society to understand buildings not as static objects of aesthetic value but rather as dynamic entities that participate in a complex system of natural energy flows and political consequences (Moore, 2004).

Energy efficient building is defined as a building that uses less energy to provide same product or service such as lighting, heating, and cooling, however, Alozie, (2019), defined energy efficiency as using less energy to provide same product or service such as lighting, heating cooling and transportation. Alozie, (2019) added that sustainability has become increasingly popular and important in the building industry in our present living that a movement to construct buildings in a more efficient and sustainable manner, which advocates reduction in energy use and the cost associated with its operation and maintenance became necessary.

### **Energy Efficiency**

According to Alozie (2019), energy efficient design remains an integral of environmental sustainability which must be discussed as an arm of the universal sustainable theme. Energy that is consumed in order to meet with the different needs associated with peoples heating and cooling energy needs (energy needed to avoid overheating). Energy efficient buildings are buildings built and constructed to use minimum amount of energy to ensure comfortable living, such as designing buildings to take advantage of passive solar potentials.

### **Net-Zero Energy Building (NZEB)**

Always referred to as next generation energy concept already operational in many locations in developed nations is taking energy efficiency to a higher step, beyond energy saving. These new edge cutting projects produce as much energy as they use over the course of a year, making them net-zero in terms of energy use. These buildings practice best energy efficient strategies, in combination with renewable source which is produced either on or off site. The buildings still remain connected to electricity grid (in case the renewable energy source supply is unavailable).

Net-Zero Energy Buildings are ultimately a necessary step towards energy independence. (U.S. Department of Energy “Net-Zero Energy Commercial Building, 2011) Reducing energy use in buildings saves resources and money while reducing pollution and Carbon Dioxide in atmosphere. The easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy need, and this could be done through intelligent design solutions that get buildings to respond to climate.

Intelligent building designs that respond to climate consider heating and cooling factors. It understands the character of solar energy such as radiation, convection, and conduction as well as materials for windows and other openings. It involves integrated design that considers daylighting, passive and active solar heating and takes great advantage of renewable energy, (Means, 2011).

## **Sustainability, Sustainable Environment and Sustainable Architecture**

### **Sustainability**

The term sustainability recognizes the interdependency of economic, social, and environmental factors necessary to sustain life on earth. The defining quote has sustainable development to seek to meet the need and aspirations of the present without compromising the ability to meet the needs of the future (McDonald, 2004).

Henderson (2012), defined sustainability as being able to live today, without compromising nature and available resources, and the children, their children, and their children, living as well as they lived without also compromising resources. In a similar contribution, McDonald (2004) concluded that sustainable architecture involves both design philosophy and technology that imbibes lessons and findings from experts in research.

### **Sustainable Indoor Environment**

Sustainable indoor environment is one that is low in toxins, contaminants, and odors. One with good air quality possible when spaces are well ventilated with outside air and protected from pollutants brought into the space or by pollutants off-gassed within the space. It is one with adequate natural lighting and developed to harness passive energy potentials. One that aims at producing zero carbon (Alozie, 2017)

### **Sustainable Architecture**

Sustainable architecture is the expression coined for environmental responsive building practices. It differs from conventional design by considering the environmental impacts of design decisions throughout the entire building lifecycle, from cradle to cradle instead of cradle to grave (Alozie, 2019, McDonald, 2004). It provides a comprehensive examination of all aspects of architectural design, including selection of site, energy conservation, passive solar strategies, low-energy systems, building materials, indoor air quality, water conservation, waste minimization, lighting, and use of renewable energies, buildings and sites that utilize natural systems to minimize their global, regional, and local environmental impacts on land, (McDonald, 2004).

The roots of sustainable architecture can be traced to the ancient theoreticians that include Vitruvius, who discussed the benefits of designing with local climate and indigenous materials (Morgan 2017) The skill of preindustrial builders, the mastery of using on-site resources such as proper orientation, thermal mass, shading, ventilation and local construction materials, were abandoned after the invention of artificial lighting and air conditioning, except for several notable exceptions, such as organic movement architecture of the half twentieth century who disregarded the environmental context of buildings (McDonald, 2004) The energy crisis in 1973, hastened the return to energy-efficient design.

### **Thermal Comfort**

Besides being aesthetically pleasing, the human environment must provide light, air and thermal comfort. Comfort is best defined as the absence of discomfort. People feel uncomfortable when they are too hot or too cold, or when air is odorous and stale. Positive comfort conditions are those that do not distract by causing unpleasant sensations of temperature, draft, humidity, or other aspects of environment (Vaughn Bradshaw, 2006).

American Society for Heating, Refrigerating and Air-Conditioning Engineers, ASHRAE (2004), defined thermal comfort as that express condition in which 80% of sedentary or partly active persons find themselves comfortable, in their environments, and that means absence of discomfort. Thermal discomfort in buildings results primarily from faulty architectural designs, construction, and operational management and this may need heating or cooling to recreate. No matter the option, energy is needed to correct. The duty of bringing thermal comfort in buildings is primarily the architect's responsibility. The architect needs to consider the following factors that may influence the indoor thermal comfort in buildings, local climate condition, orientation, ventilation, building material, planning regulation, among many others.

### **Energy Efficiency Device Systems Employed in Building Design**

Energy efficient appliance and equipment use technologies that are less energy intensive to reduce the amount of electricity used per product. Energy efficiency refers to using less energy to provide an energy service for example energy efficient LED light bulbs are able to produce the same amount of light as incandescent light bulbs by using 75 to 80 percent less electricity. Some energy efficient devices have the ability to store energy and allow it to be used when needed, while others have the ability to moderate energy consumption. Some of such devices are discussed below.

### **Photovoltaics**

Photovoltaics (PV), as the name implies, are devices that convert sunlight directly into electricity. PVs generate power without noise, without pollution, and without consuming any fuel. These are compelling advantages for several applications, especially where utility power is not available. One disadvantage of photovoltaics is that they require a large surface area to generate any significant amount of power. This is because the sunlight comes to us distributed over a wide area, and because today's PVs can only convert about 10% of the solar power to electricity. Efforts to make systems more efficient to convert more sunlight to electricity and to utilize unused roof space mitigate this problem. A second disadvantage is that PV is rather expensive due to the high-technology manufacturing processes (Vaughn Bradshaw, 2006)

### **Photovoltaic Cells & Modules**

The electric power that PV produces is DC (direct current), similar to that coming from a battery. The voltage of each cell depends on the material's band gap, or the energy required to raise an electron from the valence band (where it is bound to the atom) to the conduction band (where it is free to conduct electricity). For silicon, each cell generates a voltage of about 0.6V. The voltage decreases gradually (logarithmically) with increasing temperature. The current

generated by each cell depends on its surface area and intensity of incident sunlight. Cells are wired in series to achieve the required voltage, and series strings are wired in parallel to provide the required current and power. As increasing current is drawn from the cell, the voltage drops off, leading to a combustion, called maximum power point (MPP), changes slightly with temperature and intensity of sunlight. Most PV systems have power conditioning electronics, called a maximum power point tracker (MPPT) to constantly adjust the voltage in order to maximize power output. Simpler systems operate at a fixed voltage close to the optimal voltage.

### **Batteries**

There is an acute need to store electrical energy for many purposes beside PV systems and researches are investigating alternatives, Battery manufacturers continue to implement innovations to import performance. Batteries do have some dangers. They contain several toxic materials and are must be taken ensure that they are recycled properly. In some cases, batteries are shipped dry, with the electrolyte added on-site. During installation, care must be taken to ensure that battery electrode (battery acid) is not ingested by an installer or an unaware bystander storing battery electrolyte only in well-labeled, child-proof container can reduce this risk. Finally, batteries are capable of rapidly releasing their stored energy if they are shorted; care must be taken to avoid electrocution and fires caused by sparks. The amount battery capacity depends on the magnitude of the load and the required reliability. A typical battery capacity is sufficient to meet the load for 3 – 5 days without sun, but in applications that require high reliability, 10 days of battery storage may be recommended.

### **Charge Controller**

The function of the battery charge controller is very important for system performance and battery longevity. The charge controller modulates the charge current into the battery to protect against overcharging and an associated loss of electrolyte. The low-voltage disconnect protects the battery from becoming excessively discharged by disconnecting the load. It seems unfortunate to disconnect the load, but doing so avoids damage to the battery, and not doing so would simply delay the inevitable, since the load would not be served by a ruined battery.

### **Inverter**

Utility power in U.S. buildings is 120V or 240V AC (alternating current) of 60Hz frequency (50Hz in many countries overseas). Since many appliances are designed to operate with alternating current, PV systems are often furnished with power conditioning equipment called an inverter to convert the DC power from the PV array or the battery to AC power for the appliance in inverter technology have resulted in systems that deliver a pure sine wave form and exceptional power quality. In fact, except for the PV array, the components of a PV system are the same as those of an uninterruptible power supply (UPS) system used to provide critical users of power with the highest power quality. Inverters are available with all controls and safety features built in.

### **Generator**

For small stand-alone systems it is often cost-effective to meet the load using only solar power. Many residential systems and some commercial ones include batteries and generators even if they are grid-connected so that they can run during a power outage. Such systems are called multi-mode systems and add about 30% to the cost of a grid-connected only system. However, during extended cloudy weather this approach requires a very large battery bank and solar array. To optimize cost, the PV system can incorporate a generator to run infrequently during periods when there is no sun. This hybrid PV/generator system take advantage of the low operating cost of the PV array and the on-demand capability of a generator. In this configuration, the PV array and battery bank would ordinarily serve the load, but also to power a battery charger to recharge the batteries. When the batteries are fully charges, the generator automatically turns off again. This system if cyclically charging batteries is cost-effective even without PV, as it keeps a large generator from running to serve a small load. A hybrid system would be designed to minimize life cycle cost, with the PV array typically providing 70% - 90% of the annual energy, and the generator providing the remainder. PV is also often combined with wind power, under the hypothesis that if the sun is not shining, the wind may be blowing.

### **Engineering The Built Indoor Environment; Energy Management Strategies for achieving energy efficient architecture and sustainable indoor Thermal Comfort**

Architects and Engineers possess the skill to design buildings that will be energy efficient. Some energy: efficient buildings have the ability of generating its own energy, as in the case of Net-Zero.

1. Energy Buildings. Others depend on passive architectural design. Daylighting is an important component of energy efficient building design which the architect needs to harness from the inception of his design project and not as, afterthought.
2. Energy management in building is best initiated at design stage and carried through construction to completion.
3. Reducing energy use in buildings saves resources and money while reducing pollution and Carbon Dioxide in atmosphere. The easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy need, and this could be done through intelligent design solutions that get buildings to respond to climate.
4. Intelligent building designs that respond to climate consider heating and cooling factors. It understands the character of solar energy such as radiation, convection, and conduction as well as materials for windows and other openings. It involves integrated design that considers daylighting, passive and active solar heating and takes great advantage of renewable energy, (Means, 2011).

### **Passive Architecture**

Passive architecture seeks to increase the energy efficiency of a building by the use of a variety of active and passive design strategies can be incorporated. Active strategies usually consist of heating and cooling systems. While passive design measures include building orientation, air sealing, continuous insulation, windows, daylighting, and designing buildings to take

advantage of natural ventilation opportunities. Passive measures find ways to reduce the size of the heating and cooling system by keeping the heat (or cooled air) inside the building (Ortega, 2018)

According to Vujovic (2018), the key to passive design is to minimize the energy used by the building, including eliminating plug loads and specifying Energy Star equipment. Vujovic recommended doing an inventory of everything that uses electricity in the building, so even the plug loads can be included in design calculations.

Passive design strategies take advantage of natural energy opportunities as they relate to the location of the building's site, the local climate (and the site's microclimate if relevant), and properties of building material. According to Elrod (2018), active design strategies would then become part of the design process when mechanical and electrical systems are integrated into the building design. Elrod also added that the designers' strategies will typically add much less front — end cost to projects as compared to active design strategies by reducing heating and cooling loads so that causing a building's mechanical system to be downsized and sometimes reduces building's electrical lighting with the use of daylighting design strategies.

Passive design strategies at the architect's disposal include; building orientation, daylighting, natural ventilation, insulation and thermal mass, landscaping, vegetation, use of building materials, shading devices which include trees and sustainable construction concepts. It also advocates keeping to building laws, regulations and sustainable living practices (human ethics)

### **Building Orientation**

Passive design depends a lot on the way the building is oriented, the most successful energy-efficient designs should face south or north to allow better solar energy management (Alozie 2014), Orientation of buildings to take advantage of how the sun moves across the sky is the easiest and most effective passive strategy. The same free heat streaming through windows in cold season, can work against comfort during summer, unless it is considered in the design. Alozie (2014), affirmed that overhangs, exterior shades and deciduous trees can help keep summer sun out while thermal mass such as concrete floor or wall inside the building can store heat in cold periods.

An elongated and narrow building allows for greater portion of the building to be exposed to daylight, which is usually the best form for passive design in terms of massing. South or north facing façade is the key element of good passive design. It is typically the best to have the longest facades face north and south so that a building can take advantage of indirect sunlight (without glare and direct solar heat gain) from the north, and controlled direct solar heat gain from the south (Elrod, 2018)

Direct solar heat gain at the east and west- facing glazing can be minimized with exterior shading devices during the months a building is mechanically cooled. It is easiest to control direct heat gain at south-facing glazing where exterior horizontal shading devices can shade

the building from direct solar heat gain in the summer months when the sun is highest in the sky and allow the building to take advantage of direct heat gain during winter months when the sun is lowest in the sky (Lee, 2018).

### **Daylighting**

The climate in which a building is located may determine the type of window needed. According to Ortega (2018), in hot climates, the goal is to keep heat out of the building, so windows may have low- E coatings that exclude radiant heat and / or lower Solar Heat Gain Coefficients (SHGC). On the flip side, Ortega (2018) also said that in cold and mixed climates it could be a bit trickier since part of the year is hot and the other is cold. Accordingly, “some faces of a building are more prone to heat gain or loss, to this it is advised that window in colder climates should be specified depending on the wall they are situated.

Building orientation and exterior shading options are important considerations when locating windows and glazing. “It can be more difficult to control direct solar heat gain and glare at skylights, but it helps to orient skylights to maximize daylighting from the north. Elrod (2018), believes that north facing glazing is the best for quality daylighting, but daylighting strategies can also be very effective for south- facing glazing (and can help for west and east-facing glazing also. It is very important to use advanced window systems and technologies, including cutting- edge glazing and coatings that are available today. Alozie, (2014) noted also that it is also important to understand the impact of natural light, heat gain and glare on building systems design.

Alozie, (2019) observed that louvers and grilles can help protect the building envelope openings from unwanted debris, while allowing air to flow in and out of the building, also that louvers and grilles can also be integrated into exterior shading elements, which can help significantly in reducing solar heat gain during warmer months of the year. External shading, either operable or fixed, can block unwanted sun from entering the living space during summer, while allowing heat to enter during cold. This is because sun is at a different angle in the sky, these exterior shades and grilles can be tailored to the path of the sun for that particular location.

### **Natural Ventilation**

Natural ventilation is most effective in climates where there is a comfortable ambient air temperature outside for a number of months of the year. Using natural ventilation as passive design strategy is less common in climates where there are fewer days out of the year that a building can be comfortably occupied without being mechanically heated.

When using natural ventilation as a passive design strategy, it is important to consider how air will move throughout the space given a number of factors such as the orientation of windows and other openings to be used for natural ventilation and the physics of how air moves (e.g., cold air sinks and hot air rises) The balance between active and passive systems can be achieved by relying on the passive systems before the set point for the active system is reached.

### **Insulation/ Thermal Mass**

Adding insulation to a building is another passive design strategy. Designing a building envelope above the mere code requirement in terms of adding extra insulation is always a good passive design strategy. If a building is designed properly, the extra money invested in better insulation, better windows, and a better roof, will result in a reduction of the cost of the mechanical and electrical systems and passive design structure.

Insulation is particularly important for buildings in colder climates. Insulation helps the building envelope to resist the conductive flow of heat, and it is typically most effective when installed as continuous insulation (which significantly reduces thermal bridging as compared to cavity insulation). Continuous insulation means the building is essentially wrapped with blanket of insulation outside the structure to thermally separate the inside from the outside with no thermal bridges. This is important not just for energy performance and comfort, but for indoor air quality and mold elimination (Vujovic, 2018).

### **Landscaping and Vegetation and Building Materials**

Good landscape elements enhance thermal comfort. The architect in considering the regional and microclimate of his project site, should specify landscape finishing that stores heat in the day and transfers into the interior at night where warmth is needed at night and in reverse specify those that enhances air flow especially at night. Concrete stores heat in the day and less of it should be used where cooling is needed. Grass, shrubs and trees filter air and enhance air flow. Trees in addition provide shade. Buildings shaded by trees are noted in Alozie, (2014) to record temperature 3 degrees lower than those not shaded. Climate friendly materials earlier discussed under insulation should be a priority of the architect.

### **Sustainable Construction Concept**

“Sustainability” is one of the world's most discussed topics, whose meaning is often clouded | by differing interpretations and by a tendency for the subject to be treated superficially. For most companies, countries and individuals who do take the subject seriously the concept of sustainability embraces the preservation of the environment as well as critical development of related issues such as the efficient use of resources, continual social progress, stable economic growth, and the eradication of poverty.

In the world of construction, buildings have the capacity to make a major contribution to a more sustainable future for our planet. The Organization for Economic Co-operation and Development (OECD), for instance, estimates that buildings in developed countries account for more than forty percent of energy consumption over their lifetime (incorporating raw y material production, construction, operation, maintenance, and deconstruction). This is further assisted by the fact that for the first time in human history over half of the world's; population now lives in urban environments, and this makes sustainable buildings vital; cornerstones for securing long - term environmental, economic, and social viability (Henderson, 2012). The pace of change means we don't have luxury of time. With urban populations' worldwide swelling by around one million people every week, there's an urgent | need to come up with clever ideas that optimizes the sustainable performance of the buildings that we live and work in (Henderson, 2012).



Sustainable construction aims to meet present day needs for housing, working environments and infrastructure without compromising the ability of future generations to meet their own needs in times to come. It incorporates elements of economic efficiency, environmental performance and social responsibility - and contributes to the greatest extent when architectural quality, technical innovation and transferability are included (Henderson, 2012). Sustainable construction involves issues such as the design and management of buildings; materials performance; construction technology and processes; energy and resource efficiency in building, operation and maintenance; robust product and technologies; long - term monitoring; adherence to ethical standards; socially - viable environments; stakeholder participation; occupational health and safety and working conditions; innovation financing models; improvement to existing contextual conditions; interdependencies of landscape, infrastructure, urban fabric and architecture; flexibility in building use, function and change; and dissemination of knowledge in related academic technical and social contexts (Henderson, 2012).

### **Sustainable Living Practices**

Sustainable development is the development which does not compromise the ability of future generation to meet their own needs (Enger and Smith, 2006), while sustainable living is fundamentally the application of sustainability to lifestyle choice and decisions. One conception of sustainable living expresses what it means as meeting present ecological, societal, and economical needs without compromising these factors for future generations. Another broader conception describes sustainable living in terms of our interconnected social domains: economics, ecology, politics and culture.

1. In the first conception, sustainable living can be described as living within the innate carrying capacities defined by these factors.
2. The second conception, sustainable living is described as negotiating the relationships of needs within limits across all the interconnected domains of social life, including consequences for future human generations and non - human species.

Sustainable design and sustainable development are critical factors to sustainable living. Sustainable design encompasses the development of appropriate technology, which is a staple of sustainable living practices. Sustainable development in turn is the use of these technologies in infrastructure.

The summary of all these, is that if developing nations must achieve the objective of designing buildings that will enhance energy management and sustainable living environment, the client, and his tenant must imbibe sustainable living practices like, recycling, reusing and moderation. The culture of preservation of nature and increasing green thinking indices, such promoting the conservation of nonrenewable materials like energy and good management of edible water. The improvement of air quality by discouraging the setting of wildfire and similar environmental degrading activities which challenges life expectancy. The architect and other green experts should design for waste management right from design source to disposal.

## Conclusion

This paper is not exhaustive as researches in energy management which in other phrasing is energy efficiency and studies in sustainability are still unfolding issues which affects not only architecture, but all facets of life. Nevertheless, it the Authours believe that the paper will serve as a primer to studies in the area.

## Recommendations

The paper recommends that professionals in the built environment continuously update their knowledge. They should upgrade by acquiring trainings in new and evolving technologies, attend conferences and workshops, and must show concern over their environments by adhering to environmental ethics which calls for functionality in their designs, and for compliance with planning laws and building regulations as required by the local authorities in which their projects are sited. Some of these architectural ethics and building regulations are listed below. The knowledge of energy management which advocates for reduction in energy use should be introduced and practiced by all and environmental professionals and taught in schools, sang as jingles from media houses and read from pulpits. The easiest and least expensive way to solve the “energy problem” is not to augment energy supply, but to reduce the amount of energy need, and this could be done through intelligent design solutions that get buildings to respond to climate. Intelligent building designs that respond to climate consider heating and cooling factors.

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## **Solar Panels and their Effect on the Environment**

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### **Abstract**

**S**olar panels can provide benefits for both people and the planet. Solar energy has become an increasingly popular renewable energy source, as it is capable of generating electricity without releasing any harmful emissions into the atmosphere. Solar panels are a key component of this process and have numerous benefits for the environment.

**Keywords:** *Solar, Panels, Environment*

*Corresponding Author:* Justin Myers

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## **Background to the Study**

### **Solar Energy: The Greenhouse Gas Emission Killer**

Solar energy has an extremely low carbon footprint and does not produce any greenhouse gas emissions. Instead, it relies on a natural process known as photosynthesis to create electricity without emitting pollutants like carbon dioxide into the atmosphere. To achieve this, solar panels use solar radiation from the sun to generate heat, which is then converted into electricity. This makes solar energy one of the most eco-friendly energy sources available, as it has virtually no effect on the environment and is capable of providing clean energy for homes and businesses. Furthermore, the installation of solar panels on rooftops and other areas provides numerous benefits to communities. It helps reduce electricity bills, creates jobs in the renewable energy industry and contributes to a healthier environment by cutting down levels of air pollution.

Solar energy is quickly becoming one of the most popular sources of renewable energy around the world, with countries like Japan, China and the United States leading the way in solar energy production. With more people realizing the potential of solar energy and its ability to reduce greenhouse gas emissions, it is likely that this trend will only continue into the future. The environmental benefits of solar energy are undeniable, and as more advances are made in technology, solar energy will become an even more viable option for providing clean, renewable energy to people all across the world. With so many advantages associated with solar power, it is clear that this form of energy production is here to stay. But a lack of greenhouse emissions isn't the only environmental effect associated with solar power.

### **Solar Panels Reduce Air Pollution**

Air pollution is a serious problem that affects the health of people and other living things. However, solar panels can help reduce air pollution significantly by converting sunlight into electricity, which is then used to power homes, businesses and other structures. This means that instead of relying on fossil fuels such as coal or natural gas for energy, solar panels are an efficient and clean alternative. Using solar panels can reduce carbon dioxide and other greenhouse gases that are released into the atmosphere due to the burning of fossil fuels. What's more, solar energy is renewable, meaning it will never run out, while fossil fuels are finite resources that will eventually be depleted. By harnessing the power of the sun, solar panels can help to reduce air pollution and protect the environment for future generations. Add in the fact that solar panels are cheaper to install and maintain than traditional energy sources in the long run, and they're an increasingly attractive option for many homeowners and business.

### **Solar Panels Help Preserve Natural Resources**

It's no secret that natural resources are increasingly under pressure from human activities, with many species facing extinction and habitats being destroyed. Solar panels can help reduce the impact of these activities by providing clean, renewable energy that does not require natural resources to produce. By relying on solar power instead of burning fossil fuels like coal and oil, solar panel users can significantly reduce their carbon footprints while simultaneously preserving the earth's dwindling natural resources.

Additionally, solar panels can be used to produce electricity in remote areas where fossil fuel infrastructure is not available, further reducing reliance on finite resources like coal and oil. Solar energy also helps conserve water by eliminating the need for cooling systems that are required with traditional electricity generation methods. So, by installing solar panels, you can be part of the solution to preserving our planet's precious natural resources and reducing your environmental footprint. Solar power is not only a way to preserve natural resources, but it also has the potential to create jobs within the renewable energy industry. Investing in solar power will help create more sustainable communities and contribute to a brighter future for generations to come. Thanks to your efforts, you will help protect our planet's most precious resources while also creating jobs and providing clean energy for years to come.

### **More to the Story?**

The benefits that solar energy provides are undeniable. From reducing reliance on fossil fuels to improving air quality, the environmental advantages of solar energy make it a serious contender in the race for sustainable energy sources. However, there are still some drawbacks that need to be addressed before it can become a mainstream energy source. One of the major environmental issues with solar panels is their production process. Solar cells and other components require large amounts of energy and water during the manufacturing process, making them resource-intensive compared to other energy sources.

Additionally, solar cells contain hazardous materials like lead and arsenic that must be disposed of properly when the panels are no longer in use. As such, it's important to research the production process of any solar panel company before investing in its products. Another potential environmental issue is solar panel waste. Solar cells can last anywhere from 15 to 30 years, but as technology continues to improve, solar panels become obsolete more quickly. This creates a cycle of production and disposal that could lead to large amounts of waste if not managed properly.

Finally, there is the issue of land use. Solar farms take up a lot of space and can have an impact on wildlife habitats. The best way to reduce these effects is to use rooftop solar installations, which don't take up any additional land or find ways to incorporate solar farms into existing agricultural lands. These potential environmental drawbacks of solar panels must be addressed in order for them to be truly sustainable energy sources. With careful consideration and proper implementation, however, the benefits of solar energy far outweigh the risks. Solar energy is a viable and important part of the transition to renewable sources and can help create a more sustainable future for generations to come.

### **Conclusion/Recommendation**

The use of solar panels to power the homes and offices of everyday people is an invaluable asset for those looking to reduce their impact on the environment. Not only do solar panels decrease the negative environmental effects caused by burning fossil fuels, but they offer a reliable source of renewable energy that can be used to power practically any device or appliance.

Solar panels can be used to power household appliances, heat and cool homes and even charge electric cars. With the right setup and maintenance, solar panels can provide energy for many years to come with minimal environmental damage.

It is clear that investing in solar panels could be an effective way of reducing one's carbon footprint while still being able to take advantage of modern energy sources. By investing in renewable and clean sources of energy, we can help preserve the planet for generations to come. It is important that everyone considers their personal impact on the environment when making decisions about electricity use, and solar panels are a great way to reduce one's environmental footprint without sacrificing modern amenities.

**Reference**

<https://eonline.com/articles/2022/12/09/solar-panels-and-their-effect.aspx>



## Impact of Gully Erosion on the Residents of Kontagora, Niger State

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### Abstract

Gully erosion has become a serious environmental disaster and also a threat to well-being of people. It has threatened and destroyed many of the physical infrastructure, properties, as well as retarding the social and economic growth and development of the inhabitants. The research assesses the impacts of gully erosion on the residents viewing the physical structures and human activities in Kontagora, Niger State. Data were obtained through physical observation and questionnaire via interview; questionnaire was administered to household around the targeted residents within the study area. The questionnaires were administered based on the issues relating to the impacts of gully erosion on physical structures and the localities of the respondents. Result of the impacts of gullies on the physical and human activities revealed that, farming is the most identified means of livelihood affected by gully. Result of the gullies control measures revealed that, planting of trees and grasses, sandbag embankment, broken stone embankment and landfills were the method used in controlling gully erosion. The research, therefore, recommends channeling of runoff water to drainage for permanent control and planting of trees and other vegetation cover for temporary control of gully erosion.

**Keywords:** *Damages, Gully erosion, Human activities, Physical structures*

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### **Background to the Study**

Soil erosion is the displacement of the upper layer of soil as a form of degradation. Over the years, tremendous contributions were recorded in understanding the operations of gully erosion and its controlling factors by many scholars using different criteria (Poesen, Nachtergaele, Verstraten, & Valentin, 2003), observed that Gullies are among the morphological indication of long period of soil erosion revealing the effects of atmospheric adjustment, example is heavy rain fall and land use practice. Both natural and anthropogenic activities have been reported to trigger the extent at which this gully erosion occurred. Among the natural factors are; climate, soil structure and composition, vegetation cover and topography. While the anthropogenic factors include agricultural practices, deforestation, roads and urbanization and as well as climate change.

Gully erosion is defined as the terminal phase of a four-stage erosion process involving splash, sheet, rill, and gully (Amangabara, Njoku & Iwuji 2017). Gullies could be considered as signals of disturbances and accelerated erosion brought about by climate or land-use change. Erosion by gullies can be an acute problem causing high sediment yield, removal of fertile soil, destabilization of hill slopes, and the lowering of water tables in alluvial aquifers. Apart from the loss in soil fertility and continuous diminutions of cultivable land, there is additional loss of properties to include losses of homes, household belongings, farm crops and utilities (Danladi & Ray, 2014).

Gullies could be considered as signals of disturbances and accelerated erosion brought about by climate or land-use change. Erosion by gullies can be an acute problem causing high sediment yield, removal of fertile soil, destabilization of hill slopes, and the lowering of water tables in alluvial aquifers. Apart from the loss in soil fertility and continuous diminutions of cultivable land, there is additional loss of properties to include losses of homes, household belongings, farm crops and utilities (Danladi & Ray, 2014). Erosion in Niger State is devastating and has caused a lot of human and material losses, most especially in Kontagora area where there are active gullies which is dispersed across. Gully erosion is active and at alarming rate due to soil texture and structure, slope, rainfall, human activities such as deforestation, over grazing, excessive cultivation, over grazing and construction works amongst others in Kontagora (Ojoye, 2021). Another major factor that contributes to erosion is population increase. The population growth rate of Kontagora Local Government Area was 3.5% according to National Population Commission (Niger State Population Statistics, 2020) and naturally when there is an increase in human population; both human and physical activities will be under pressure (Mbaya, 2012). It is against this background that this research examines the effects of gully erosion in the environment as a result of the interplay between human activities and natural elements in Kontagora.

### **Aim and Objectives**

The aim of the study is to assess the impact of gully erosion on the residents of Kontagora, Niger state.

Therefore, the specific objectives are:

- i. To identify the distribution of erosion in the study area
- ii. To assess the causes of gully erosion
- iii. To assess the extent of the damages of gully erosion
- iv. To evaluate the control measures for the gully erosion

### Research Questions

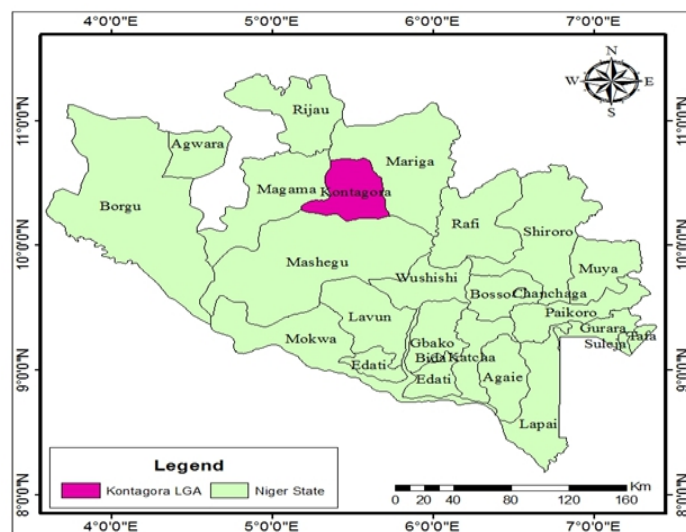
1. What are the distribution patterns of erosion in the study area?
2. What are the causes of gully erosion?
3. To what extent has gully erosion caused damages to the study area?
4. What are the possible control measures for gully erosion?

### The Study Area

Kontagora reservoir lies in the Northern Guinea Savannah zone between Latitude  $5^{\circ} 10'$  and  $5^{\circ} 40'$  East and longitude  $10^{\circ} 10'$  and  $10^{\circ} 40'$  North as seen figure 1.1. The climate is characterized by distinct dry and rainy season. In Kontagora, the wet season is oppressive and overcast, the dry season is partly cloudy, and it is hot year-round. Over the course of the year, the temperature typically varies from  $58^{\circ}\text{F}$  to  $97^{\circ}\text{F}$  and is rarely below  $53^{\circ}\text{F}$  or above  $103^{\circ}\text{F}$ .

Based on the tourism score, the best time of year to visit Kontagora for warm-weather activities is from early December to late January. The hot season lasts for 2 to 3 months, from February to April, with an average daily high temperature above  $94^{\circ}\text{F}$ . The hottest month of the year in Kontagora is April, with an average high of  $96^{\circ}\text{F}$  and low of  $74^{\circ}\text{F}$ . The cool season lasts for 4 months, from June to October, with an average daily high temperature below  $86^{\circ}\text{F}$ . The coldest months of the year in Kontagora is December and January, with an average low of  $59^{\circ}\text{F}$  and high of  $88^{\circ}\text{F}$  (Weatherspark, 2016).

**Figure 1:** Map of Niger State Showing Kontagora Local Government Area



**Source:** GIS Lab Department of Geography A.B.U Zaria, Using Arc GIS 10.3 Software

To show variation within the months and not just the monthly totals, we show the rainfall accumulated over a sliding 31-day period centered around each day of the year. Kontagora experiences *extreme* seasonal variation in monthly rainfall. The *rainy* period of the year lasts for 7 months, from *March* to *November*, with a sliding 31-day rainfall of at least 0.5 inches. The month with the most rain in Kontagora is *August*, with an average rainfall of 9.4 inches. The *rainless* period of the year lasts for 5 months, from *November* to *March*. The month with the least rain in Kontagora is *December*, with an average rainfall of 0.0 inches (Weatherspark, 2016).

### **Methodology**

Before the survey was carried out Field/ground observation was done. The investigation utilized personal observation methods and Photographs were taken to demonstrate the reality of erosion menace in the study area, and the pictures were presented in the analysis.

### **Sources of Data**

The data used in this research are both qualitative and quantitative which are data on physical structures, gully's location, and extent of damages. Questionnaire was used as an instrument to collect information from the respondents, who are inhabitants of the study area. The questionnaires were administered to respondents via interview behind Abuja Electricity Distribution Corporation (AEDC) along Federal College of Education Kontagora (FCEK)) road, Along Universal Basic Education (UBE) primary school at old Kwangwara, beside (FCEK) fence and behind old market. Information collected include effects of gullies on physical and socio-economic activities, gullies control measures put in place and opinion on how best to manage the effects of gullies within the study area. Observation checklist method was used in data collection through field visitation and appraisal of gullies, in order to answer some questions relating the distribution, effects and management strategies of gullies within the study area.

The target populations of the study are the total number of people residing in the households either temporarily or permanently. After taking a census of the household along these sites of gully, approximately 2,000 was the number obtained. In order to determine a sample size of proportional or percentage Study (prevalence Study), (Poesen, 2011 Ronán, 2016) suggested a population size of 146 -333 for a total population of 1,000 - 2,500 with acceptable error margin of 5 -7.5%. Following the nature of this study and with the total population size 150 samples which represent 15% of the total population were considered. The total sample size of the population selected falls within the required population size of 146-333 and acceptance error margin of 5 -7.5% as documented by (Ronán, 2016), as such sample size of 15% from each sample area was considered in this study. For adequate coverage of the study area, the samples collected from the study area is based on a total of 150 questionnaires representing 15% of the study population, but only 135 questionnaires were retrieved from the respondents.

### **Sampling Technique**

Purposeful sampling technique was adopted in the selection of localities where gulling are prevalent within the study area. It is a non-probability sampling which relies on the judgment of the researcher when it comes to selecting the units i.e. piece of data to be studied. Purposeful

sampling procedure focus on particular characteristics of a population that are of interest, which best answer the research questions of the study. The researcher apply his own criteria purposely when defining sample of gully sites in four selected localities for the study because they possess some characteristics of interest to the researcher during the study. In other to determine a sample size of proportional or percentage Study (prevalence Study), Simple random sampling technique was applied in the administration of questionnaires. The questionnaire was administered to the respondents with the help of other group members represented as field assistants and it is expected that the respondent to fill as appropriate and return it to the researcher.

### Method of Data Collection

For the field research, measuring tape and ranging poles were used to measure the height, depth and width of the selected gullies. The measurements were taken in meters. The gully length (L), depth (D), height (H) and width (W) were measured with a linen tape and ranging poles. The length of each gully was obtained by marking and measuring out points on the floor of the gully from the head to the mouth using the linen tape and the ranging poles. To measure the widths, each points was marked with a ranging pole in succession, and at each point, the tape was stretched across the gully bed from one side perpendicular to the other. At this point, the bed width reading on the tape was recorded in meters. The same procedure was repeated at the shoulder at the same point with the tape tight stretched across the gully to ensure that it did not sag at the middle. The depth was also recorded in meters to the last hole of the gully on the bed. The height of the gully was measured from the gully head to the top of the slope with record in meters.

These procedures were repeated for all the marked interval points along the floor and the average gully width (W) was computed as shown in Equations (1) and (3) respectively.

$$W_b = \frac{\text{Sum of bed width readings}}{\text{Number of interval points}} \quad (1)$$

$$W_s = \frac{\text{Sum of shoulder width readings}}{\text{Number of interval points}} \quad (2)$$

$$\text{Average gully width } W = \frac{W_b + W_s}{2} \quad (3)$$

The average gully depth (D) was measured by having a third person place one of the poles at the deepest part of the gully floor at the same interval point where the bed and shoulder widths were measured. The tape was placed at the ground level and stretched across the gully channel over the ranging pole. The third person holding the ranging pole on the gully floor noted and recorded the reading on the ranging pole as it made contact with the linen tape. At points where the gully depth was more than 1.90 m, the ranging poles were tied together using 10 m ropes to increase their total vertical length. The elongated poles were then used to measure the depths using the above procedures. Thus, the average gully depth was obtained by using equation 4.

$$D = \frac{\text{Sum of interval depths}}{\text{Number of intervals}} \quad (4)$$

The gully parameters actually measured in the field and collected were the Length (L), average depth (D), and the average width (W), average depth (D) and height. For these sets of variables (L, D, W, H), a total of four for each gully, the descriptive analysis and inferential analysis were used to investigate the relationships between gullies.

### **Method of Data Analysis**

Analysis techniques for this study involved descriptive analysis. It deals with the methods and techniques of summarizing and describing information (data). That is, it tends to describe incidence, events, and qualities in the elements. This includes the use of tables, frequencies and pictograms.

### **Results and Discussions**

#### **Identification of Gully Erosion Areas**

The field observation identified many gullies erosion vulnerable areas but by selection, four sites in Kontagora Local Government area were selected based on some of the characteristics observed in the survey, they are as follows:

1. Behind Abuja Electricity Distribution Corporation AEDC along Federal College of Education (FCE) road, in Kontagora: This is site A, in figure 2, it is selected because the site is used for molding of mud blocks and sand excavation during the rainy season. It is a rock formed as a result of accumulation of sand and stones. The red soil of the rock is clayey and very good for molding of blocks this is why human activities of this kind takes place there. During the rainy season the exposed soil is vulnerable to erosion and being excavated for sand filling eroded areas in the community. Human factor is the major cause.

**Figure 2:** A Mud block industry behind AEDC (Site A)



**Figure 3:** A damaged road beside UBE primary school, old Kwangwara (Site B)



2. Along Universal Basic Education (UBE) primary school at old kwangwara: This is site B, it is selected because the area is along a minor road surrounded by houses. The area is seen in figure 3; it is known to be vulnerable to erosion due to the local geologic setting, the permeability, porosity, cohesion and hydrodynamic events in the area. The gully erosion menace is thriving as a result of absence of well-coordinated control measures and inadequate and urgent attention it deserves.

**Figure 4:** A damaged road beside FCE Kontagora fence (Site C)



3. Beside Federal College of Education (FCE) fence: This is site C, as observed in figure 4, it is within clustered settlement beside FCE fence, and it is occupied by residents of staff and students of the college. Due to the porosity of the soil geology run-off played significant role in gulling, runoff at vulnerable region where there is poor drainage shows elevation changes within valley slopes which is observed in this site.

**Figure 5:** A modern block making industry with gully erosion behind old market (Site D)



4. Behind Old Market: This is site D, It is selected because it is within clustered settlement dominated by the indigenes of Kontagora behind old market as seen in figure 5. The areas has poor drainage pattern and it is also characterized by human activities such as modern block making and irrigation farming. Refuse are also dumped and cabbages litter around known as 'bolla' in Hausa language.

#### **The Causes of Gully Erosion**

In the Field/ground observation, the main factors found to cause gully include local geologic setting, depth to water table and annual rainfall. Others are permeability, porosity, cohesion and hydrodynamic events in the areas. The gully erosion menace is thriving as a result of absence of well-coordinated control measures and inadequate and urgent attention it deserves. For instance, in spite of the devastating impact on humans and structures and potential threats on more structures if not well managed the synoptic view of the affected area. Behind Abuja Electricity Distribution Corporation (AEDC) along FCE Kontagora road, the erosion is caused by anthropogenic influence.

Human activities of mud block making has affected the area thereby making it vulnerable to erosion, the area has a wide pit as a result of excavation and digging out of soil for construction purposes. An observation behind old market also shows that the area is influence by human activities of modern block making and irrigation farming. These Anthropogenic factors combine to weakened soils to produce severe gullies. The soils are hence loose and slumps under high intensive rainfall that renders them easily detachable. Some of the soils have the tendency to slake and form seals under such intense rainstorms thereby resulting in considerable runoff and soil erosion. The soil erodibility factor has since been recognized as a contributing factor to soil erosion hazard.

The area along Universal Basic Education (UBE) at old Kwangwara and the area beside the fence of FCEK lay gullies caused by natural and anthropogenic factors. The natural cause is



because of the geology of soil. The soil type or texture determines how water flows through it. Soil types with predominantly sandy characteristics allow for pockets of space that water easily moves through. For this reason, sandy soils do not have the ability to hold nutrients and support plant life. Without plants extending their roots into the soil and solidifying it, the chances of soil erosion increase even more. Since erosion plays a large role in soil depletion in this area, it is important to consider fertilization and irrigation when attempting to grow crops.

The soil in Kontagora is sandy, its geological materials are vulnerable to aggressive energy of wind, rainfall, and runoff. High erosion risks match with units of weak unconsolidated geological formations. This is more pronounced when such geological units coincide with medium to long and even very long slopes with marked gradients. In these formations, these sites of worst catastrophic soil erosion therefore play direct and indirect influence on the gully formation. The anthropogenic factor is caused by lack of good drainage system, self-effort by residents towards erosion control like pavement of their compounds, indiscriminate logging activities, lack of or implementation of erosion control measures by Governments at all levels.

In the event of uncontrollable grazing caused by the dwellers and indiscriminate foot paths created on the landscape helped the incipient channels on the landscape to form. These channels eventually metamorphose to gullies especially when they are not checked at inception. Road constructions including uncontrolled infrastructural developments have contributed significantly to gully developments. Some road networks under construction have been abandoned in the region due to gully formation. Even the road beside FCEK fence have collapsed and now become an abandoned road as a result of these factors. It is also observed that constant deforestation of plants and trees due to population explosion and increased agricultural activities in the region expose the bare soils to the vagaries of weather thus escalating the soil erosion problems. The implication is that the soils are frequently subjected to different degrees of erosion including accelerated erosion.

### **The Width, Height, Length and Depth of Gully Erosion**

As observed in table 1, site A has the width of 49m, height of 6m, length of 50m and depth of 10m. Site B has the width of 10m, height of 1.2m, length of 56m and depth of 1.3m. Site C has the width of 41m, height of 2.45m, length of 100m and depth of 2.85m. Site D has the width of 5m, height of 0.70m, length of 39m and depth of 1m.

**Table 1:** The Width, Height, Length and Depth of the selected sites

<b>Measurement</b>	<b>Site A</b>	<b>Site B</b>	<b>Site C</b>	<b>Site D</b>
Width	49m	10m	41m	5m
Height	6m	1.2m	2.45m	0.70m
Length	50m	56m	100m	39m
Depth	10m	1.3m	2.85m	1m

**Source:** Authors' Calculation 2022

From the above table, it is observed that site C beside FCEK fence has the longest length 100m, it is observed that the length extended to a long distance and collapsed a minor road which is now abandoned for only foot parts and used for waste land where cabbages, excreta and refuse are littered. More so, foundations of buildings along this part are collapsed. Site A has the deepest depth of 10m. This is as a result of continuous excavation of mud soil for block making and for sand filling over a long period of time which has finally led to a gully. In essence it has the highest height of 6m this shows how high the hill is. The gully in site B of old Kwangwara UBE primary school road has a peculiarity because the gully is formed on the road where humans and cars pass.

By observation, it is concluded that the gully is a result of natural and human cause. The soil type is very porous, and it lacks drainage pattern. There is a threat on the road presently because it could collapse at any time if control measures are not taken. The peculiarity in site D is that it is found beside a bridge, irrigation farm and modern block industry where the soil is threatened by all these human activities, and because of the geology of the soil, the soil is easily loosened and eroded.

### **The Extent of the Damages Caused Gully Erosion**

In table 2, it was observed that 16.6% of the respondents indicated that gullies wash away farmland and farm produce. 17.2% of the respondents reveal that gullies lead to sedimentation of water bodies, 15.9% of the respondents reveals that gullies caused difficulty in farming activities, 17.8% of the respondents indicated that gullies destroyed grazing fields and uproot economic trees respectively. Others include 14.6% of the respondents who indicated that gullies damage other means of livelihood apart from the ones listed in their localities.

**Table 2:** Damages caused by Gullies.

<b>Damage cause by gullies</b>	<b>Frequency (%)</b>	<b>Mild (%)</b>	<b>Moderate (%)</b>	<b>Severe (%)</b>
Washing farmlands and produce	26(16.6)	6(14)	9(18.8)	11(16.7)
Sedimentation of water bodies	27(17.2)	7(16.3)	8(16.7)	12(18.2)
Difficulty in farming	25(15.9)	2(4.7)	10(20.8)	13(19.7)
Destruction of grazing fields	28(17.8)	8(18.6)	10(20.8)	10(15.2)
Uprooting of economic trees	28(17.8)	8(18.6)	7(14.6)	13(19.7)
Others	23(14.6)	12(27.9)	4(8.3)	7(10.6)
Total	129(100.0)	43 (100.0)	48(100.0)	66(100.0)

**Source:** Authors' Calculation 2022

Most of the respondents admitted that destruction of grazing fields and uprooting of economic trees are the most affected sector in the study area. The respondents also indicated the level of gullies severity on the various livelihood means. 40(27.4%) of the respondents reveals that the damages caused by gullies are Mild, while 48(30.6%) of the respondents believe that the damage caused by gullies are moderate and 66(42.0%) of the respondents

reveals that gullies action is severe on the diverse livelihood means of the inhabitants in the study area.

**The Degree of Damages caused by gully Erosion.**

The empirical evidence provided in table 3 revealed the proportions of gullies damaged on the existing physical infrastructural facilities as follows; the most damage is destruction of roads with 11.9% respondents, 11.5% was for cutting of bridges, destruction of culvert and difficulties in construction respectively. Also 11.1% of the respondents indicated that damages were collapse of built-up structures, danger pits and breaking of water pipes respectively.

**Table 3:** The Degree of Damage Caused by Gullies

Damage caused by gullies	Frequency (%)	Mild (%)	Moderate (%)	Severe (%)
Cutting of bridges	27(11.5)	16(22.9)	7(8.2)	4(4.8)
Destruction of coverts	27(11.5)	11(15.7)	10(11.8)	6(7.2)
Collapse of built-up structures	26(11.1)	4(5.7)	9(10.6)	13(15.7)
Danger pits	26(11.1)	10(14.3)	6(7.1)	10(12.0)
Difficulties in construction	27(11.5)	8(11.4)	10(11.8)	9(10.8)
Breaking of water pipes	26(11.1)	5(7.1)	14(16.5)	7(8.4)
Uprooting of power poles	24(10.2)	3(4.3)	10(11.8)	14(16.9)
Destruction of road	28(11.9)	3(4.3)	10(11.8)	15(18.1)
Others	24(10.2)	10(14.3)	9(10.6)	5(6.0)
Total	235(100.0)	70(100.0)	85(100.0)	83(100.0)

**Source:** Authors' Calculation 2022

Uprooting of power poles and others reveals 10.2% respondents. In terms if severity of gullies damage in the study area 70(29.8%) of the respondents claim that the damages by gullies are Mild, another 85(36.2%) of the respondents believe that the damage caused by gullies are moderate and 83(35.3%) of the respondents believe that gullies damages caused are severe on the existing physical infrastructural facilities in the study area.

**Table 4:** Gully Control Measures

Gully Control Measures	Frequency (%)	Lowly (%)	Moderate (%)	Highly (%)
Sand embankment	23(19.3)	8(25.5)	8(19.5)	7(14.9)
Broken stone embankment	24(20.1)	7(22.6)	8(19.5)	9(19.1)
Planting of trees and grasses	24(20.1)	4(12.9)	11(26.8)	9(19.1)
Land fills	24(20.1)	6(19.4)	10(24.4)	8(17.0)
Construction of drainage	24(20.1)	6(19.4)	4(9.8)	14(29.8)
Total	119 (100.0)	31(100.0)	41(100.0)	47(100.0)

**Source:** Authors Calculation 2022

Result of the major gullies control measures taken by the various sites as indicated in table 4 revealed that 19.3% of the respondents suggested that sandbag embankment will control the excesses of gullies, 20.1% of the respondents are of the opinion that broken stone

embankment, planting of trees and grasses, landfills and construction of drainages respectively will control gully erosion within their localities. Most of the respondents indicated relative successes as a result of adopting one or more of the various control measures. As seen in the table, 47(39.5%) of the respondents recorded high success in the control measures, 14.9% of the respondents was indicated for sand embankment, 19.1% for broken stone and planting of trees and grasses, 17.0% for landfills while 29.8% was for construction of drainages.

### **Discussions**

In regard to the impact of gullies on the physical infrastructures, it was observed that, all the respondents admitted that gullies do exist in their localities ever since they were residing there, and gullies affect virtually all the physical infrastructural facilities type that exist in their respective communities. The most affected physical facility is identified to be housing which indicates that human shelter is most threatened by gullies in the study area which agreed with the view of Mbaya (2012). In addition, impact of gully erosion on human activities revealed that, farming is the most identified mean of livelihood affected by gully, which implies that, there is need for urgent control measures to check mate gullies in order to attain food security in the study area. This result agrees with the findings of Danladi and Ray (2014).

It was also observed that gullies have high impact on physical structures such as cutting of bridges abutments, destruction of culverts and roads. In addition, farmlands and farm produce are the most affected sector or means of livelihood by gully erosion in the study area. Following the information collected, it is clear that entire study area experience severe negative impact of gullies on various physical structures and means of livelihood of the residence.

Gullies control measures based on interview and questionnaires revealed that, the residence cannot adopt expensive erosion control measures such as construction of drainage channels, bridges among others, as such they adopted measures such planting of trees and grasses, sandbag embankment, broken stone embankment, sanitary landfills, construction of drainages which is similar with the view of Ojoye (2021). In addition, the respondent revealed that, they recorded relative success as a result of adopting one or more of the various control or mitigation measures used in controlling gully erosion but the methods with a highest success are the construction of drainages.

### **Conclusion and Recommendations**

This study was conducted in order to ascertain the impact of gully erosion on the residents of Kontagora vis-à-vis distribution, causes, extent of damages and control measures. Generally, all erosion activities including gully are directly or indirectly induced and the fact remains that they are not boundary restricted. It is a function of the drainage line, soil type and characteristic, anthropogenic activities and of cause climate change of late. When erosion activities metamorphose into gully formation, the multiplier effect is always colossal and thereby requiring collective effort to mitigate. There is no doubt therefore that the residents of Kontagora communities have seriously contributed to the degradation of the entire area that is

tending toward badland formation causing loss of lives and properties in the area. Cultural practices such as agro-forestry system, planting of cover crops in their farms, planting trees along the streets as well as other local factors that can mitigate the gully erosion but there is need for the construction of drainages in the locality for the permanent control of gully erosion in the study area.

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## **Challenges and Prospects of Integrating Information and Communication Technology in Adult Education in Nigeria**

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### **Abstract**

**A**dult education is indispensable tool for illiterate adult populace to fit into the modern society. It offers the adult members of the society opportunities to acquire skills, knowledge, competencies, attitudes, values etc. Adult education requires Information and Communication Technology (ICT) to be strengthened. Inspiring adult education using information technology equipment touches all aspects of human lives in this information age. This helps in increasing the individuals' ability to manage affairs, and resources both human and material things. The researcher gathered data from secondary sources e.g., Nigeria National policy on education editorial, public reports, journals, published and un-published books, and other relevance documents using qualitative analysis for achieving the aim of the paper. The paper contains; concept of ICT and ICT integration in adult education, importance and challenges of ICT in adult education, problems and prospects of integrating ICT in adult education as well ways forward. The researcher concluded that the integration of ICT in adult education will engender positive development in actualizing societal goals and associating with the terrain of computer age.

**Keywords:** *Adult education, Information and Communication Technology, Problems and Prospects*

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## **Background to the Study**

Adult as many people especially those outside the field of adult education say, 'is a person who is old enough to maintain a family'. Ojo (2011) opined that it is a stage of life where test of maturity and responsibility is ascertained. Being found to be matured and responsible, an adult is required to display inherent qualities before he/she can be referred to as an adult. Therefore, what is adult education?

According to UNESCO Institute for Statistic (2011) defined adult education as education specifically targeting individuals who are regarded as adults by the society to which they belong to improve their technical or professional qualifications, further develop their abilities, enrich their knowledge with the purpose to complete a level of formal education, or to acquire knowledge, skills and competencies in a new field or to refresh or update their knowledge in a particular field. This also includes 'Non-formal Education', Continuing Education', Recurrent Education' or 'Second Chance Education'. To strive better in adult education, ICT integration is essential.

## **ICT Integration in Adult Education**

There has always been strong relationship between the development of new technology, major social transformations, and changing definitions of what it takes to be a literate person. UNESCO (2006) defined ICT as a form of technology that are used to transmit, store, create, share or exchange information. On the other hand, ICT integration in adult education is the use of ICT to introduce, reinforce, supplement and extend skills in adult education Centre (Pisapia, 2014). Based on the pivotal role of ICT in adult education, the Federal Republic of Nigeria in her National Policy on Education stated that:

*In recognition of the prominent role of Information and Communication Technology (ICT) in advancing knowledge and skills necessary for effective functioning in the modern world there is urgent need to include Information and Communication Technology (ICT) at all levels of education in Nigeria” (Federal Republic of Nigeria (National Policy on Education), 2004, section 4, No. 19 (m), p. 17). Likewise, the same policy stated that “Local Government Councils shall be responsible for provision of physical facilities for rural libraries, reading rooms, television viewing centers and radio listener's clubs in Mass Literacy, Adult and Non-formal Education” (National Policy on Education, 2004, Section 6, No. 38 C (v), p. 28). Also, the Federal Ministry of Education in her national guidelines to implement ICT in education declared to “promote ICT proficiency in mass and non-formal education with focus on children, women and people with special needs” (Federal Ministry of Education (National Implementation Guidelines for ICT in Education), 2019, Section 2.2.5, p. 11). Serial No. 5 of the same section of the guidelines, mandated to “establish ICT clubs as a co-curricular activity in Non-formal Education Centre (Federal Ministry of Education (National Implementation Guidelines for ICT in Education), 2019, Section 2.2.5, No. 5, p. 12).*

For the forgoing, both the 'Federal Ministry of Education' and the 'National Policy on Education' recognized the important of ICT in adult education.

### **Importance of ICT in Adult Education in Nigeria**

According to Kozma (as cited in Igwe, Oyiboka, and Johnson, 2016) pinpoint some importance of ICT in adult/non-formal education. Among others, are:

1. ICT helps to produce ICT literate adults who will be useful to themselves and the society.
2. ICT provides adult learners the opportunity for distance learning nation-wide.
3. ICT provides adult educators with new sources of information and knowledge.
4. ICT encourages self-directed learning because adults love to engage in personal learning.
5. ICT produces adults who are capable of working in the new societies arising from ICT.
6. ICT in adult education add to community empowerment.

### **Problems with Adults using ICT in Adult Education**

1. The fear of using ICT technology.
2. Physical challenges like limited vision, impaired hearing, issues with motor skills, etc.
3. Diminished working memory.
4. Difficulty in staying focus.
5. Misuse of the technology for leisure.

### **Challenges of Integrating ICT in Adult Education**

Most adult education programmes require the use of ICT from the stage of program development to program evaluation. It is established that factors affecting ICT integration in adult education in one country may therefore not be applicable to another country (Anadarajan, Igbaria, and Anakwe, 2002). Therefore, to establish the existing challenges of integrating ICT in adult education considering Nigeria will be regarded to policy level and planning, infrastructure, communication barrier, capacity building, financing, among others (Fasakun (as cited in Igwe, Oyiboka, and Johnson, 2016)).

1. **Policy level and longtime planning:** Policy planners always have challenges of stakeholders' identification and harmonization of efforts across different interest groups. The piloting of the chosen ICT-based model and specification of the existing sources of financing always and do take a long period of time.
2. **Failure of policy implementation:** 'Easy said than done'. Nice and appropriate policy might be made available but putting it to action is a bone in the throat. Bardach (2017) in his studies, observed that diversion of resources, deflection of policy goals, dilemmas of administration and dissipation of energies added to the failure of policy implementation in adult education.
3. **Lack of infrastructures:** The absence of appropriate buildings and rooms to house ICT technologies, irregular power supply and Continuous disruptions in network services are things of the day in adult education Centre. Nzeneri (2008) noted that adequate facilities have not been provided in adult education centers despite the efforts of government, individuals, governmental and non-governmental agencies and communities.



4. **Instructors' poor capacity building:** Adult education is facing the challenges of severe shortage of ICT skills and personnel, obsolete curriculum, poor attitude and perception of teachers and administrators in ICT (Federal Ministry of Education, 2019). Most instructors lack professional training for them to be ICT skilled and computer literate. In fact, skill gap of the people implementing ICT is one of the key impeding challenges of ICT integration in adult education (Nnazor, 2005).
5. **Communication barrier:** Another challenge of integrating ICT in adult education is the inability of ICT systems to support instructions in multiple languages. One of the critics on media works was on its lack of ability to support multiple languages. Adults learn better when learning materials are presented in their respective languages (Wagner and Kozma, 2003). Hendro, Zaim, Syahrul, and Augustina (2018) also stated that potential barriers that might be face by adult learners using ICT in adult education is lack of English proficiency.
6. **Learners' low self-efficacy:** Self-efficacy is the extent or strength of one's belief in one's ability to complete tasks and reach goals (Ormrord, 2006). Most adult learners do not have positive attitude toward ICT. They lack enthusiasm. This could be as a result of religious belief, fear of loosen their customs and traditions, or the wrong impression “dry pot cannot be reshaped”. Which means old people cannot learn new things.
7. **Low financial budget:** ICT in adult education requires large capital investment. The cost of purchasing, installing, and maintaining ICT gargets are the great weakness to ICT integration in adult education. Most adult education Centre are ill-equipped with ICT gadgets and assistive technologies for the disabilities due to huge capital involvement.
8. **Accessibility challenge:** Adult education Centre with ICT equipped are mostly found in urban places. There is almost none existing in the rural areas chiefly because most rural places were located in area with bad terrains. Vehicles cannot access or convey ICT tools, coupled with no electricity. Therefore, integrating ICT in adult education in such places is like a blind man lacing a needle.
9. **Maintenance:** Maintaining ICT tools is another challenge of ICT integration in adult education in most countries especially in Africa. Poor maintenance culture is known with underdeveloped and developing countries. These countries can budget for ICT implementation but not its maintenance. Some adults' attitudes toward the use of ICT tools are equally problematic to their maintenance.

### **Prospects of ICT Integration in Adult Education**

For ICT to be successfully integrated in adult education, the following prospects must not be deviated:

1. ICT-enhanced adult education requires clearly stated objectives for mobilization of resources and political commitment of the concerned bodies (Igbo, 2008). The call for ICT policies in Nigeria is to allow individual citizens, including adults to access the training and services connected to ICT. In the light of this, the government set up the National ICT for Development (ICT4D) strategic action plan committee to develop a new ICT policy for development and for all education sectors, including adult education.

2. Nigerian government is aware of the need for ICT development and training to boost the manpower, improve the people's wellbeing and sustain the economy. As a result, many governmental and non-governmental bodies in Nigeria should strive to assist in the provision of ICT infrastructures and training programmes at all levels including work environments (Ibe, 2008).
3. Adult educators are now benefiting from workshops and professional development programmes focused on the use of computers and ICT in teaching and learning. This is in line with Bauer and Kenton (2005) who opined that teachers receive ICT instructions, schools now integrate computers and ICT into the curriculum, provide hardware and software needed for teaching ICT, computers and ICT become essential components of teacher preparation programs. Another restructuring measure for capacity building is the intention of improving ICT competencies, professional development of teachers and develop contents based on approved curricula. (Federal Ministry of Education, 2019).
4. Federal Ministry of Education (2019) shall organize appropriate manpower development on ICT content in indigenous languages to promote ICT proficiency in mass and non-formal education. Provision of multimedia classrooms such as e-classroom, virtual classroom through the use of teleconferencing studio, radio, television in which learners' languages will be used to impact lesions.
5. Creating awareness through mass and local media including social media the important of ICT in adult life will encourage self-esteem. Also, offering sponsorship to people with special needs and the under-served ones on ICT will equally bring in people to the system. This is in-line with Nnazor (2005) who stated that people with disabilities should be equipped with assistive technology skills to be fit in their communities.
6. ICT funding in adult education should be increase by engaging the existing funding channels (NITDF, PTDF, CBN, NITDA, etc.) and such funds should be use appropriately. Also, the use of creative financing models by identifying and establishing collaboration with development partners and seeking intervention for the funding of ICT in adult education (Federal Ministry of Education, 2019).
7. Although, ICT is having a revolutionary impact on educational methodology globally, but this revolutionary trend is not widespread and needs to be strengthened to reach a large percentage of the population (Dabesaki, 2005). Kinuttia (2008) stressed that adult education programmes have usually been carried out via radio, television and instructor-led lessons, but more recently some organizations have incorporated newer technologies. He pointed out that adult education programmes are now delivered through Community Multi-media Centre (CMCs).
8. Appropriate use of computers and other ICT gargets by instructors and adult learners has great significant effect on the life span of these gargets. Adult learners should be properly oriented about the do and don't when using the ICT gargets and equally guided to avoid ill use. Federal Ministry of Education (2019) stated that it shall adopt strategies for technical support and maintenance of ICT in adult education.

### **Ways Forward**

1. ICT policies in education should be properly enforced by the government through her agencies like NITDA, NCC, etc., with more focus on adult education.
2. The federal government in collaboration with state, local government and NGOs should emphasized, fully recognized and provide physical structures, facilities and ICT resource materials readily available as well encouraged to finance ICT in adult education.
3. Professional ICT educators should be developed and deployed to all adult education Centre. Regular monitoring and evaluation should also be carrying out to restructure ICT capacity building in adult education.
4. Adult education instructors and learners should be provided with Language Translation Devices like Langogo Pocket AI, Zoto Smart, Tarvis Touch Go, etc. These devices support multiple languages. Microsoft team and Microsoft translator are also good for multilingual conference and teachers/students' communication translation (Microsoft, 2020).
5. Careful labor market and cost benefit analysis should be taken. These in some cases might reveal other proven technologies that might provide necessary textbooks, peer tutoring, training, supervision and quality teachers in adult education.
6. Concessional employment should also be given to ICT professionals among the adults to attract people especially the under-served ones into ICT profession.
7. Government should sign, support and maintain agreement with vendors for regular training, maintenance and support staffs as well budget for ICT maintenance.

### **Conclusion**

It is crystal clear that ICT empowers adult citizens to continuously adapt to community, national and global developmental challenges, as well to develop the required knowledge, skills associated with life-long learning. There is need for appropriate integration of ICT in adult education settings to enhance the capacity of both adult educators and adult learners to become more responsive to new challenges in ICT. Integrating ICT in adult education programmes would provide everyone with basic skills and to use such new technologies during developmental training, workshops, seminars, conferences, teaching and learning environments.

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## The Effect of Military Internal Operations in Plateau State, Nigeria: Militating or Gravitating Insecurity?

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### Abstract

This paper examines the responsibility of a state for the protection of its citizens against external aggression and internal violence and disturbances. Conventionally, the latter is normally the duty of the police. This is the situation in Plateau State, Nigeria, where the military is used for military internal security operations. Since violence broke out between Christians and Muslims in Jos, several studies have indicated support for the use of the military as a 'necessary evil' to enforce ceasefires and ensure the return to peace. However, this study finds that using the military evokes several challenges that undermine both the legitimacy of the military mission and its professional image. To understand the problem, the study reviewed the separation, integration, agency, and concordance theories and argued that they are limited in scope and application. The aim of the study was to understand whether the Nigerian state is exercising adequate civil control over the military to ensure that it does not become a threat to the citizenry and exacerbate insecurity. 55 one-on-one interviews with civilians across different social categories were conducted in six local government areas in Plateau State to understand this. The study found that the military acts unprofessionally and that soldiers abuse of civilians is a recurring phenomenon; hence, civilians are dissatisfied with the military.

**Keywords:** *Military, Internal Security, Civil Military Relations, Conflict Resolution*

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### **Background to the Study**

The military is an important organization in the modern state. Its contribution to nation-building cannot be overemphasized or waved aside. Despite the fundamental role of the armed forces, their relationships with civilians have been a major concern. The military has been noted in the past for the use of violence in dealing with civilians and their desire to topple civilian governments at the slightest mistake. The military has used this access to the instruments of violence to control the government not only in Nigeria but in other African countries. In Nigeria, during the various military regimes, civil-military relations were marred by violations of human rights and consequent strains in the relationship. Civil-military relations refer to the totality of relations and interactions between military personnel and civilians in any political system. With the current democratic system of the fourth republic, it seems there is a new dimension to the relationship between the civilians and the military (Ajiteru, 2019). It is therefore in the context of this fourth republic that this study will examine the symbiotic relations between civilians and military personnel. This study aims at the examination of civil-military relations in the fourth republic. It is apparently important to examine the symbiotic relationships that involve the effective control of the military by the civilian government.

### **Rationale for the Study**

Using the military in an internal role to suppress violence and enforce law and order has been the subject of much debate among scholars, given the consequences it holds for the state and its citizens. While the literature shows that the problems often recur, few studies have examined how civilians experience the use of coercive force by the military (Ajiteru, 2019). This study aims to provide a deeper understanding of the use of the military in ISOPs, the effect on civil-military relations, and the security of citizens, with a focus on Plateau State, an ethnically heterogeneous society in Nigeria (Abalaka, 2020). Few studies have examined the interaction of the military and civilians in military ISOPs from a CMR perspective, and this study argues that it presents a shortcoming in the CMR literature. The field suffers from theoretical weaknesses and inadequacies on several fronts, especially in the 'civil' (social) sphere.

Studies in the field have focused extensively on preventing the military from intervening in politics, while important aspects, such as how the 'civilian' (social) sphere affects the relationship, have received little attention. In fact, scholars have made little attempt to integrate the citizenry and civil society as actors in CMR whose agency influences the relationship between. This also means that it is difficult to know if the internal use of the military for security enforcement is productive or counter-effective, potentially worsening the security situation after a ceasefire (Ajiteru, 2019). Hence, this study tries to bridge the gap by advancing the theoretical debate beyond the traditional focus on preventing domestic military intervention in politics. This can increase our understanding of the interaction between the military institution and citizens, especially when it acts in an internal role for which it is neither trained nor specialized. This is important because it provides a means to examine how the interaction affects the professional stature of the military (Abalaka, 2020).

### **Research Questions**

1. Does using the military improve or aggravate the security situation of the citizenry?
2. Does the Nigerian state exercise adequate civil control over the armed forces to ensure that they do not become a threat to the citizenry and exacerbate insecurity?

### **Research objectives**

The study aims to achieve the following objectives:

1. Understand the nature and type of threats armed groups pose to states, how this impact the ability of the state to protect its citizens, and the subsequent use of the military in an internal role.
2. Explore the current threats posed by armed groups in Nigeria and the conditions that have necessitated the use of the military in an internal role, with specific reference to Plateau State.
3. Examine the nature of civil control over the armed forces and how Nigeria regulates and controls the military.
4. Explore the perceptions and experiences of civilians in Plateau State to determine whether they believe the military is improving or undermining their security.

### **History of Civil-Military Relations in Nigeria**

The first republic witnessed a resentful military in Nigeria. According to Ademoyega (2021), the military was not happy with the political class and the fact that the British deliberately created a tripartite political situation in the country. The Nigerian military at that time had some revolutionaries who were ideological. In essence, there was no synergy between the military and the civilian leaders, as most of the soldiers that participated in the coup claimed that they were oblivious to the political situation of the country. That was the reason the military claimed they executed the coup to save Nigeria from collapse and disintegration. They even considered themselves nationalists carrying out nationalistic roles. The second republic was truncated after merely four years of democratic rule. It might not be out of place to say that the military during the second republic was in a hurry to return to power. The military officers at this time perceived the civilian leaders as corrupt individuals who could not steer the nation's ship to its desired destination. This implies that the military still had reservations toward the civilian rule. During the third republic, the military retained its hegemony despite the transition to democratic rule at the state level. The then military president, General Ibrahim Babangida, rather than handing power over to the acclaimed winner of the June 12 presidential election, handed power over to an interim administrator. The system of government in the third republic could be described as diarchy," in which civil and military rules were run concurrently. The third republic therefore witnessed the military control of the civil rule.

### **Civil-Military Relations in the Fourth Republic**

The civil-military relations in Nigeria under the Fourth Republic have taken a favorable pattern. The interest in civil-military relations stemmed from the peculiar features of the military. At the onset of the fourth republic, the executive had positioned itself to dominate the military. The reason could not be far-fetched considering the military background of the first



president of the fourth republic. In his speech at the National War College in Abuja on July 24, 1999, he laid out his plans to reform the military by establishing civilian supremacy. The paradox is that an institution set up to protect the state can at the same time turn around and brutalize civilians and overthrow a legitimate and democratically elected government. Obviously, military rule constitutes an aberration in every state since they are not trained to rule but rather to defend. After a series of military regimes in Nigeria that spanned almost 30 years since the country gained independence, the transition to democratic rule gave a new dimension to the relationships between civilians and the armed forces. The observed patterns or dimensions of civil-military relations suggest a position of subordination (Abalaka, 2020). Therefore, President Obasanjo changed the nature of civil-military relations because his administration proved to be under the control of the military. This was made easier by the fact that the Nigerian Army was centrally administered and in no way subjected to regional control. Even military court-martial judgments have been subjected to Supreme Court review. Obasanjo's administration, however, was noted for the brutality of the civilian population in a way that marred the civil-military relations from the perspective of the civilian populace. In November 1999, there was a massacre of civilians by the military personnel in Odi, as well as the October 2001 attacks in Zaki Biam. Throughout his tenure, Obasanjo exerted his control over the military and effectively dominated the armed forces.

The civil-military relationship under the late President Yar'Adua was not quite different from that under Obasanjo. Yar'Adua also continued with the same pattern of appointing the service chiefs without recourse to the National Assembly's approval. The health challenge of the late President Yar'Adua, which eventually resulted in his death, did not make it possible for him to make a substantial contribution to civil-military relations. Though his death did not create any lacuna in civil-military relations or governance, his vice president, Goodluck Jonathan, was able to step in and maintain his grip on the military. President Jonathan, as a successor to the office of President, in order to consolidate his political achievements, quickly retired some members of the military's top hierarchy. Like his predecessor, he saw the need to remove the military officers who were likely to plot a coup against him. However, his own retirement did not go without a challenge from the military, asking the court to nullify the compulsory retirement meted out to the top military hierarchy. In a judgment delivered by the Federal High Court, the compulsory retirement of military officers was declared illegal and therefore null and void. The judgment was since legislative approval was not granted before Abalaka's retirement. President Buhari was sworn in as the new democratically elected president on May 29, 2015. His government inherited the Boko Haram crisis from the Goodluck Jonathan administration. Buhari's government has deployed the armed forces to the areas under the terrorists' control. The civil-military relationship under Buhari has not taken on any different dimensions from past administrations. The civilians still retained their control over the military. Though there are few skirmishes between the civilians on the street and the members of the armed forces, there are cases of military intimidation of civilians on slight provocation. The presence of the military at some checkpoints, with serious dehumanization of any civilian who mistakenly violates any of their self-proclaimed rules, has made many civilians dread the military personnel.

## **Terrorists**

Much like armed groups, terrorism is difficult to define given the many different forms of terrorist groups that exist (Fletcher, 2016). These range from single or lone actors to loose cells and organized groups having defined chains of command and authority through which to further their cause. The working definition by the United Nations International Convention for the Suppression of the Financing of Terrorism (1999), which was adopted by Security Council Resolution 1566 (2014), defines terrorism as follows:

*Terrorism is any other act intended to cause death or serious bodily injury to a civilian or to any other person not taking an active part in the hostilities in a situation of armed conflict when the purpose of such an act, by its nature or context, is to intimidate a population or to compel a government or an international organization to do or abstain from doing any act.*

Thus, terrorists seek to achieve political goals such as overthrowing or replacing a government, forcing policy changes, or influencing political decisions. The political motive could be ideological, such as the desire to influence or change a government or its policies, and not necessarily to seize and control territory, as with insurgents (Thompson, 2016). In other instances, terrorists advocate for the inclusion and granting of better access to minority or politically marginalized groups in society. Where this is the case, they mobilize along identity lines, such as ethnic, racial, interest, or religious affiliation (Shultz *et al.*, 2016). However, several contemporary terrorist groups advocate for a form of religious or mystical goal that is interwoven with the political aim of establishing a religious state or replacing the secular laws of a state with religious laws. A few examples include Al Qaeda operating in the Middle East, the Taliban in Afghanistan and Pakistan, Hezbollah in Lebanon, and the Islamic State (IS), which is active in about 28 countries.

In Africa, the Al Shabab terrorist group operates in Somalia and Kenya, and Boko Haram operates in Nigeria and its neighboring countries of Chad, Niger, and Cameroon (Institute for Economics and Peace, 2015). Targets of terrorist attacks are usually civilian groups that are neither related to their interest group nor supporting their cause. Other non-human targets, such as critical state infrastructure (airports, train stations, water sources, etc.) that could cause serious disruption, fear, or panic among the population, are also attacked. Unlike insurgents, terrorists rarely engage in any form of warfare with state forces unless directly confronted and seeking to escape. For this reason, terrorists mostly direct their attacks at civilian targets and critical state infrastructure (soft targets). Thus, given that the primary targets of terrorists are non-combatant civilians, civilian casualties from their attacks are usually high. Attacking soft targets also helps terrorists create fear and panic, which they advance through media propaganda aimed at eroding the legitimacy of the state by presenting it as incapable of defending its population.

Unlike insurgents, terrorists often lack a popular support base and do not enjoy the same material and financial support from civilian populations as insurgents. Typically, terrorists' finances come from predatory and criminal activities, and they often prey on the livelihood of civilians in their strongholds through the imposition of levies and taxes. Others attack and rob

banks, and some engage in high-profile kidnappings for ransom collection. Another source of funding is from other foreign groups that share similar aims. For example, in "the 1990s, al Qaeda created an elaborate set of connections with... likeminded terrorist groups in as many as 60 countries. It also developed a sophisticated financial network for collecting and transferring money for the organization and its operations" (Shultz *et al.*, 2016). Through this means, they elicit financial assistance from individuals sympathetic to their cause and from groups with which they have established linkages. While this provides us with an insight into the transformation and sophistication of terrorism, critics argue that the features of the 'new' terrorism do not differ from what was previously known and should rather be seen as new waves of terrorism. However, terrorists and insurgents are not the only armed groups whose activities require attention. Other armed groups, such as militias, equally pose significant threats and security challenges that could destabilize a state and undermine the provision of public goods and services, hence the need to understand the militia-armed group.

### **Conflict resolution and third-party intervention**

Conflict resolution refers to different techniques for managing, settling, negotiating, mediating, or ending various forms and types of conflict situations. The aim of conflict resolution is to provide alternatives to violence and to end the use of violence by armed groups or hostile belligerents. Several scholars, analysts, policymakers, and mediators have proposed models and frameworks for managing and resolving conflicts of interpersonal, group, or interstate nature, depending on the context in which they manifest (Kriesberg, 2019). This made Hansen (2008) describe the field as a "pluralistic discipline requiring a number of conceptions and methods to address different kinds of conflict." However, one framework that provides important insight for understanding the resolution of new wars using military might, such as the Plateau incidence in this study, is third-party intervention, a common approach in contemporary conflict resolution (Abalaka, 2020). Third-party intervention involves an external actor acting in various capacities such as conciliation, mediation, arbitration, or as a peacekeeper (Ajiteru, 2019). In recent times, "there has been a shift from seeing third-party intervention as the primary responsibility of external agencies towards appreciating the role of internal 'third parties' or indigenous peacemakers". Often, this includes the use of the military to suppress violence and force a return to peace.

Contemporary counter insurgency, counter terrorism, and the fight against criminal and transnational armed groups are militarized and executed by the armed forces with little support from the police and other intelligence agents (Abalaka, 2020). From the discussion, we see that using the military in society for peace enforcement operations as third-party interveners could serve as a useful strategy, particularly when hostility overwhelms the police, but its activities require close monitoring. This is because the military has 'destructive' power, which can be abused when they support a particular ethnic or religious group. Instead of promoting peace and the smooth resolution of conflict, this can generate further insecurities and threaten the already fragile situation, Sulaiman (2021), conclude that "hard power has always been important in violent conflict, but soft power may be more important in conflict *management*." Given this, it is important to understand the ambiguity that arises when the military is used internally to suppress and contain the threats they pose.

### **Boko Haram Terrorism**

Another form of armed conflict has arisen in North-East Nigeria: the Boko Haram terrorist group, as a microcosm of the Maitatsine terrorist group, which existed in the 1980s in Kano State, North-West Nigeria. Unlike the former, Boko Haram (which literally translates as 'Western education is sacrilegious') has been more resilient and powerful in its dogma and military capability. The group has a contested origin. One account holds that it began in 2002 after a meeting between Mohammed Yusuf (an Islamic cleric) and some dropouts from the University of Maiduguri, where he claimed that 'Western' education is sinful (Gusau, 2019). Yusuf developed this ideology, asking followers to destroy their school certificates because they were in contradiction with Islamic culture due to their association with 'Western' (infidel) culture (Abalaka, 2020). This led to its popularity as Boko Haram, although it emerged as "the Prophet's teachings and Jihad. From the name, the intention is made clear, although it did not begin waging "jihad" until the execution of Mohammed Yusuf in state custody in 2009. This led to the resurgence of the group under the leadership of Abubakar Shekau, who made true the threat to wage war on Nigeria, particularly on 'infidels' and those sympathetic to or aiding them.

Since he assumed leadership of the group, Shekau has waged war on Nigeria, posing a serious existential threat to the political stability of Nigeria (Onapajo & Usman, 2015). In its 2015 report, the Global Terrorism Index named Boko Haram the deadliest terrorist group in the world (Institute for Economics and Peace, 2015: 2). Its sinister campaign of violence has plunged the country and its neighboring states into a humanitarian crisis, displacing over 1.5 million people across Chad, the Niger Republic, and Cameroon. Since 2009, it has launched several insurgent attacks against the military and bombed or destroyed several critical infrastructures and international agencies, including the UN office in Abuja, Nigeria's capital city. The death toll from its attacks in Nigeria is between 13,000 and 17,000 people, inclusive of security forces. The group is also responsible for the infamous kidnapping of the 276 Chibok girls from their school dormitory on April 14, 2014. Although the Nigerian government has negotiated the release of some of the Chibok schoolgirls, as of today (1 August 2018), 112 of the girls are still missing or in captivity. Not only this, but the group has also shown it is a serious force with the ability to gain and exert control over territory. Between 2014 and 2015, it seized control of about 14 local government areas (approximately 20,000 square meters of land) in three states in north-east Nigeria and declared this an Islamic Republic (Blair, 2015). It took the efforts of a Civilian Joint Task Force (CJTF) (a group of hunters, vigilante members, and volunteers familiar with the terrain) and the multinational joint task collaboration of Nigeria, the Niger Republic, Chad, and Cameroon before these areas were liberated from Boko Haram in 2016.

Funding is secured through several illegitimate means, as is typical in the new war thesis. Some have argued that Boko Haram has acted as a militia for desperate politicians seeking political power, who in turn fund it before they lose control. Along with this, the group uses extortion, ransom/prisoner swaps, and high-profile bank raids and robberies. By December 2011, it had raided about 30 commercial banks and stolen millions (Onu & Muhammed, 2021). Some funding originates from Al-Qaeda in the Islamic Maghreb, Saudi Arabia, and the

United Kingdom. However, the counterterrorist measures of the Nigerian government have weakened Boko Haram's coercive capacity, regained control of captured territories from the group, and negotiated the release of some of the kidnapped schoolgirls. Due to his weak and ineffective approach, former President Goodluck Jonathan significantly contributed to the group's capacity to wage sustained warfare against the state. To date, Boko Haram continues to unleash terror and sporadic attacks in several parts of Borno State and North-East Nigeria, killing many civilians, causing a humanitarian crisis, and disrupting social and political stability in this region of Nigeria.

### **Methodology**

This study examines the lived experiences of Nigerians who interact with military personnel conducting ISOPs in a society that has been subject to violent conflict. As this study examines the perceptions, attitudes, and experiences of people, it uses a qualitative approach. This is because understanding how the citizenry experiences the internal use of the military requires an approach that allows the participants to narrate their individual accounts of incidents.

A quantitative research design would have been limited to quantification and generalization rather than exploring the issues in depth. As there is little research on the interaction of the military with civilians, this was the best approach for this study. Interviews were conducted with a total of 55 participants. The interviews were conducted with people from diverse walks of life until saturation was reached. The interviews were audio recorded and subsequently transcribed and analyzed using thematic analysis with the help of Atlas computer-aided qualitative data analysis software (CAQDAS). In line with the precepts of inductive studies, themes emerged from the fieldwork data following the phases of thematic analysis.

### **Research Strategy**

This research was designed as an exploratory study due to its focus on understanding the experiences of civilians with respect to military operations in Plateau State. In line with the above-mentioned philosophical assumptions, the qualitative research strategy was used to guide this research. For conceptual clarity, a research strategy is the fundamental framework which guides the overall conduct and process of social research (Bryman, 2017). The qualitative research strategy places emphasis on understanding rather than measuring, quantifying, and generalizing from the data derived or used for the study. It focuses on giving thick and detailed descriptions of human experiences through observation and interaction with those involved to understand the meaning they attach to their experiences. Several reasons informed the choice of the qualitative research strategy for this study. One was the need to produce a thick textual description of citizens' experiences, perceptions, and attitudes regarding the military operations in their communities. This is important because few studies have examined this in Plateau State, Nigeria. In addition, while several studies have examined the conflict in Plateau State, a thorough literature search across databases and local publications reveals that few have examined it from the perspective of the interaction and experiences of civilians with the military (Abdullahi *et al.*, 2016).

A quantitative study would have required knowing what indicators to use to measure the effect the military has on the security situation in the State, which was not known. However, with qualitative research, themes, ideas and theories are derived from findings made from the data collected in the field. Furthermore, using qualitative strategies generates the primary data to fill the gap in existing theories of CMR to fully explain the phenomenon in Plateau State. Several scholars indicate that this is the most appropriate and suitable research method to elicit the perceptions, experiences, and attitudes of people.

### **Site of the Study**

The study site for this research was Plateau State, north-central Nigeria. As indicated in the previous chapter, several other states face recurrent and intermittent violence in Nigeria. These include the Niger-Delta oil-producing region and several states in the Northeast, such as Borno, Adamawa, and Gombe, affected by severe threats and violence from Boko Haram and military coercion. While these states could have been used, Plateau State has been adopted for several reasons. One is that I am more knowledgeable about the terrain, geographical landscape, and conflict situation in Plateau State as I have been a resident here for over 20 years. This insider knowledge was important because it enabled me to navigate the conflict zones with great care and caution to ensure my own safety and security and that of my participants.

Another key factor was my understanding and ability to speak, read, and write the Hausa language, which is spoken as a second language in some localities in Plateau State. This meant language and communication pitfalls were minimized, and participants could speak about their experiences and express their opinions comfortably without having to use an interpreter. The last, and possibly the most important, reason for using Plateau State is the ongoing violence and continuous use of the military to curb the conflict. Despite the military's presence and excessive use of force, they have been unable to stabilize this once-peaceful state in Nigeria. On the contrary, the military has been engaged in extrajudicial killings and genocide, with one of the most recent attacks on civilians on May 2, 2015, in Tarok communities. The actions of the military have affected its relationship with civilians, who are no longer willing to interact with or cooperate with them. The citizenry feels that the military has brought little relief and has rather become part of the security problem (Crisis Group, 2017). This made Plateau State relevant in terms of the aims and goals of this study.

Plateau State has 17 Local Government Areas (LGAs). Of these, six LGAs were used as sites from which participants were selected for this study. These LGAs included:

- i. Jos North LGA
- ii. Jos South LGA
- iii. Riyom LGA
- iv. Barkin Ladi LGA
- v. Mangu LGA
- vi. Bokkos LGA

After a preliminary investigation, several reasons informed the decision to use these LGAs as the sites of the study. These include the fact that military operations in these LGAs were still

very active and that the presence of military personnel in several parts of each of the LGAs was visible and pervasive. Along with this, these LGAs have continued to face violence that involved the military and the local population, and the recentness of the violence meant participants could more readily recollect, narrate, and discuss the issues as they were topical and fresh in their minds.

### **Selection of Participants**

Given that the study aimed to investigate the experiences of civilians during military operations in Plateau State, only civilians were recruited as participants for this study. A criterion was that they must have been residents of any of the LGAs for at least the past five years. They should also not have traveled or stayed away from the state for more than two months within the past five years. These measures were put in place to ensure that every person selected to participate in the study had some level of experience with the conflict and the use of the military. The assumption was that when individuals reside in an environment for a long period of time, they can observe the changes in the environment, develop coping strategies, and adapt to the changing environment. Thus, only participants with the required lived experiences were included in the study. Another criterion was that they were to be over 20 years of age in order to avoid the challenges associated with researching minors, as they may not possess adequate first-hand experience and a good grasp of the origin of the violence.

To elicit a broad spectrum of views and perspectives, participants were sampled from different social categories across the six LGAs. These categories included students of tertiary institutions; traders and artisans; public and private sector employees; employers of labor; unemployed persons; elected representatives; and community leaders, as detailed below.

1. Students of tertiary institutions: In each of the mapped LGAs, there is at least one tertiary learning institution, and these institutions were the point of locating and recruiting participants. These educational institutions were the University of Jos, the Jos Campus of Plateau State Polytechnic, the Barkin Ladi Campus of Plateau State Polytechnic, the College of Nursing and Midwifery Vom, the College of Education Gindiri, and Plateau State University Bokokos.
2. Traders and artisans: Sampling for this category took place at their respective places of work or trade. For traders, markets and shops in each of the sites were used as venues for recruitment. Artisans, such as vehicle mechanics, blacksmiths, tailors, and barbers, were reached by visiting their workshops, garages, stores, or shops.
3. Public and private sector employees: Recruitment for this category came from the respective secretariats, private sector offices, and government offices in each of the LGAs.
4. Employers of labor: A visit to private sector organizations was made to seek the consent of entrepreneurs who employ labor in each of the six LGAs.
5. Unemployed persons: Community and youth leaders in each of the LGAs served as leads for recruiting this category of participants, given the vast knowledge they have of members of their communities.
6. Elected representatives: Snowball sampling was used here to contact and arrange meetings with individuals in this category due to the difficulties faced in accessing them.

7. Community leaders: Most community members easily know their community leaders, and oral inquiry was used to contact and locate them.

Criteria-purposive sampling and snowball sampling techniques were used because they offered flexibility in selecting participants who met the objectives of the research (Holstein & Gubrium, 2015; Patton, 2022). Using criterion-purposive sampling ensured that participants met the stated requirements, and I assumed that civilians who fulfilled the criteria must have had some form of interaction with the military. The benefit was that it presented the opportunity to elicit both good and unpleasant experiences with the military, providing a more balanced view. In addition to the broad social categories of participants, I also considered ethnic and religious affiliation when sampling participants to ensure that I included all spectrums in the sampled population. This was important as it included individuals from diverse backgrounds, affiliations, and orientations who had interacted with the military, which enabled me to capture diverse views.

### **Data Collection**

As this study aimed to investigate the views, perceptions, experiences, and attitudes of people in relation to the military, participant observation and one-on-one qualitative interviews were used for data collection. Participant observation was helpful because it provided the opportunity to observe and encounter the role of the military in terms of how they act and behave when interacting with civilians. This was important because it aligned my experience of the military as a researcher (within the period of data collection) with that of participants. It also facilitated a deeper understanding of the experiences of civilians without presenting the challenge of behavior alteration and inaccurate description during interviews. The qualitative interviewing method was selected because it supports the use of open, unstructured conversations with participants and counters the limitations of using a structured interview guide or a standardized questionnaire for all participants. Rather, it requires the use of an aide memoire or broad questions to elicit in-depth responses from participants and to gain 'first-hand experience' with the phenomenon of study (Kvale, 2016). This approach provided the conversational space to comprehensively explore the experiences of participants, the meaning they attached to them, and the opportunity to investigate 'unanticipated' areas of inquiry.

A total of 55 interviews were conducted for the study. This number was decided upon due to the recommendation of conducting not less than 15 interviews for research using qualitative strategies (Bertaux, 2021; Guest, Bunce, & Johnson, 2016). The view is corroborated by many scholars because it is expected that saturation of categories would be achieved from this number of interviews. However, as I wanted to capture diverse views, interviews were continued until a point of saturation was reached. Table 5.1 below presents a breakdown of participants and the sites at which they were sampled.



**Table 1:** Breakdown of Interviews by LGAs and Social Categories of Participants

<i>S. No</i>	<i>Students</i>	<i>Traders/Artisans</i>	<i>Public/Private Employees</i>	<i>Employers of Labour</i>	<i>Unemployed Persons</i>	<i>Elected Reps.</i>	<i>Community Leaders</i>	<i>LGAs</i>
1.	2	1	2	2	1	1	1	Jos North
2.	2	1	2	1	1	1	1	Jos South
3.	2	1	2	1	1	1	1	Riyom
4.	2	1	2	1	1	1	1	B/Ladi
5.	2	1	2	1	1	1	1	Mangu
6.	2	1	2	1	1	1	1	Bokkos
<i>Sum</i>	12	6	12	7	6	6	6	55

**Source:** Fieldwork Notes

Although the table does not present other characteristics, such as religious affiliation and ethnicity, careful consideration of these characteristics was made in the sampling process. Another characteristic not covered in the table but that needs emphasizing is the gender of my participants. Of the 55 participants interviewed, 36 were men and 19 were women. Some participants had less interaction with the military than others, irrespective of gender. Interaction with the military was not a criterion used in selecting participants, and the reasons for this are discussed later on in this paper

### **Data Analysis**

Although there are several qualitative data analysis techniques, thematic analysis was used for this study. This choice arose from the exploratory nature of this study and its desire to investigate complex human experiences. It was considered adequate given that it focuses on identifying and describing both obvious and hidden truths within the data. As an analytical tool, thematic analysis is considered the most adequate and useful tool for investigating "complexities of meaning within a textual data set". Braun and Clarke (2016) indicate that it is a vital analytical tool for describing and examining the meanings and experiences individuals have about a given phenomenon. This shows the approach was suitable for this study, which sought to understand the lived experiences of people. The analysis was conducted with the aid of Atlas.ti 8 computer-aided qualitative data analysis software (CAQDAS). It followed a six-phase approach, which involved getting familiarized with the data, coding the data, generating themes, reviewing the themes, defining, and naming the themes, and producing the report by way of analysis. As this was an inductive study, themes were derived from the fieldwork and not from existing literature or my prior knowledge.

### **Conclusion and Recommendations**

This study has examined the experiences of civilians with the military ISOPs in Plateau State, Nigeria. The aim was to understand whether the state exercises adequate civil control over the armed forces to ensure that they do not become a threat to the citizenry and exacerbate insecurity. To understand the issues, the study argues that there is a relationship between

authority and conflict; hence, a conflict theory explanation was used to explain why conflicts occur in society. It notes that dissatisfaction with marginalization or the deprivation of certain sections of society tends to compel the desire for social change, including using violence where non-violent alternatives fail. Typically, where the problems are not addressed promptly, it results in insecurity that threatens both the political and social stability of the state.

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## Towards Compliance Assurance with Data Protection Regulations in SaaS Applications

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### Abstract

Enforcing regulatory compliance relating to security and privacy in Software as a Service (SaaS) applications have increasingly received much attention recently from industries such as the oil and gas because of potential benefits SaaS applications could bring to it. However, regulations such as European Union General Data Protection Regulation (GDPR) and the Nigerian Data Protection Regulation (NDPR) aimed at ensuring the protection of the rights of data owners, are legal documents and therefore, unable to ensure the enforcement of compliance. In this paper, we propose a policy language capable of defining and expressing data protection policies at each level of the data lifecycle for unambiguous compliance enforcement in SaaS applications. We propose new extensions of the Prime Life policy language to create the Security and Privacy-PPL extensions that can help to enforce compliance. Lastly, we show proof of usability of our proposed policy language using smart gas station-showing interactions between all the data actors and how compliance can be enforced using the SP-PPL.

**Keywords:** *Cloud, Compliance, Data, Nigeria, Data protection regulation, Privacy, Security, and Software as a service*

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## **Background to the Study**

Security and privacy compliance in Software as a Service (SaaS) applications are increasingly becoming relevant across all sectors. In particular, software applications continue to play critical roles in the oil and gas industry from exploration, transportation, to decision making, attraction of essential skills, strategy formulation and to the entire retail ecosystem, thus, implementing SaaS cloud solutions become highly relevant for this industry.

Additionally, recent developments in cloud computing have changed the means to which software is delivered and consumed. Thus, presenting the industry with several unique advantages such as scalability and pay as you go pricing model. Despite the benefits of SaaS applications [1], they still suffer from several significant drawbacks such as [2] governance control, compliance with established laws and data protection regulations, trust, identity and access management, software isolation, and incident response [3] and others relating to security and privacy of personal data. [4].

Against these challenges, debates continue about the best strategies for overcoming these challenges relating to the handling of personal data handling practices, location of data and other issues such as multitenancy in SaaS applications [5], this is coupled with a significant rise in data nationalism on the control of data within national boundaries [6]. To that effect, data protection regulations have been enacted by governments, regional bodies and industry organisations such as the European Union General Data Protection Regulation (GDPR) [7] and a similar version implemented in Nigeria called the Nigerian Data Protection Regulation (NDPR) [8]. These regulations have a significant impact on the operational activities of organisations within the oil and gas industry.

Data protection regulations are rules meant to carry out a specific piece of legislation relating to personal data handling, and they are made and maintained by an authority [9]. The regulations are unique to their purposes and countries of origin, but according to [10] in many cases, they are similar and designed to achieve local needs. For example, the GDPR is similar to the NDPR in many areas such as their aim to guarantee reliable protection of the personal data of natural individuals from organisations who collect, use and share information. Other areas of similarities include their scopes, how they define key terms, their legal basis, their recognition of rights and enforcement. Conversely, they are different in other areas, especially in enforcement and implementation. For example, the GDPR is implemented by member countries of the EU through an independent body such as the Information Commissioner's Office [11] in the United Kingdom, while the NDPR is implemented by the Federal Government Ministry of Communication [12] via the Nigerian Information Technology Development Agency (NITDA) [13]. In this research work, we consider the NDPR while baselining it to the GDPR.

The NDPR [8] and the EU GDPR regulations contain the rights of persons who are living and whose data are processed. On the other hand, these regulations also specify responsibilities for data controllers who handle the data and the rights of the data subject [14]. Because of these regulations impact, organisations are now concerned about compliance

when deciding to adopt software technologies such as SaaS applications. Decision-makers weight the advantages of SaaS applications against issues of compliance relating to data protection and privacy of personal data before migrating into the SaaS model. Recently, British Airways was fined £183.39 million pounds, and Marriott International Inc. [15] was fined 99 million pounds for a data breach under the GDPR [16]. Similarly, in Nigeria, the government licensed some data protection organisations and charged them with the responsibility of ensuring compliance with the NDPR to avoid personal data breaches within Nigeria [17]. For example, NITDA recently investigated the activities of Truecaller for the alleged violation of the privacy rights of Nigerians [18]. True caller is a service that helps to identify incoming calls from unknown numbers [19] efficiently.

Consequently, the concern for compliance has created a situation where organisations in the Oil and Gas Industry in Nigeria are beginning to include compliance into their strategic plans. To put things in the right perspective, within the context of this research, we define compliance as a means enforcing rules that implement the policies relating to the protection and privacy of data based on the preferences of data subjects and service providers as provided for in NDPR and GDPR.

As compliance is now a legal obligation under item Section 1.2 of the NDPR, organisations especially service providers are required to key in data privacy in Section 2.5 and security in Section 2.6 into their processes to ensure compliance. However, with the take-off of the NDPR in Nigeria, there is a significant challenge for its compliance by SaaS service providers, as the regulation is textual and can be misinterpreted and therefore making compliance challenging. Therefore, effective compliance remains a challenge to licensed data protection organisations due to the lack of enforcement mechanisms in Nigeria,

In order to solve the compliance challenge in a cloud environment such as the SaaS model, several solutions have been advanced including policy languages such as XACML [19], PPL [20], A-PPL [21], CPPL [22] with either a generic application or bespoke to some specific contexts to help with the compliance enforcement. However, we have identified some drawbacks of these languages when applied to SaaS applications: (i) the languages lack flexibility (ii), designed with defined set of requirements and application domains and therefore not suitable to express the requirements of every regulation as contemplated in Section 4.1 of the NDPR regulation.

Furthermore, looking at it from a technical perspective, all these extensions did not use any formal method to design these policies and therefore leaving room for ambiguity. Our approach relies on the advantage of using formal approaches to design our compliance policies so it can be easily verified mathematically unlike other languages such in [23]

To mitigate these drawbacks, we propose a policy language for ensuring compliance with data protection regulation for the protection of personal data by SaaS providers. The proposed policy language will extend the PPL language and can be used to enforce compliance with similar data protection regulations within in a SaaS setting. Specifically, our contributions in

this paper are:

1. We provided a comprehensive review of related studies with an emphasis on compliance and policy languages in a distributed environment with a focus on the SaaS applications.
2. We mapped the security and privacy obligations of the NDPR and aligned them to the data life cycle for ease of enforcement.
3. We present SP-PPL, the proposed security and privacy policy language, as an extension of the PPL designed for SaaS application based on the requirements of the NDPR.
4. Finally, we show the validity and the applicability of SP-PPL within the context of SaaS applications.

### **Data Protection Regulations**

Sion et al. [24] described data protection as a genuinely interdisciplinary effort involving many stakeholders such as legal experts, requirements engineers, software architects, developers, and system operators. Data protection laws require controllers to comply with their numerous provisions when it comes to the processing of personal data. Arguably, building software-intensive systems, including SaaS applications, which respect the fundamental rights to privacy and data protection, is a result of intensive dialogue and trade-off decisions, particularly in the area of compliance. Wayne Jansen et al. [25] defines compliance as the responsibility of an organisation to work in observance of relevant laws and regulations, standards and specifications, in this case, data protection regulations. In Section I above, we indicated that we consider data protection regulations such as the GDPR, NDPR, which we consider to be relevant to this work.

#### ***Data Protection Regulations Provisions***

From the legal perspective, data protection regulations are for legal experts and subject to legal and ambiguous interpretations. These interpretations further compound the challenges to their compliance. For example, the NDPR and the EU GDPR aim to ensure the protection of personal data by requiring compliance by organisations who are involved in the collection, usage, storing and forwarding of personal data and they apply to contexts where personal data was either collected online using electronic means or offline. While the NDPR came into effect in April 2019, the EU GDPR became effective in May 2018. Both regulations share very similar objectives. The NDPR's sole objective is to safeguard the privacy of data relating to natural persons in Nigeria. It sought to achieve this by ensuring that all transactions involving the transfer of personal data are free from manipulation. The regulation also stipulates a penalty for violation, with 2% of Annual Gross Revenue for data controllers who handle personal data of at least 10,000 data owners and 1% for data controllers handling less than 10,000 data owners.

On the other hand, the EU GDPR primarily aims to protect the privacy of residents within the geographical space of the EU by regulating how personal data is handled and processed by organisations in their operations. The EU is a significant economic bloc; therefore, the GDPR's reach, and impact became global. As highlighted above, the two regulations bear



similarities in many areas such as their objectives, definitions of terminologies, scope, and safeguards to the rights of natural persons to data privacy. However, they are different in ways such as enforcement mechanisms and authorities, child rights, and penalties where violations occur. In the following, we discuss these similarities and differences.

### **Scope**

The scope of GDPR is global as it applies to organisations outside of EU handling personal data of EU citizens, while the NDPR's impact applies to any organisation handling the personal data of Nigerians, hence, it certainly does not have the reach of the GDPR [8]. Furthermore, **Articles 3, 4 (1) of the GDPR** and Part 1 (1.1) of the NDPR clearly stated that the regulations only protect and safeguard the rights of individuals and not legal persons or entities. Therefore, in terms of scope, the two regulations are reasonably consistent.

### **Key Definitions of Terms**

On definitions of critical terms such as personal data, the data subject, data controller, data processor and child, both the GDPR and NDPR have similar definitions but differ on two key areas such as the definition of a child and data processor. While the role of a data processor is the same as the data controller in the NDPR, the GDPR classifies them as two separate roles.

1. **Personal data:** Personal data refers to any form of data that can be associated with a living person such as full name, national ID numbers, phone numbers, IP addresses, email addresses directly or indirectly [17], [26] [5]. Data Subject refers to an identifiable person. In this case, a person who can directly or indirectly be identified by referring to a number or any specific characteristic such as social, economic, physical and cultural or other identifiers such as IP addresses and email addresses[27].
2. **Data Controller:** A data controller refers to a person or an entity that handles personal data relevant to their operations. A data controller can refer to a legal person, authority or body that defines the reasons and channels of processing of personal data.
3. **Data Processor:** the GDPR described the data processor role as that of a natural or legal person who processes personal data in the interests of a data controller [28]. The GDPR sees this as an entirely different role or party in the handling of personal data. While the NDPR describes the data processor role as the same as that of a data controller, it went on to describe liabilities of a data processor or controller in Section 5 of the NDPR to include all third parties who handle personal data on their behalf.
4. **Child definition:** The GDPR recognises children as natural persons who are vulnerable and require special data protection. This special protection should have applicability to marketing or services tailored for children[29]. Conversely, the NDPR does not have any special recognition of children as natural persons requiring special data protection. Instead, it imposes all provisions on all-natural persons.

### **Rights**

Both the GDPR and NDPR uphold the right to be forgotten. The right to be forgotten provides a clear guideline on how the data subjects can request the erasure of personal data. For the sake of data protection, data controllers or service providers must comply with demands for erasure unless if there is an overriding interest such as listed in Art. 17(3)[30].

The scope of this right to erasure extends to third parties who may have processed data on behalf of a data controller. The exercise of this is free. Other similar rights guaranteed by both regulations include the rights to data portability, information, to object, to not be subject to discrimination, and the right to access personal data.

### **Enforcement**

As enforcement is the actual process of ensuring compliance with regulations, the GDPR and NDPR regulations made provisions for monetary penalties to be issued where there is non-compliance. However, the penalties, procedures and amounts differ significantly.

**Monetary penalties:** The GDPR charges 2% of global annual turnover, or 10 million euros, whichever is higher or 4% of global turnover or 20 million euros, whichever is higher. Similarly, the NDPR regulation charges 2% of the annual gross of a preceding year or 10 million naira's. The penalty applies to data controllers processing more than 10,000 data subjects. As for data controllers processing less 10,000 data subjects, the charge is 1% of annual gross revenue or 2 million naira's. Therefore, the regulations differ in what they charge in monetary terms and the percentage of revenue of the organisation.

**Supervisory authority:** Article 51 of the GDPR provides for an independent authority to implement the provisions of the regulation by member states of the EU. The authority is vested with the responsibility of assisting organisations in understanding their obligations and compliance. On the contrary, the NDPR does not have any provisions for the establishment of an independent monitoring authority but mandated the NITDA to oversee the application of the NDPR.

### **Civil Remedies**

In order to persuade or coerce relevant parties to take responsibility, provisions for civil remedies are in the GDPR as well as the NDPR. It affords individuals with cause to seek redress for violations of their privacy or the privacy of their data. According to the GDPR's **articles, 79 – 82, recitals 141 -147[5], a violation is a justifiable cause to start legal action.** Similarly, in Section 4.2 of the NDPR regulation, the right to seek for redress is affirmed while the Agency retained powers to set up an investigative Administrative Redress Panel to investigate violations[8].

### ***Data Life Cycle***

According to Butin et al. [31], personal data protection can only be beneficial when organisations implement protection policies at each stage that makes up the entire data life cycle within the context of personal data. Data life cycle is the sequences that a unit of personal data goes through from when it is initially collected, to how and where data is stored. Furthermore, how organisations share data with third parties and how it is deleted or erased. They went on to argue that regulations help set our obligations, and these obligations can help in the exercise of responsibility and the verification of handling practices by organisations handling personal data.

Following this, our proposed policy language specifies policies on the stages of data life cycle for activities such as data collection, policies enforcing storage preferences such as preferred location, policy for enforcing usage of collected data, and lastly, deletion, and forwarding of data to third parties.

1. **Data Collection:** The NDPR in Section 2.3 requires data controllers to make their purposes known before they collect personal data. It also requires them to make known how they intend to process the data. Furthermore, to avoid where data is collected arbitrarily, the regulation sought to limit data collection to the purpose for which it is collected [17].
2. **Data usage:** In Sub-section 2.1.a of the NDPR, data controllers are requested to collect data according to a clear lawful purpose. This purpose is to be communicated and have the consent of the data subject. A service provider's policy should have indicated details on (i) consent for use, (ii) purpose and (iii) who will use the data.
3. **Data storage:** The NDPR declared a policy relating to data storage in Sub-section C where the storage of personal data is within a period which it is reasonably needed. In a situation where a specific type of data is held in storage by a data controller or SaaS service provider, (i) the location of storage must be known, (ii) must be in a secure storage infrastructure and (iii) a periodic review on why the personal data is in storage.
4. **Data deletion:** On data deletion rights or the right to erasure, as in the case of the GDPR, the NDPR in section 3.1 (9) also described the deletion rights that data subjects can exercise. Therefore, by implication, service providers are required to have mechanisms or provisions for the enforcement of these rights by creating policies relating to deletion and retention of data with particular attention to details such as (1) who is authorised to delete data on a service providers storage, (ii) what type of data is the authorised personal allowed to delete or retain and (iii) whether the deletion has a period of delay.
5. **Data forwarding:** As service providers continue to depend on each other to provide services to users, the need to share data amongst them becomes critical. Therefore, to ensure effective regulation and the rights of data subjects, data protection regulations require that for data forwarding to be permissible consent must be obtained. In Sections 2.11 and 2.12 of the NDPR, data forwarding criteria described how a service provider or a data controller could transfer personal data to a third-party recipient. Some of the conditions are (i) consent provided by the data subject, (ii) an unambiguous purpose stating why the data will be forwarded and (iii) a list detailing the recipients of the personal data.

### **Review of Related Work**

We give an overview of relevant works in this section. We emphasize compliance and policy languages within the context of data security and privacy protection regulations in SaaS applications.

### **Compliance**

Compliance in the cloud today is a challenging subject, to that effect, several solutions and regulations advanced to help with the challenge of compliance to data protection regulations

such as the GDPR and NDPR. The US National Institute of Standards and Technologies defines compliance [25] as the responsibility of an organisation to work in observance of relevant laws and regulations, standards and specifications.

Recently, many countries and governmental bodies have implemented new types of regulations relating to data protection with applicability at different levels of government, such as national jurisdictions, regional and/or local governments. Thus, making compliance a highly complicated concern for cloud service providers (i.e., data controllers) and by implication, SaaS applications.

We, therefore, define compliance as being capable of enforcing the rules that are required to implement policies in regulations such as GDPR and NDPR. Furthermore, [1] described that compliance is one of the most critical requirements for many software systems; this is also true with SaaS. Compliance with the GDPR is mandatory, and failure to comply will lead to penalties [32], this is also true for the NDPR. Some existing research has provided data protection techniques to support compliance with regulations. For example, Jayasinghe [27] proposed a GDPR trust-based compliant framework for data controllers, Ta [6] proposed a formal design and conformance check of personal data protection policies and architectures, Yu et al. [33] proposed a technical framework that can help generate snapshots that are verifiable. These snapshots they assert can be used as data trails to help track disclosure of personal information.

Additionally, Al-Zaben [34] proposed an architecture relying on blockchain technology to help manage personal identifiable information. The architecture relies on a local database and blockchain ledgers that are not within the same location to help preserve the privacy of personal data. Elluri *et al.* [35] advanced an integrated ontology that is semantically rich. This ontology shows in detail the representation of data protection regulations rules such as the GDPR and other regulations. They argue that the ontology can help ensure compliance as the data regulations are only available in textual format.

Other forms of compliance with particular reference to SaaS applications was put forward by Indhumathil [36], they proposed third-party auditing in SaaS applications and cloud computing. They went on to argue that there is a relationship between the hesitation of organisations to use cloud-based services such as SaaS applications due to privacy, security and reliability concerns. Similarly, Lins et al. [37] argue that in order to increase the trustworthiness of cloud-based services, the practice of auditing continuously of carefully selected criteria will help assure users of the security of their data in the cloud.

However, although these solutions and technologies may be useful to enhance the compliance to data protection regulations, they do not suggest how the enforcement of compliance can be possible within the context of SaaS applications. Thus, these approaches are limited in their approaches and unable to provide information on how compliance with data protection regulations can be enforced by relying on the preferences of the data subject with the aid of by policy languages.

### *Policy Languages*

Henze et al. [22], described a policy language as the formalisation and expression of privacy and security policies into machine-readable languages. A policy language must fulfil a certain number of vital requirements to help enforce policies in environments such as distributed environments as with the SaaS applications. The requirements are (i) minimal or least storage footprint, (ii) efficient policy checking, (iii) expressiveness, (iv) extendibility, (v) incremental deployment and (vi) matching.

In order to enforce compliance with security and privacy preferences of data subjects, policy language is required. Consequently, we discovered a handful of policy languages proposed for modelling and enforcing privacy, security, and access control rules. Similar to the authors in [12], authors in [6] described security policy language as languages used in the formulation of rules and the enforcement of policies with relation to confidentiality and availability of data. It also refers to the integrity of properties of data. On the other hand, a privacy policy language is used for creating rules that are capable of preserving and safeguarding the privacy of personal data [37]. For example, an access control policy language such as the XACML is foundational but has remained relevant today.

XACML, as indicated, is an access control centred policy language. It has an inbuilt request/response language for effective two-way communication [19]. Furthermore, it consists of standard XML elements and standard extension points for specific rules, different data types and procedures. Due to its standardisation based on OASIS, there exists many implementations and extensions for access control rules. For example, these extensions includes profiles for usage control[38], privacy policy[39], PPL[40], A-PPL[21].

Enforcing access control was the sole reason for developing The Prime Life Policy Language (PPL) [40] using certified credentials before granting access. These credentials include attribute and role-based access control [41], [4] systems. The PPL extension of the XACML introduced a very effective means of enforcing rules using the concept of the obligations and enforced by a matching engine using a combination of a trigger and an action to execute the obligations.

Another policy language is C2L [42]. The C2L aims at enforcing configurations that are permissible in a cloud environment. The language uses spatiotemporal logic which enforces these permissible configurations by providing policy constraints statements on colocations, hosting, security and migration of data and others such as availability of data. However, C2L only focused on formalism and not real-life application in a live cloud environment.

Similarly, [23] extended the PPL Language and proposed an accountability framework to improve the safety and accountability of data by service providers in handling personal data. Using an abstract policy language, they expressed the data subject's preferences and service provider's obligations in a human-readable fashion, thus, achieving ease in mapping to the enforcement of policies[23]. The A-PPL [43] is a follow up to [23] as an extension of the PPL designed to express machine-readable accountability policies as opposed to the human-

readable language. A-PPL can define accountability and transparency rules on personal data handling using the developed extensions on data retention, data location, logging and notification.

Another extension of the PPL is CPPL [22], the Compact Privacy Policy Language that enforces the privacy of personal data by compressing privacy policies using flexibly specialised domain knowledge. In addition to the contributions and extensions to PPL by [42], [44], [23], [22], [43], the authors in [45] presented a set of fundamental requirements that must be met by cloud providers or service providers to satisfy the accountability requirements of their customer's data. They outlined several tools for an accountability-based approach such as Payment Card Industry Data Security Standard [46]

Another policy language is PriArmor [47]. It proposed to work with the Infrastructure as a Service (IaaS) model of the cloud. The PriArmor approach allows data subjects to express their privacy preferences aligned to regulations using an ontology model that includes all concepts on data access and usage within a distributed environment such as the cloud.

However, all these PPL extensions discussed above are focused on some specific aspects of security and privacy enforcement and the research projects for which they were proposed to address. Among these extensions, A-PPL extension is the closest to this work, but with focus on accountability properties and the role of an auditor, the C2L focused on the formalism of requirements on spatiotemporal modal logic, the PriArmor extension purely focused on the IaaS, and the CPPL focused on the storage of data.

### **Limitations of the Existing Policy Languages**

Based on the analysis of existing policy languages in [48], and other domain-specific PPL extensions such as A-PPL [49], C-PPL [22], we choose to extend the PPL as the most suitable policy language, due to its extensibility, and contextual application. Therefore, we will create new PPL extensions to build the SP-PPL.

A major weakness of all these PPL extensions is that they did not envisage the provisions and compliance requirements imposed by new regulations such as the GDPR and NDPR. They also were not focused on the SaaS model of the cloud, but they are all built on a significant advantage of the PPL, which is that it is extensible to the new realities of recent regulations in the areas of expressing, designing and implementing compliance. In this work, as a contribution, we intend to extend the PPL to satisfy and implement the provisions of the NDPR as it is a regulation within the immediate operating environment of organisations in the case study.

**Table 1:** Comparison of policy languages

Policy Language	Security	Privacy	Expressiveness	Extensibility	Policy matching	Compliance checking
XACML	-	-	-	✓	-	-
PPL	-	✓	-	✓	✓	-
C2L	-	✓	-	-	-	-
A-PPL	-	✓	✓	✓	✓	-
CPPL	-	✓	-	-	✓	-
PRIAMOR	-	✓	-	-	✓	-
PDC	-	-	-	✓	✓	-
SP-PPL	✓	✓	✓	✓	✓	✓

Table 1: Comparison of policy languages. A Language fulfils this requirement (✓), a Language does not fulfil this requirement (-).

### The System Model

SaaS application service providers collect user's data to allow for the use of their applications or services, thus creating the need to ensuring compliance with data handling regulations. In order to understand the intuition behind this work, we will in this section, present a SaaS scenario to help put into context how data control is transferred from the data subject to the service provider, we will go on to provide a set of generic requirements that a standard policy language must address.

### Scenario

As indicated above, we consider a scenario where data is collected and transferred out of the data subject's control to the infrastructure of the service provider. The data could be used in manners that may conflict with the data handling preferences of the data subject thus raising security and privacy concerns [41] thus resulting in a loss of control over own data [1]. In the past, many approaches have been put forth to mitigate these concerns such as the sticky policies in the works of [19] which attempts to enforce user preferences to data in order to enforce access control. Generally, these policy languages aim to enforce the privacy preferences of the data subject on all data handlers based on some specific data protection regulation.

In the following, we start by mapping the security and privacy compliance requirements in the GDPR before developing our PPL extension SP-PPL.

### Mapping of Compliance Requirements in the GDPR

Following the analysis of the obligations of data controllers as set out in the GDPR, the proposed policy language would be able express data handling rules that correspond to the collection, usage, storage, deletion and retention, and data forwarding. In addition to the requirements extracted from the GDPR, in order to successfully extend the policy language to meet our needs, we also considered some the generic requirements put forward by Henze et al [22] such as minimal storage footprint, efficient policy checking, expressiveness, extend ability and ease of deployment. Additionally, this is backed by our analysis of the data protection and

handling expectations of the GDPR. We found out that the expectations of the GDPR requires that the proposed policy language should be able to express data compliance rules relating to collection, usage, retention and storage location to which the PPL [23] language fulfils some of the requirements (e.g., access control and privacy). Moreover, it should also be extensible enough to fulfil the requirements of the GDPR in the context of SaaS applications. However, the limitation of the requirements is by no means exhaustive, but it satisfies the contextual objective of checking compliance to data protection regulations in SaaS applications.

#### ***Requirement #1 Data Collection***

While the importance is attached to the entire states of the data lifecycle, specific areas become very vital at the collection stage of personal data. At this stage, organisations are generally faced with the challenges relating to consent and opt-out rights [14]. This is because one of the key issues relating to data collection is consent when processing personal data. Although the data subject approves to the processing, consent may be withdrawn at any given time, thus adding to the compliance challenges where a third-party processing has already taken place. Accordingly, this is a requirement Section 2.3 (a) of the GDPR, which describes how the purpose of data collection and processing must be known to the data subject before the collection of personal data to authorise or give consent to the processing of data.

#### ***Requirement #2 Data Usage***

In order to use SaaS applications, organisations collect and share data with service providers. This raises a challenge particularly of conflicting interest relating to usage and thus raising data handling concerns on how the service provider and other third parties may use the collected personal data. In this scenario, service providers may want to use the data for other purposes by employing other legal means such as in the subscription or service agreements. Other challenges relating to the usage state of the data life cycle is the profiling and tagging of personal data and subsequent exploitation as part of Big Data analysis. To address these concerns, Section 2.1 Sub-section (a, b) of the GDPR requires that data is collected with consent and for clearly defined specific, legitimate and lawful use purpose as a contract to which the Data Subject is party or in order to take steps at the request of the Data Subject before entering into a contract.

#### ***Requirement #3 Data Storage***

To achieve service availability of SaaS applications data, SaaS service providers depend heavily on continuous data copy and backup, which usually contain personal and usage data. While the availability and integrity of the data is the aim of this continuous backup, it comes with the challenges of compliance to consent collection, especially where third party storage services are involved. To mitigate this challenge, data should only be held in storage within the time which it is reasonably needed. Accordingly, the GDPR in part two Section 2.1, subsection (c) stipulates the period within which personal data may be held within a reasonable period of time needed to store data. This is to help protect personal data and minimise the amount of data collected and held in storage.



#### ***Requirement #4 Data Deletion and Retention***

At the end of data processing, personal data should be deleted. Data deletion in a cloud computing environment such as SaaS applications may occur for several reasons, for example, an exit strategy, the lack of lawfulness or legitimacy of processing. While data destruction is an essential part of sustaining compliance, it comes with several challenges, such as technical and complexities mainly due to multi-cloud environments of different providers requiring different data deletion processes towards different types of requests.

Interconnectivity of systems is further seen as a challenge, as deletion of data in one system may cause ripple effects in other systems. Other challenges include the *Right to Erasure* due to the ambiguous nature of this right, and some organisations are not sure what erasure means. If there is no legal basis for the continued processing of personal data, deletion is required. Simply delinking the data with a data subject can be seen sufficient to fulfil the right to the deletion request. Other situations may require a complete deletion of the data where data is unlawfully processed (i.e., processed without the consent of the data subject). Regardless, complying with request for data deletion requires tracking down each instance of the personal data collected and copied to other locations.

Furthermore, verifying deletion to demonstrate compliance may become even more challenging in SaaS applications, owing to transparency issues. Organisations collecting personal information need to be able to handle constant requests to maintain compliance as required by data protection regulations such as in Section 3.1 of the GDPR regulation, and sub-section (9) stipulating the rights of the data subject regarding the deletion and retention of data.

#### ***Requirement #5 Data Forwarding***

As the last stage of the data lifecycle, data forwarding happens when a service provider transfers or share data with a third-party during processing. During the processing of personal data by SaaS service providers, some risks and challenges emerge as data is shared and forwarded to third parties in the course of processing or service delivery. Challenges such as trust and the verification of compliance with relevant data protection regulations. In order to prove compliance, service providers should be able to deploy mechanisms for verification performed by data subjects. However, demonstrating compliance, such as deletion, may be obstructed by the lack of transparency of the service providers. Other compliance challenges relating to data forwarding include how secure the components or infrastructure used for the transfer. In order to avoid any violation of the rights of data subject with relation to how data is transferred and shared between data controllers, Sections 2.3 sub-section (e) and 2.12 of the GDPR states that a data controller is under obligation to ensure that consent of the Data Subject has been obtained without fraud, coercion or undue influence in situations where personal data may be transferred to a third party for any reason whatsoever.

#### **Limitations of the Ppl**

As discussed in our review of the PPL in **Section III**, the PPL was proposed to specify machine-readable privacy policies by building on the XACML [19]. This was achieved using

extensions by defining a new syntax for obligation and authorisation. Within the PPL, an obligation is expressed using the pair Trigger-Action. Triggers are events related to an obligation and filtered by conditions[49]. Triggers fire actions such as personal data collection performed by a data controller. Some examples of PPL triggers and actions are[20]:

a) Triggers = condition + event (e.g., within 7days after the deletion of an address, or when using a phone number for calling purpose, within 3 hours of using a phone number for calling purpose,) e.g., trigger constructs:

*TriggerPersonaDataDeleted*(address, 7 days)  
*TriggerPersonalDataAccessedForPurpose*(phone, {call}, default)  
*TriggerPersonalDataAccessedForPurpose*(phone, {call}, 3 hours)

b) Actions (e.g., delete an address, anonymize name and address, notify Pete via email) e.g., action constructs:

*ActionDeletePersonalData*(*{address}*)  
*ActionAnonymizePersonalData*(*{name, address}*)  
*ActionNotifyDataSubject*(*email, {Tukur}*)

Authorisations define the actions that the data controller is allowed or prohibited to perform such as (a) authorisation for usage purposes and (b) authorisation for data forwarding to third parties. Although several requirements such as access control, privacy and usage can be handled by the PPL, it has no definitions for compliance check to data protection properties at granular levels policies at each stage of the data life cycle.

Given the above limitation of PPL, we propose in section VI our Security and Privacy compliance policy language SP-PPL that extends the PPL at each stage of the data life cycle within the context of SaaS applications. SP-PPL will rely on the PPL architecture and to express the requirements. Furthermore, we use a new step showing a formal application of the SP-PPL to the end-to-end data life cycle within the context of SaaS applications.

### **Introducing Sp-Ppl Policy Language**

We propose SP-PPL our security and privacy policy language for the specification of preferences of the data subjects, and preferences of service providers for the purposes of compliance checking and assurance. The language will have, as provided in the regulations, a data subject, and a data controller as actors. This is consistent with the earlier versions of the PPL. SP-PPL will be able to present policies at each level of the data life cycle as detailed in **Section II** above. This can be used to define policies across all the stages of the data life cycle within the context of SaaS applications.

To the best of our knowledge, this is the first work in the context of security and privacy compliance with data protection regulations in the context of SaaS business applications. The SP-PPL syntax and the corresponding application of the proposed policy language with compliance regulations such as the NDPR, and the data life cycle makes the proposed policy language versatile.

### SP-PPL Syntax

In this section, we present the extensions added to the PPL to create the SP-PPL while still maintaining the original PPL structure. The SP-PPL identifies the following roles: Data subject, Data processor and Data controller and third-party data controller. These roles already exist within the PPL architecture. For the NDPR and compliance checking, the following syntax is proposed: Unlike the PPL, the following is our syntax for enforcing data protection regulations such as the NDPR and GDPR.

1.  $Pcol = (cons, cpurp)$ , with  $cons \in \{Y, N\}$ . *Y- Yes, N- No*
2.  $Puse = (cons, upurp, whouse)cons \in \{Y, N\}$ .
3.  $Pstr = (wh, ho, revdate)$ ,  $decl \in \{Y, N\}$ .
4.  $Pdel (placedel, when, decl)$ , where  $decl \in \{Y, N\}$ ,
5.  $Pfw = (cons, fwpurp, 3rdparty)$ ,  $decl \in \{Y, N\}$ .

Our policy specifications are inspired by a number of works including [6] but with an extended and a combination of formal and XML expressive syntax to express the data protection properties for personal data handling in SaaS applications. Our language is adaptable to any data controller and applicable to recent data protection regulations such as the GDPR and NDPR. The syntax of the language will be expressed as:

Going forward, a set of policies focused on the protection and privacy of data will be defined and aligned to the data life cycle in SaaS applications. The syntax for the proposed security and privacy protection policies are defined as tuples and aligned to the data life cycle and presented below in Table 1.

**Table 1:** Data lifecycle policy sets

S/N	END-TO-END DATA LIFE CYCLE	POLICY DEFINITION EXPRESSION
1	Data collection	<i>PolCol</i>
2	Data usage	<i>PolUse</i>
3	Data storage	<i>PolStr</i>
4	Data deletion or retention	<i>PolDel</i>
5	Data forwarding	<i>PolFw</i>

### Definitions

The syntax for the security and privacy policies are defined as the following tuples. We define the set of high-level data protection policies (*POL*), which are composed of the five sub-policies based on the end-to-end data life cycle. Namely, the sets of data collection (*Pcol*), data usage (*Puse*), data storage (*Pstr*), data deletion (*Pdel*), data forwarding policies (*Pfw*).

This is further expressed as:

1.  $POL = PolCol \times PolUse \times PolStr \times PolDel \times PolFw$
2.  $Pcol = (cons, cpurp)$

3  $P_{use} = (cons, usepurp, whocanuse)$

4.  $P_{str} = (wherestore, howstore)$

5.  $P_{del} = (placedel, when, decl)$

6  $P_{fw} = (cons, fwpurp, 3rdparty, decl),$

1. Data collection policy includes consent required ( $P_{col}$ ) for certain data types (e.g., personal data) and collection purposes ( $cpurp$ ).
2. Data usage policy  $P_{use}$  specifies the consent ( $cons$ ) for data usage and the purpose of data usage ( $usepurp$ ), and the set of entities who are allowed to use the data ( $whocanuse$ ). Data storage policy.
3. The data storage policy  $P_{str}$  specifies where the data is stored ( $wherestore$ ) how the data is stored ( $howstore$ ).
4. The data deletion policy  $P_{del}$  specifies the location where the data ( $placedeldecl$ ) is deleted ( $when$ ),  $when = (rdelay = dd)$  with defined retention period and  $when = (gdelay = gd)$  the global retention delay .
5. Finally, the data forwarding policy  $P_{fw}$  policy involves the consent  $cons$  and forwarding purpose  $fwpurp$  the third-party entities to which the data will be forwarded ( $3rdparty$ ),  $decl$

Each data protection policy is designed on a data type ( $\theta$ ), precisely, let  $P\_typeset1, P\_typesetk \in POL$  , be a policy defined on a data type  $\theta$ , and the five policies relating to the data life cycle  $P_{col} \in Polcol$ ,  $P_{use} \in PolUse$ ,  $P_{str} \in Polstr$ ,  $P_{del} \in PolDel$ ,  $P_{fw} \in PolFw$ , where

$$Pol = (P_{col}, P_{use}, P_{str}, P_{del}, P_{fw})$$

In the policy expressions above, we have defined policies around all the data life cycle for data collection, ( $P_{col}$ ), data usage ( $P_{use}$ ), storage of data ( $P_{str}$ ), data deletion ( $P_{del}$ ) and the forwarding of data, ( $P_{fw}$ ).

1.  $P_{col} = (cons, cpurp)$ , with  $cons \in \{Yes, No\}$ . Here we specify that a consent is required to be collected from users when collecting their personal data. With Y denoting Yes, and N denoting No.  $cpurp = (P\_typeset. P_{col}, decl)$ , where  $P\_typeset. P_{col}$  represents the set of purposes in the for data collection  $typeset$ , while  $decl \in \{Y, N\}$ .  $decl$  specifies if the collection purposes which can take the value of Y (Yes) or N (No).
2.  $P_{use}(cons, usepurp, whocanuse, decl)$  Here, we specify sub policies for usage to require consent, for the usage of personal data and denoted as  $cons$ . The usage purpose  $usepurp$  and  $whocanuse$  denoting who is allowed to use the data, including third-party entities expressed as  $cons \in \{Y, N\}$  A policy for consent collection.  $usepurp$  a policy for usage purpose.  $whocanuse$  a policy for who is allowed to use the data. where  $decl \in \{Y, N\}$
3.  $P_{str} = (wherestore, howstore, decl)$ , where  $decl \in \{Y, N\}$ , Here we propose a policy for data Storage specifying where data is stored and denoted as  $wherestore$ , and  $howstore$  the method with which data is stored.  $wherestore$ , a set of places where the  $data$  is stored, such

3.  $P_{str} = (wherestore, howstore, decl)$ , where  $decl \in \{Y, N\}$ , Here we propose a policy for data Storage specifying where data is stored and denoted as *wherestore*, and *howstore* the method with which data is stored. *wherestore*, a set of places where the *data* is stored, such as in the service provider's (*SPstorage*) servers.  $wherestore \in \{(SPstorage, 3rdpartyStorage, decl)\}$ . *wherestore* storage locations where data is stored. *howstore* = (Available, Hidden) where *howstore* is where data encrypted with the service provider's key and content is available to the service provider (*howstore* = "available") and *decl* specifies the declaration of this information for users.  $decl \in \{Y, N\}$
4.  $P_{del} = (placedel, when, decl)$ , where  $decl \in \{Y, N\}$ , Here we specify *placedel* as a set of elements ("mainstorage", "backupstorage", "3rdparty"). *when* = (*rdelay* = *dd*) as a numerical retention delay value, namely, the semantics for the policy  $P_{del} = (placedel, (rdelay = rd, gdelay), decl)$ , where (*placedel*, *gdelay* and *decl*), can have any possible/defined value. And we went on to specify *when* = (*gdelay* = *gd*) where *gd* is a numerical worst-case delay value, namely, the semantics for the policy  $P_{del} = (placedel, (rdelay, gdelay = gd), decl)$ , where *placedel*, *rdelay* and *decl* can have any possible/defined value (in the language alphabet).  $decl \in \{Y, N\}$ .
5.  $P_{fw} = (cons, fwpurp, 3rdparty, decl)$ , where  $decl \in \{Y, N\}$ ,  $cons = \{Y, N\}$ , The policy for Data Forwarding requires consent for the data forwarding denoted as (*cons*) and list of forward *fwpurp*, a list of *3rdparty* and declarations  $decl \in \{Y, N\}$  which takes the value of Y-(YES) and (N-NO).

Assuming a finite set  $\{typeset1, \dots, typesetm\}$  for all the data types that are supported by the SaaS application provider. Therefore, the data protection policy for the SaaS service provider is defined as:  $SPPL = Pol = \{P_{typeset1}, \dots, P_{typesetk}\}$

The proposed end-to-end SP-PPL, therefore, enables a fine-grained policy specification and compliance checking on the entire data life cycle that is also consistent with the provisions of the GDPR.

#### ***Semantics of the Policy Language***

Here we extend the syntax of the PPL showing Service Provider and User point of views or preferences.

##### ***1) Service Provider preferences***

We define policy for each data typeset.

$P_{typeset} = (P_{col}, P_{use}, P_{str}, P_{fw}, P_{del})$ , so we will have

$Pol = \{P_{typeset1}, \dots, P_{typesetk}\}$ , where *typeset1*, ...*typesetk* are different set of types (no common element)

1.  $P_{typeset}. P_{col}$  -> reference to collection policy for type *type*
2.  $P_{typeset}. P_{use}$  -> reference to usage policy for type *type*
3.  $P_{typeset}. P_{str}$  -> reference to storage policy for type *type*
4.  $P_{typeset}. P_{del}$  -> reference to deletion policy for type *type*
5.  $P_{typeset}. P_{fw}$  -> reference to forwarding n policy for type *type*

### *User or Customer Preferences*

We define Customer requirement for each data type.

$R_{typeset} = (R_{col}, R_{use}, R_{str}, R_{fw}, R_{del})$ , so we will have

$REQ = \{R_{typeset1}, \dots, R_{typesetk}\}$

1.  $R_{typeset}. R_{col}$  -> reference to collection policy for type set *typeset*
2.  $R_{typeset}. R_{use}$  -> reference to usage policy for type set *typeset*
3.  $R_{typeset}. R_{str}$  -> reference to storage policy for type set *typeset*
4.  $R_{typeset}. R_{del}$  -> reference to deletion policy for type set *typeset*
5.  $R_{typeset}. R_{fw}$  -> reference to forwarding policy for type set *typeset*

### *Obligation Language*

Relying on the existing PPL language, we enforce compliance by comparing security and privacy compliance obligations using extended triggers and actions. In this context, triggers serve as events considered by the obligation engine. The obligation engine accepts this as a set of actions such as a Do **Action** when a particular **Trigger** is called. These triggers are events that are considered by an obligation and are seen as the set of events that result in actions such as Do **Action** when **Trigger**.

### *Compliance and Matching Rules*

In order to match and compare SaaS service provider's security and privacy policy preferences with the data subject's preferences, the engine will have to match based on the rule that a SaaS service provider security and privacy policy is less (or equally) permissive than data subject's security and privacy preferences as captured in the NDPR.

For example, in order to collect data, a consent is required, therefore based on the matching rule above, a SaaS Service provider provide less (or equal) consent than data subject and that SaaS service provider should define more (or equal) obligations than data subjects preferences as provided in the NDPR in order to obtain consent.

Hence, we define a Service provider's data handling policy as a set of consents and a set of obligations. Within the context of this research, this will be applied to entire stages of the data life cycle.

### *B. Collection*

**At the Collection Phase**, both service provider policy (POL) and customer requirements (REQ) are matched to ensure compliance and the syntax expressed as

#### *1) Case 1.0*

The syntax for  $Pol_{typeset}$ , and  $Pcol = (cons=Y, cpurp)$  has the following semantics: "whenever a piece of data of the type in the set of types *typeset* is collected then previously consent needs to be collected with the purposes in the set *cpurp*." Formally this can be defined by:

$$\begin{aligned} & \text{Whenever during the system operation/trace} \\ & \exists \text{ ActionCollectPersonalData}(\text{typeset}, \text{time1}) \rightarrow \\ & \exists \text{ ActionCollectConsent}(\text{typeset}, \text{time2}) \text{ and } \text{time} > \text{time2} \end{aligned}$$

Here, we further define two new action constructs to capture the semantics of our new syntax.

### C. Usage

#### 1) Case 2.0:

The syntax of the policy  $P_{use} = (cons, usepurp, whocanuse, decl)$ , where  $decl \in \{Y, N\}$ ,  $cons \in \{Y, N\}$ , is as follows: Has the following semantics:

“Whenever a piece of data of the type in the set of types  $typeset$  is used then consent needs to be collected with the set of purposes in the set  $usepurp$  and who can use the data in the set  $whocanuse$  with the conditions declared by  $decl \in \{Y, N\}$ ”

Formally this can be defined by:

#### 2) Case 2.1

$(cons = Y)$  besides any possible/defined value of  $usepurp, whocanuse, decl$

$\exists$  ActionDataUsage ( $typeset, withpurp, bywhom, time1$ )  $\rightarrow$   
 $\exists$  ActionCollectUsageConsent( $typeset, P_{use}.usepurp, P_{use}.whocanuse, decl, time2$ ) and  
( $time2 < time1$ )  
and ( $withpurp \subseteq P_{use}.usepurp$ ) and ( $bywhom \subseteq P_{use}.whocanuse$ )

#### 3) Case 2

$(cons = N)$  besides any possible/defined value of  $usepurp, whocanuse, decl$

$\exists$  ActionUseData ( $typeset, withpurp, bywhom, time1$ )  $\rightarrow$   
( $withpurp \subseteq P_{use}.usepurp$ ) and ( $bywhom \subseteq P_{use}.whocanuse$ )

#### 4) Case 2.3

$(decl = Y)$ , besides any possible/defined value of  $cons, usepurp, whocanuse$

$\exists$  FinishRegisteringToService ( $datatypesforusedregister, time1$ )  $\rightarrow$   
 $\exists$  DeclaredUsage( $P_{use}.usepurp, P_{use}.whocanuse, time2$ ),  $time2 < time1$

### D. Storage

#### 1) Case 3.0

The syntax of the policy  $P_{str} = (wherestore, howstore, decl)$ , where  $decl \in \{Y, N\}$ ,  $wherestore$  is a set of places where data is stored “SPstorage”, “3rdpartyStorage and  $howstore$  the method with which data is stored”

Has the following semantics:

“whenever a piece of data of the type in the set of types  $typeset$  is stored in a set of places  $wherestore$  and the method with which it is stored  $howstore$  with the conditions is declared by declaring  $decl \in \{Y, N\}$ ” Formally this can be defined by:

#### 2) Case 3.1

$decl=Y$ , besides anyhow and when

Whenever during the system operation/trace

$\exists$  FinishRegisteringToService ( $typesforstorage, time1$ )  $\rightarrow$   
 $\exists$  DeclareStorage ( $P_{str}.wherestore, P_{str}.howstore, time2$ ),  $time2 < time1$

3) Case 3.2

wherestore = (OwnServers, 3rdPartyServers) where OwnServer is service provider owned storage and 3rdPartyServers is storage owned by a 3rdParty where personal data is stored by a service provider or on behalf of a service provider. howstore = (Available, Hidden) where howstore is where data encrypted with the service provider's key and content is available to the service provider (howstore = "available") or encrypted with the customer's key = content is hidden to the service provider (howstore = "hidden").

The semantics for the policy, where wherestore, howstore and decl can have any possible/defined value.

4) Case 3.2.1

For (Pstr.wherestore = {OwnServer}, and Pstr.howstore = {Available})

Whenever during the system operation/trace

$$\begin{aligned} \exists \text{ ActionStore}(\text{typeset}, \text{time1}) &\rightarrow \exists \\ \text{ActionSaveEncryptedData}(\text{typeset}, \text{secretkey}, & \\ \text{servers}, \text{time2}), \text{time2} < \text{time1}, \text{secretkey} \in & \\ \text{Keys}<\text{serviceprovider}>, \text{servers} &\subseteq \\ \text{Servers}<\text{serviceprovider}> & \end{aligned}$$

5) Case 3.2.2

For (Pstr.wherestore = {OwnServer}, and Pstr.howstore = {Hidden})

$$\exists \text{ ActionStore}(\text{typeset}, \text{time1}) \rightarrow \exists \text{ ActionSaveEncryptedData}(\text{typeset}, \text{secretkey}, \text{servers}, \text{time2}), \text{time2} < \text{time1}, \text{secretkey} \in \text{Keys}<\text{customer}>, \text{servers} \subseteq \text{Servers}<\text{serviceprovider}>$$

6) Case 3.2.3

For (Pstr.wherestore = {3rdPartyServers}, and Pstr.howstore = {Available})

$$\exists \text{ ActionStore}(\text{typeset}, \text{time1}) \rightarrow \exists \text{ ActionSaveEncryptedData}(\text{typeset}, \text{secretkey}, \text{servers}, \text{time2}), \text{time2} < \text{time1}, \text{secretkey} \in \text{Keys}<\text{serviceprovider}>, \text{servers} \subseteq \text{Servers}<3\text{rdparty}>$$

7) Case 3.2.4.

For (Pstr.wherestore = {3rdPartyServers}, and Pstr.howstore = {Hidden})

$$\begin{aligned} \exists \text{ ActionStore}(\text{typeset}, \text{time1}) &\rightarrow \exists \\ \text{ActionSaveEncryptedData}(\text{typeset}, \text{secretkey}, & \\ \text{servers}, \text{time2}), \text{time2} < \text{time1}, \text{secretkey} \in & \\ \text{Keys}<\text{customer}>, \text{servers} &\subseteq \text{Servers}<3\text{rdparty}> \end{aligned}$$

E. Deletion

1) Case 4.0

The syntax for Pol\_typeset, and Pdel=(placedel, when, decl), where decl ∈ {Y, N}, placedel is a set of elements "mainstorage", "backupstorage", "3rdparty") and when = (rdelay, gdelay). has the following semantics: "whenever a piece of data of the type in the set of types typeset is deleted then personal data deletion mode needs to be stated as well as the delay period and whether data is fully deleted as with the conditions should be declared by declaring by decl ∈ {Y, N}".

Formally this can be defined by:



Formally this can be defined by:

2) *Case 4.1*

$decl=Y$ , besides any how and when

Whenever during the system operation/trace

FinishRegisteringToService (typesforregister, time1)  $\rightarrow$

DeclaredDel(Pdel.placedel, Pdel. When, time2), time2 < time1

3) *Case 4.2*

when = (rdelay=dd, gdelay) where dd is a *numerical* retention delay value, namely, the semantics for the policy

$Pdel = (placedel, (rdelay=rd, gdelay), decl)$ , where *placedel*, *gdelay* and *decl decl* can have any possible/ defined value.

Whenever during the system operation/trace

$\exists$  ActionInitDeletionData(typeset, time1)  $\rightarrow$

$\exists$  ActionDeleteData(typeset, fromwhere, time2) and (time1+rd  $\geq$  time2) and (fromwhere  $\in$  Pdel.placedel)

$\exists$  ActionDeleteData(typeset, fromwhere, time1)  $\rightarrow$

$\exists$  ActionInitDeletionData(typeset, time2) and (time1+rd  $\geq$  time2) and (fromwhere  $\in$  Pdel.placedel)

4) *Case 4.3*

when = (rdelay, gdelay=gd) and ("*3rdparty*"  $\notin$  Pdel.placedel) where gd is a numerical worst-case delay value, namely, the semantics for the policy  $Pdel = (placedel, (rdelay, gdelay = gd), decl)$ , where *placedel*, *rdelay* and *decl* can have any possible/ defined value (in the language alphabet).

Whenever during the system operation/trace

$\exists$  ActionFinishedUnRegisteringFromService (alltypesintheservice, time1)  $\rightarrow$

$\exists$  ActionDeleteData(alltypesintheservice, fromwhere, time2) and (time1+gd  $\geq$  time2) and (fromwhere  $\in$  Pdel.placedel)

$\exists$  ActionDeleteData(alltypesintheservice, time2)  $\rightarrow$

$\exists$

ActionFinishedUnRegisteringFromService(alltypesintheservice, fromwhere, time1)

and (time1+gd  $\geq$  time2) and (fromwhere  $\in$  Pdel.placedel)

5) *Case 4.4*

when = (rdelay="DF", gdelay) where "DF" (i.e., defined) is a *non-numerical* retention delay value such as "Until required for a national security law at a country". Namely, the semantics for the policy  $P_{del} = (placedel, (rdelay="DF", gdelay), decl)$ , where *placedel*, *gdelay* and *decl* can have any possible/defined value.

Whenever during the system operation/trace

$\exists \text{ActionInitDeletionData}(\text{typeset}, \text{time1}) \rightarrow$

$\exists \text{ActionDeleteData}(\text{typeset}, \text{fromwhere}, \text{time2})$  and  $(\text{time1} + \text{RDelay}(\text{law}) \geq \text{time2})$  and  $(\text{fromwhere} \in \text{Pdel.placedel})$ , where  $\text{RDelay}(\text{law})$  returns a retention delay based on the given law *law*

$\exists \text{ActionDeleteData}(\text{typeset}, \text{fromwhere}, \text{time1}) \rightarrow$

$\exists \text{ActionInitDeletionData}(\text{typeset}, \text{time2})$  and  $(\text{time1} + \text{RDelay}(\text{law}) \geq \text{time2})$  and  $(\text{fromwhere} \in \text{Pdel.placedel})$ , where  $\text{RDelay}(\text{law})$  returns a retention delay based on the given law *law*

6) *Case 4.5*

when = (rdelay, gdelay = "DF") where "DF" (i.e., defined) is a *non-numerical* worst-case delay value such as "Until required for a national security law at a country". Namely, the semantics for the policy  $P_{del} = (placedel, (rdelay, gdelay = "DF"), decl)$ , where *placedel*, *gdelay* and *decl* can have any possible/defined value.

Whenever during the system operation/trace

$\exists \text{ActionInitDeletionData}(\text{typeset}, \text{time1}) \rightarrow$

$\exists \text{ActionDeleteData}(\text{typeset}, \text{fromwhere}, \text{time2})$  and  $(\text{time1} + \text{GDelay}(\text{law}) \geq \text{time2})$  and  $(\text{fromwhere} \in \text{Pdel.placedel})$ , where  $\text{RDelay}(\text{law})$  returns a worst-case delay based on the given law *law*

$\exists \text{ActionDeleteData}(\text{typeset}, \text{from where}, \text{time1}) \rightarrow$

$\exists \text{ActionInitDeletionData}(\text{typeset}, \text{time2})$  and  $(\text{time1} + \text{GDelay}(\text{law}) \geq \text{time2})$  and  $(\text{fromwhere} \in \text{Pdel.placedel})$ , where  $\text{RDelay}(\text{law})$  returns a worst-case delay based on the given law *law*

F. FORWARDING

1) *Case 5.0*

The semantics of the policy  $P_{fw} (cons, fwpurp, 3rdparty, decl)$ , where  $decl \in \{Y, N\}$ ,  $cons = \{Y, N\}$ , is as follows:

2) Case 5.1

(cons = Y) besides any possible/defined value of fwpurp, 3rdparty, decl.

$\exists$  ActionForwardData (typeset, withpurp, towhom, time1)  $\rightarrow$

$\exists$  ActionCollectFwConsent(typeset, fwpurp, 3rdparty, time2) and (time2 < time1)  
and (withpurp  $\subseteq$  Pfw.fwpurp) and (towhom  $\subseteq$  Pfw.3rdparty)

3) Case 5.2

(cons = N) besides any possible/defined value of fwpurp, 3rdparty, decl.

$\exists$  ActionForwardData (typeset, withpurp, towhom, time1)  $\rightarrow$

(withpurp  $\subseteq$  Pfw.fwpurp) and (towhom  $\subseteq$  Pfw.3rdparty)

4) Case 5.3

(decl = Y), besides any possible/defined value of cons, fwpurp, 3rdparty.

FinishRegisteringToService(datatypesforusedregister, time1) $\rightarrow$

DeclaredFw(Pfw.fwpurp, Pfw.3rdparty,time2), time2 < time1

“whenever a piece of data of the type in the set of types typeset is forwarded to a third party then consent needs to be collected with the set of purposes in the set fwpurp ”

**Compliancy Check Based on Our Syntax**

**Property 1:**

(Pol  $\leq$  REQ) iff ( for every P\_typeset\_i in Pol there is a R\_typeset\_i' in REQ such that P\_typeset\_i  $\leq$  R\_typeset\_i')

**Property 2:**

P\_typeset\_i  $\leq$  R\_typeset\_i' iff typeset\_i'  $\subseteq$  typeset\_i, and  
Pcol  $\leq$  Rcol, Puse  $\leq$  Ruse, ..., Pdel  $\leq$  Rdel

**Property 3:**

Pcol  $\leq$  Rcol iff (Pcol.cons = N & Rcol.cons = N) or Pcol.cons = Y, and Rcol.cons can be N or Y,  
and (Pcol.cpurp  $\subseteq$  Rcol.cpurp)

**Property 4:**

Puse  $\leq$  Ruse iff (Puse.cons = N & Ruse.cons = N) or Puse.cons = Y and Ruse.cons can be N or Y,  
and (Puse.upurp  $\subseteq$  Ruse.upurp) (Puse.whouse  $\subseteq$  Ruse.whouse)

**Property 5:**

Pstr  $\leq$  Rstr iff (Pstr.wh = N & Rstr.wh = N) or Pstr.wh = Y and Rstr.wh can be N or Y, and  
(Pstr.ho  $\subseteq$  Rstr.ho) (Pstr.revdate  $\subseteq$  Rstr.revdate)

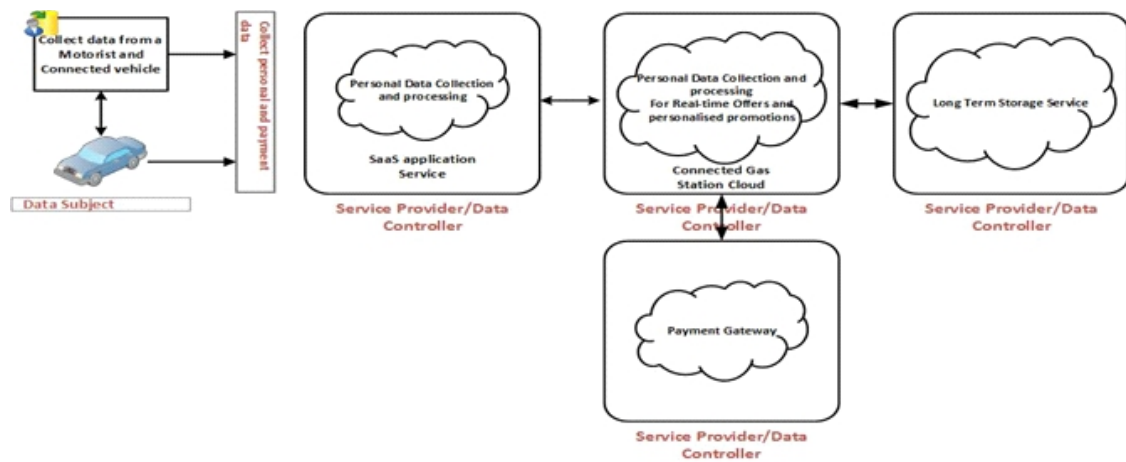
**Property 6:**

$P_{del} \leq R_{del}$  iff  $(P_{del}.how = N \ \& \ R_{del}.how = N)$  or  $P_{del}.how = Y$  and  $R_{del}.how$  can be N or Y, and  $(P_{del}.deld \subseteq R_{del}.deld) \ (P_{del}.geld \subseteq R_{del}.geld)$

**Property 7:**

$P_{fw} \leq R_{fw}$  iff  $(P_{fw}.cons = N \ \& \ R_{fw}.cons = N)$  or  $P_{fw}.cons = Y$  and  $R_{fw}.cons$  can be N or Y, and  $(P_{fw}.fwpurp \subseteq R_{fw}.fwpurp) \ (P_{fw}.3rdparty \subseteq R_{fw}.3rdparty)$

**Use Case of SP-PPL: An Example**



This use case shows the flow of data within an oil and gas retail services scenario. It shows how data is handled across the stages of a data life cycle within the context of SaaS applications and connected petrol stations via the cloud. The SaaS application is used to support the interaction of motorists with a smart petrol station by collecting and processing personal data from data subjects via connected vehicles using internet connectivity. In the following, we explain the data life cycle for this use case.

1. **Data Collection:** In order to serve the customer at the smart petrol station, the customer's personal and payment data is collected by the station using a SaaS retail application to fulfil the service request such as refuelling and/or car servicing.
2. **Usage:** At this stage, the service provider of the retail SaaS application processes the personal data to serve the data subject (i.e. the customer).
3. **Storage:** The personal data at this stage is stored to serve the user based on data subject's data handling preferences in the future. The SaaS service provider also can at this stage, depending on the purpose, store the data on third-party storage infrastructure.
4. **Deletion:** Relying on consent and lawful purposes for retention, the SaaS service provider and their third-party partners destroy or delete data to sustain compliance. However, this comes with several challenges, such as technical and complexities primarily due to multi-cloud environments of different providers requiring different data deletion processes towards different types of requests.

5. **Data forwarding:** Data forwarding and sharing with the SaaS application service provider and payment processing company occurs at this stage. The SaaS provider is responsible for the services and interaction platform between the petrol station and the customer. The SaaS service provider, as the data controller, is responsible for the personal data that will be collected to enable interaction and service.

In order to enforce compliance to GDPR, we rely on the abstract extensions of the SP-PPL to check for a match or a mismatch in the data subject obligations/preferences and data controller obligations/preferences using a binding or matching policy that takes input from both sides.

### **Conclusion And Further Work**

In this paper, we highlighted the key benefits and challenges that are faced when using SaaS applications in distributed environments when it comes to compliance to data protection regulations. We analysed the SaaS deployment scenario and the suitability of a related policy language to address the requirements of the scenario. We presented SP-PPL, a proposed security and privacy policy language, as an extension of the PPL designed for the contexts of SaaS applications based on the requirements of the GDPR. We validated and showcased the applicability of SP-PPL within the context of SaaS applications using a smart petrol station use case. We have shown that there are still opportunities for improving effective compliance to security and privacy protection in SaaS applications using policy languages to enforce compliance at a granular level.

Our experiments have shown that the proposed SP-PPL can be used to define, express and enforce data protection properties across different scenarios. We have also mapped the data lifecycle to the GDPR to show applicability to recent regulations. Our proposed policy language is highly expressive and extensible. This paper also analysed the state-of-the-art of policy languages and policy schemes. Our proposed policy language proves that existing policy languages cannot be used to enforce security and privacy compliance in new data protection regulations such as the GDPR in the context of SaaS applications. Further comparisons against existing policy languages were also carried out to highlight their weaknesses in fulfilling the requirements of enforcing compliance in SaaS applications. Future work could be done on the implementation of a cloud-hosted tool focused on the oil and gas retail industry and adopting the policy language approach to enforcing compliance at granular levels.

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