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Adaptive Capacity, Vulnerability and Resilience of Beneficiaries in Managing Agro-Allied Projects and Interventions in Nigeria

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Abstract

This study, undertaken among 1544 farming households within 25 LGAs in 12 states of Nigeria, examined adaptive capacity, vulnerability, and resilience among beneficiaries of agricultural projects or interventions between 2005 and 2025. The results show that resilience is shaped primarily by human capital, infrastructure, market access, and service provision, while vulnerability consistently undermines outcomes. Adaptive capacity, both at household and project levels, emerges as the strongest pathway to improvement. The ordered logit model isolated two groups of covariates: those that gave consistent signals across the models and mixed or context-specific effects. These findings are closely in line with regional and global evidence, reinforcing calls for building capacity first, then providing awareness within the context of the interventions. In addition, supported infrastructure, based on the beneficiaries' capacities and awareness, would consolidate adaptive capacity and resilience to fight vulnerability. Policies that integrate education, extension services, and infrastructure development, while reducing vulnerability through risk management and diversification, offer the most promising route to long-term resilience. However, the study has shown that projects and intervention promoted in Nigeria in the last 25 years has not produced sustainable outcomes.

Key words: Exposure; Sensitivity; Transformative capacity; Vulnerability status; Nigeria

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1. INTRODUCTION

Adaptive capacity is the ability of individuals or communities to adjust to changing environmental, economic, and institutional conditions, while vulnerability is the susceptibility to harm or loss from shocks and stresses, and resilience represents the capacity to absorb, recover, and transform in response to shocks and stresses. Building resilience is therefore essential for farm households in Nigeria, where agricultural livelihoods are continuously exposed to climatic variability, market instability, and institutional uncertainties. Rural communities employ diverse adaptation strategies such as crop diversification, early planting, and reliance on climate information while being assisted by governmental and non-governmental agricultural interventions. These interventions aim to improve food security, reduce poverty, and strengthen livelihoods in developing economies. However, their effectiveness depends critically on the adaptive capacity, vulnerability status, and resilience of beneficiaries, particularly in agrarian environments that are associated with high risks like Nigeria, which remains among the countries most exposed to climate and socioeconomic shocks affecting agricultural production (Lumenyela *et al*., 2024; Kambuni & Osoro, 2024; Dowd-Uribe *et al*., 2024; ND-GAIN, 2023; Adelekan *et al*., 2015; Oparinde and Hodge, 2011).

Globally, agricultural development policy increasingly emphasizes resilience building as a pathway to sustainable livelihoods. International frameworks identify adaptive capacity enhancement and vulnerability reduction as

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central mechanisms through which interventions are expected to improve welfare outcomes (IPCC, 2022; World Bank, 2021; FAO, 2016). Yet recent empirical syntheses reveal a persistent gap between resilience policy objectives and measurable long-term household outcomes. Multi-country evidence shows that agricultural interventions frequently produce short-term gains in productivity or income but rarely demonstrate sustained resilience after external support wanes (Hossain *et al*., 2024; Shilomboleni *et al*., 2024). Comparative studies across vulnerable farming systems further indicate that resilience outcomes are highly contextual, being shaped by interactions of household assets, institutional support structures, and exposure to repeated shocks, among others, rather than by interventions alone (Zhang et al., 2025; Yusuf & Akinola, 2025; Upton *et al*., 2022; Zhang *et al*., 2024; Barrett & Constas, 2014; Béné *et al*., 2014).

Emerging global scholarship also highlights a critical empirical limitation in resilience research indicating that adaptive capacity, vulnerability, and resilience are often studied separately, despite theoretical recognition that they operate as interdependent processes (Singh, 2024; Sakeel *et al*., 2025). Systematic reviews emphasize the scarcity of household level integrated analyses capable of tracing how institutional interventions translate into adaptive capacity formation, vulnerability reduction, and ultimately durable resilience outcomes in real-world situations (Rogers *et al*., 2023; Terefe *et al*., 2025). This limitation is particularly pronounced in developing agrarian economies characterized by multiple overlapping development interventions, institutional fragmentation, and persistent exposure to compound shocks. Consequently, a major unresolved question in global resilience scholarship concerns whether development interventions generate sustained adaptive transformation (Lumenyela *et al*., 2024) or merely temporary coping capacity.

Within Nigeria, several studies have examined agricultural interventions and rural livelihoods, as well as adaptive responses to climate risks (Aderinoye-Abdulwahab & Abdulbaki, 2021**;** Adelekan *et al*., 2015; Awotide *et al*., 2016; Iwuchukwu *et al*., 2013). However, empirical evidence systematically linking adaptive capacity, vulnerability, and resilience among beneficiaries of agro-allied interventions remains limited. Existing research largely focuses on project outcomes or adaptation strategies without empirically testing the assumed causal pathways through which institutional support enhances resilience in heterogeneous agricultural systems. Furthermore, despite extensive implementation of agricultural programs over the past two decades, little or no evidence exists on whether beneficiaries develop sustained resilience after repeated exposure to interventions and shocks at the household level.

This study addresses these interconnected global and national evidence gaps by examining the relationships of adaptive capacity, vulnerability, and resilience among beneficiaries of agro-allied projects and interventions in Nigeria implemented between 2005 and 2025. Using household level data, the research empirically tests whether widely assumed mechanisms linking institutional interventions to adaptive capacity formation and resilience outcomes operate as theorized in agricultural systems that are highly exposed. By integrating these constructs within a unified analytical framework, the study contributes to global understanding of how development interventions influence resilience trajectories under conditions of persistent vulnerability.

To achieve this objective, the study addresses the following research questions:

i. What is the relationship between adaptive capacity, vulnerability, and resilience among beneficiaries, and how do these factors influence project implementation and management outcomes?

ii. What are the key determinants of resilience capacity among beneficiaries, and how can these factors be leveraged to enhance the sustainability of agricultural interventions?

Accordingly, the study aims to:

i. examines the relationships between adaptive capacity, vulnerability, and resilience among beneficiaries and their impact on project implementation; and

ii. determine the key factors influencing resilience capacity and identify strategies for enhancing sustainable outcomes.

The following hypotheses are tested:

i. Institutional interventions have no influence on adaptive capacity.

ii. Adaptive capacity is not associated with vulnerability.

iii. Vulnerability reduction does not influence resilience.

iv. Resilience does not influence sustainable project outcomes.

v. Contextual factors do not moderate the effect of institutional interventions on adaptive capacity.

vi. Contextual factors have no effect on resilience and sustainable outcomes.

By empirically examining these relationships within a high-risk agricultural system, the study provides evidence on whether development interventions generate durable resilience or temporary adaptation. The findings contribute to both national policy design and the broader global discourse on resilience formation in vulnerable agrarian economies.

1.1 Conceptual Framework

This study adopts an integrated resilience formation framework that conceptualizes adaptive capacity, vulnerability, and resilience as sequential and interdependent processes shaped by institutional interventions and contextual conditions. The framework is grounded in resilience theory, the Sustainable Livelihoods

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Approach, and participatory capacity analysis traditions, which collectively emphasize that livelihood outcomes emerge from dynamic interactions among assets, institutional structures, and exposure to shocks, stresses, changes, and uncertainties rather than from interventions alone (Rivera and Ubels, 2022; Oxfam, 2013; UNDP, 2009; Walker & Salt, 2006; DFID, 1999; Chambers, 1994).

Recent empirical scholarship demonstrates that resilience cannot be treated as a direct outcome of development interventions but rather as a mediated process in which institutional support influences household capabilities that subsequently shape vulnerability and adaptive responses (Krishna *et al*., 2025; Terefe *et al*., 2025; Shilomboleni *et al*., 2024; Zhang *et al*., 2024; Rivera & Ubels, 2022; Upton *et al*., 2022; Krausmann *et al*., 2012). Accordingly, this study conceptualizes resilience as a latent outcome produced through a causal pathway linking institutional interventions to adaptive capacity formation, vulnerability reduction, and sustained livelihood functioning. This sequential logic responds to calls in global resilience research for integrated empirical models capable of capturing the interaction between capacity formation and risk exposure in real-world agricultural systems.

Within this framework, institutional interventions such as training programs, innovation platforms, extension services, and infrastructural support function as enabling mechanisms that expand access to knowledge, resources, and opportunities (Arteaga & Wilde, 2023). These mechanisms strengthen adaptive capacity by enhancing human capital, productive assets, market integration, and information access. Adaptive capacity, in turn, reduces vulnerability by lowering exposure and sensitivity to climatic, economic, and institutional shocks. Reduced vulnerability enables households to absorb disturbances, adjust livelihood strategies, and maintain functioning, thereby generating resilience. Resilience subsequently influences sustainable project outcomes, particularly income-generating capacity and livelihood stability.

The framework further recognizes that resilience formation is contextual. Structural and environmental factors, including ecological conditions, market dynamics, sociocultural norms, and institutional accessibility, moderate the effectiveness of interventions and shape the translation of adaptive capacity into resilience outcomes. These contextual factors explain heterogeneity in resilience trajectories across households exposed to similar interventions and are therefore incorporated as moderating variables within the analytical model.

Conceptually, the framework advances three propositions consistent with recent empirical evidence. First, resilience is not an inherent attribute of households but a dynamic process emerging from the interaction between institutional support and household capabilities. Second, adaptive capacity functions as the primary transmission mechanism through which interventions influence resilience. Third, vulnerability represents the critical mediating condition that determines whether adaptive capacity translates into sustained livelihood stability under repeated shocks.

Operationally, the framework models resilience as a latent construct composed of absorptive, adaptive, and transformative capacities, reflecting contemporary resilience measurement approaches. Adaptive capacity and vulnerability are also operationalized as composite indices capturing multidimensional household characteristics and exposure conditions. The hypothesized relationships among institutional interventions, adaptive capacity, vulnerability, and resilience are empirically tested using household-level data and structural modelling techniques, allowing simultaneous examination of mediation and moderation processes as shown in Figure 1.

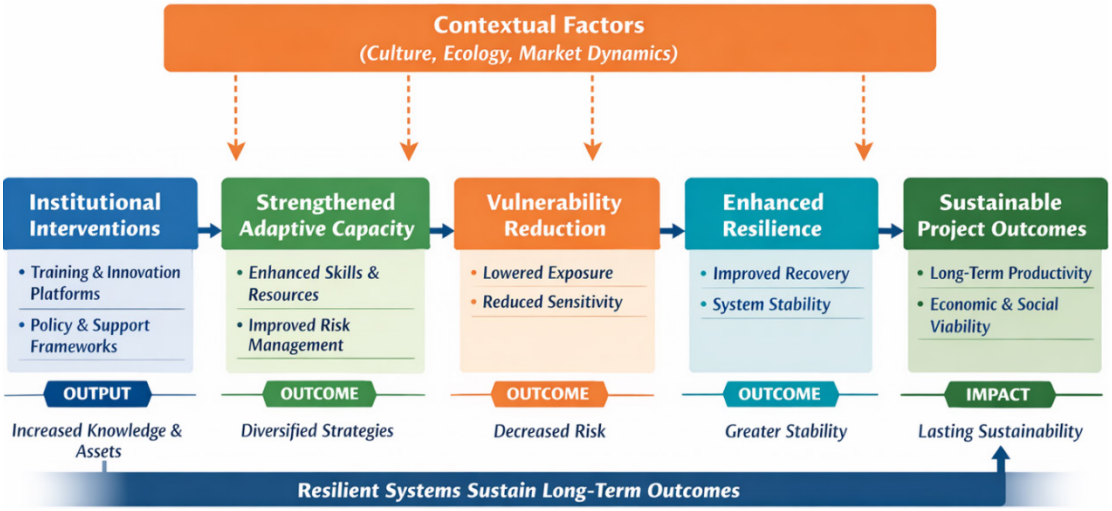


Figure 1
Conceptual Framework for Adaptive Capacity, ulnerability, and Resilience
Source: Authors construct

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By integrating institutional mechanisms, household capacities, and contextual constraints within a unified analytical structure, the framework provides an empirical platform for evaluating whether agricultural development interventions generate durable resilience or temporary coping capacity. This integrated perspective directly addresses the central gap identified in global resilience scholarship, i.e., the lack of household-level evidence linking institutional support to sustained resilience outcomes through adaptive capacity formation and vulnerability reduction in high-risk agrarian systems.

2. LITERATURE REVIEW

Agricultural systems in developing economies are increasingly exposed to compound risks arising from climate variability, environmental degradation, market volatility, and institutional instability. Within this context, resilience has emerged as a central objective of agricultural development policy. Contemporary resilience scholarship conceptualizes resilience as a dynamic process involving absorptive, adaptive, and transformative capacities that enable households to maintain or improve livelihood functioning under repeated shocks (IPCC, 2022; Upton *et al*., 2022). Adaptive capacity reflects the ability to mobilize assets, knowledge, and institutional support to respond to change, while vulnerability captures exposure and sensitivity to disturbances. These constructs are theoretically interdependent, yet empirical evidence examining their interaction within development intervention contexts remains limited.

Recent global empirical studies demonstrate that agricultural development interventions frequently generate improvements in productivity, income, or technology adoption but provide limited evidence of sustained resilience outcomes beyond the period of external support. Multi-country impact assessments show that resilience gains often diminish when institutional assistance declines, indicating that interventions do not automatically translate into endogenous adaptive capacity (Igirimbabazi & Amolo, 2025; Hossain *et al*., 2024; Shilomboleni *et al*., 2024). Comparative analyses across vulnerable farming systems further reveal that resilience outcomes are strongly conditioned by household asset structures, institutional accessibility, and exposure intensity rather than intervention participation alone (Terefe *et al*., 2025; Zhang *et al*., 2024; Chetri *et al*., 2021). These findings challenge linear assumptions that institutional support directly produces durable resilience.

A growing body of literature identifies a major methodological limitation in resilience research: adaptive capacity, vulnerability, and resilience are frequently operationalized as independent constructs despite theoretical recognition of their causal interdependence. Systematic reviews highlight the scarcity of integrated empirical models capable of tracing how institutional interventions influence adaptive capacity formation, how adaptive capacity modifies vulnerability, and how these processes jointly determine resilience outcomes (Singh, 2024; Sakeel *et al*., 2025). Measurement approaches also vary substantially across studies, limiting comparability and weakening causal inference regarding resilience formation (Upton *et al*., 2022). Consequently, global scholarship increasingly calls for micro-level empirical analyses that test resilience pathways within real-world intervention environments characterized by heterogeneous contexts and repeated shocks.

Within Sub-Saharan Africa, resilience-building strategies emphasize capacity strengthening, extension services, innovation platforms, and market integration as mechanisms for enhancing adaptive responses among smallholder farmers. Evidence suggests that these institutional mechanisms can improve access to information, technology, and financial resources, thereby expanding adaptive capacity (Alih, 2025; Krishna *et al*., 2025; Abilla & Luketero, 2024; Dowd-Uribe *et al*., 2024). However, structural constraints such as poverty, limited infrastructure, and institutional fragmentation continue to shape vulnerability patterns and may limit the long-term effectiveness of interventions. Empirical findings therefore suggest that resilience is not an inherent outcome of development programs, but a contextual process mediated by household characteristics and institutional environments (Adnan *et al*., 2025, Gitau & James, 2025).

Nigeria represents a critical empirical setting for examining these dynamics due to its high exposure to climate risks, dependence on rain-fed agriculture, and extensive implementation of agricultural development programs. Evidence indicates that Nigerian farming households employ indigenous adaptation strategies including diversification, improved crop management, and local knowledge systems to cope with climate variability (Aderinoye-Abdulwahab & Abdulbaki, 2021). Institutional interventions such as training programs, extension services, and innovation platforms have been shown to improve access to resources and enhance short-term project outcomes (Dowd-Uribe *et al*., 2024; Ekanem & Inyang, 2014). However, Nigeria continues to exhibit high vulnerability and limited adaptive preparedness relative to global benchmarks, reflecting persistent structural constraints (Adelekan *et al*., 2015; ND-GAIN, 2023).

Despite substantial program implementation, empirical research in Nigeria remains largely fragmented across thematic domains such as technology adoption, extension effectiveness, or climate adaptation strategies. Few

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studies examine the joint dynamics of adaptive capacity, vulnerability, and resilience among beneficiaries of agricultural interventions. Existing evidence therefore provides limited insight into whether repeated exposure to institutional interventions strengthens endogenous resilience or produces temporary coping responses. Furthermore, longitudinal and large-scale household-level analyses capable of testing resilience formation pathways in high-risk agrarian systems remain scarce.

Three key insights emerge from the global and regional literature. First, resilience formation is dynamic and depends on contextual process shaped by interactions among household assets, institutional support, and exposure to shocks. Second, institutional interventions function as enabling mechanisms rather than direct determinants of resilience outcomes. Third, empirical evidence linking institutional support to sustained resilience through adaptive capacity formation remains limited, particularly in vulnerable agricultural systems subject to overlapping interventions and persistent shocks.

Accordingly, a critical knowledge gap persists regarding how beneficiaries of agricultural development interventions develop, maintain, or fail to maintain resilience over time. Specifically, there is limited empirical evidence testing whether institutional interventions enhance adaptive capacity in ways that reduce vulnerability and produce durable resilience outcomes at the household level. Addressing this gap requires integrated analytical frameworks capable of capturing the sequential and interactive relationships among institutional support, adaptive capacity, vulnerability, and resilience.

This study responds to this unresolved global and national research need by providing household-level empirical evidence from Nigeria, a high-exposure agricultural system with extensive intervention experience. By modelling adaptive capacity, vulnerability, and resilience within a unified framework, the study evaluates whether widely assumed mechanisms of resilience formation operate as theorized under real-world development conditions. The findings contribute to advancing empirical understanding of resilience trajectories in vulnerable agrarian economies and provide evidence relevant to the design of sustainable agricultural interventions.

3. METHODOLOGY

To answer the critical questions raised about adaptive capacity, vulnerability and resilience of project beneficiaries, a table survey was conducted to identify various agriculture-based projects and intervention implemented between 2005 and 2025 in the selected states. At the end of the survey, 52 projects and interventions were identified and listed (Appendix I). In relation to these projects or interventions, cross-sectional data, collected from 12 selected states of Nigeria were utilized (Fig. 2). The states were selected to include those that at least three of such projects were implemented and are accessible to enumerators. From each selected state, two LGAs were randomly selected, and two Village Areas were randomly selected from each LGA giving a total of 25 LGAs and 50 villages. The respondents were randomly selected from farming households from the villages. Their basis of inclusion is those who have either benefited or participated in any of the projects or intervention. At least 10 respondents were selected from each village and a total of 1544 respondents were enumerated for the data. The details of the spatial and socio-economic characteristics of the states and the samples per LGA are in Appendices II & III. The data collected included socio-economic characteristics, awareness and effectiveness of each project or intervention experienced, wealth change, present state of income generating capacity, environmental and climatic variables as well as assets and social capital. The instrument for the data collection was open-source data kit-powered structured questionnaire (www.kobotoolbox.org, 2024) simultaneously administered by trained enumerators via interview schedules in a cordial atmosphere between June and October 2025. The respondents provided all the information requested from them without any compulsion.

The data collected was analysed using descriptive and inferential statistical tools and results presented by means of tables and charts.

Resilience capacities were computed by summing the capacities from the three components i.e. Adaptive, Absorptive, and Transformative as presented in eq. 1.

$$RC_i = ABC_i + ADC_i + TC_i \qquad \text{q. 1}$$

where: RC_i = resilience capacity; ABC_i = absorptive capacity; ADCi = adaptive capacity; and TCi = transformative capacity. For each of the capacities, their standardized values were obtained using the model in eq. 2.

$$C_i = \sum_{j=1}^{n} \frac{x_{ij}\gamma_{ij}}{n} \qquad \text{eq. 2}$$

$$RC_i^* = \frac{RC_I - RC_{min}}{RC_{max} - RC_{min}} \qquad \text{eq. 3}$$

where C_i = *ABCi, ADCi, or TCi* = are the resilience capacity indexes for the i^{th} beneficiary, x is the indicator value of each resilience capacity indicator, $\gamma > 0$ is the factor loading, j is the type of indicator, and n is the total number of indicators (43, 41, 40 respectively). To ensure that RC_i lies between 0 and 1, a min–max scaling was applied to eq. 1 as in eq. 3.

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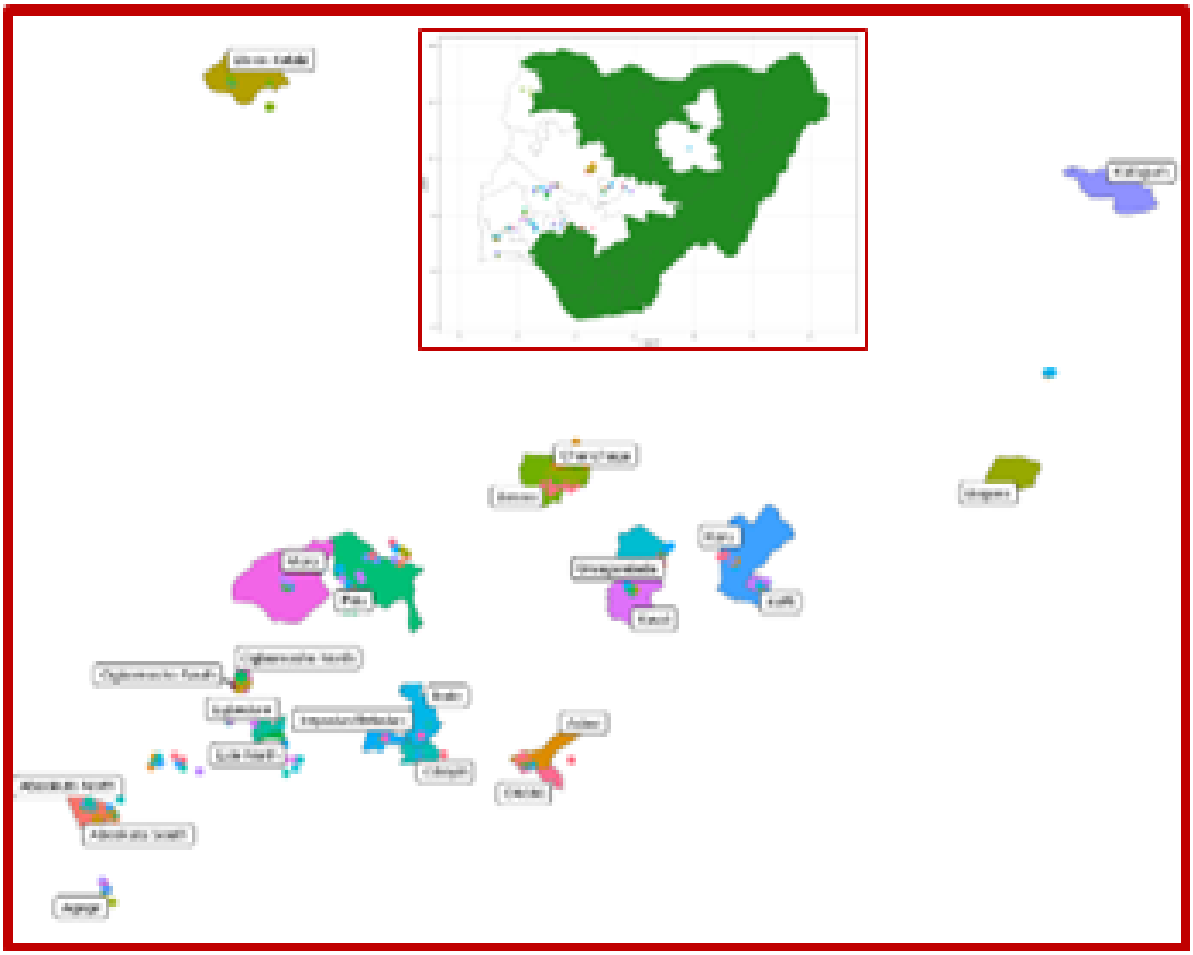


Figure 20
Map of Nigeria showing the selected states and LGAs for the study
Source: Data from field survey, 2025, graphics from Wickham (2016)

$$RCi^* = \frac{RC_I - RC_{min}}{RC_{max} - RC_{min}} \qquad \text{eq. 3}$$

Where RC_i* is the scaled resilience capacity index for the i[th] beneficiary, RC_i is the resilience capacity index value of the i[th] beneficiary, RC_{min} and RC_{max} are the minimum and maximum index values for the resilience capacity index. After RCi was estimated, the beneficiaries were then divided into five classes as follows:

Fragile	RCi <= 0.20
Low	RCi > 0.20 & RCi <= 0.40
Medium	RCi > 0.40 & RCi <= 0.60
High	RCi > 0.60 & RCi <= 0.80
Resilient	RCi > 0.80

Resilience is not observable as such it is considered a latent variable depending on the component capacities on the righthand side of the equation which were determined using latent factor loadings of the environmental factors the beneficiaries were exposed to as well as their socio-economic characteristics and factor endowments. The capacities were estimated through factor and principal component analyses in line with Sanusi & Dries (2025). The basic factor, which robustly estimated resilience are comprehensive enough (see also Terefe *et al., 2025,* Zhang *et al*., 2024, Upton *et al*., 2022; Lyng *et al., 2022*) which are represented by the model as specified in eq. 4 while the factor loadings are in Appendices IV, V & VI.

$$\begin{aligned} Y_1 &= a_{11}X_1 + a_{12}X_2 + *** + a_{1n}X_n \qquad \text{eq. 4} \\ Y_2 &= a_{21}X_1 + a_{22}X_2 + *** + a_{2n}X_n \\ Y_3 &= a_{31}X_1 + a_{32}X_2 + *** + a_{3n}X_n \\ * & \qquad\qquad * \\ * & \qquad\qquad * \\ Y_n &= a_{n1}X_1 + a_{n2}X_2 + *** + a_{nm}X_n \end{aligned}$$

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Where:

, , ……, = Observed variables.

- = factor loading or correlation coefficients.

, …..., = Unobserved underlying factors contributing to the factor loadings.

Vulnerability index, which also has adaptive capacity, exposure and sensitivity components, was calculated at the household level rather than at national level in line with Sallawu *et al*. (2020) as presented in eq. 5 in line with Duong *et al*., (2017).

$$VI_i = \frac{E_i + S_i + (1 - ADC_i)}{3} \qquad \text{eq. 5}$$

Where VI_i = Household level vulnerability index, E_i = Household level exposure index, S_i = Household level sensitivity index, ADC_i = Household level adaptive capacity

After VI_i was estimated, the households were divided into five classes as follows:

Negligible	VIi <= 0.20
Low	VIi > 0.20 VIi <= 0.40
Medium	VIi > 0.40 & VIi <= 0.60
High	VIi > 0.60 & VIi <= 0.80
Critical	VIi > 0.80

In estimating the adaptive capacity in this context, the knowledge levels and usage of systems, like an ex-post evaluation of the system is utilized while exposure and sensitivity are experiences regarding climate and extreme events. The knowledge-based adaptive capacity was determined as presented in eq. 6.

$$ADC_i = \frac{ADC_{ij}}{N} \qquad \text{eq. 6}$$

Where

$$ADC_{ij} = \frac{K_{ij} + U_{ij} + V_{ij} + A_{ij} + C_{ij} + F_{ij} + B_{ij} + I_{ij}}{N_A}$$

ADC_i = adaptive capacity of an i^{th} beneficiary

N is the number of observations

ADC_{ij} = adaptive capacity of an i^{th} beneficiary to j^{th} project/intervention

K_{ij}, = knowledge of the i^{th} beneficiary

U_{ij} = level of usage by i^{th} beneficiary

V_{ij} = availability to i^{th} beneficiary

A_{ij} = accessibility to i^{th} beneficiary

C_{ij} = level of consultation by i^{th} beneficiary

F_{ij} = affordability by i^{th} beneficiary

B_{ij} = economic benefit to i^{th} beneficiary

I_{ij} = sources of information to i^{th} beneficiary

N_A = the sum of applicable attributes.

The following variables were used to determine exposure and sensitivity, i.e., Minimum temperature, Maximum temperature, Highest temperature of the year, Lowest temperature of the year, Average annual temperature, Average sunshine hours, Annual rainfall, Number of floods recorded in 10years, Incidence of drought in 10years, Average daily sunshine hours, UV index, T2M (2-Metre Temperature), Sunshine, Wind, Solar energy, Humidity ratio, Gender ratio, Population growth rate. Basically, the variables were normalized and converted to weights (eq. 2) to obtain exposure and sensitivity indices.

Regression analysis was used to determine the factors influencing the resilience of beneficiaries. Four algorithms, normal ordered logit, stepwise ordered order logit, and Beta were tried for consistency, reliability, and triangulation. Additionally, normal ordered logit regression model was tried using another dependent variable with some selected independent variables.

Ordered logit regression model is appropriate when the dependent variable is ordinal, meaning its categories have a natural order but the distances between them do not signify any magnitude. The underlying assumption is that an unobserved continuous latent variable (Y*) is related to the observed ordinal outcome (Y). The model posits an unobserved continuous latent variable Y_i* for everyone is determined by a linear combination of predictor variables (x_{ij}) and a random error term (ϵ_i). The full model is specified in eq. 7 and the description of the covariates is presented in Table 1.

Table 1
Variables in the ordered logit regression and their units of measurements

Variable	Unit	Remark	Apriori expectation
Resilience	factor	Resilient, High, Medium, Low, Fragile	+
Zone	factor	North, South	±
Access road	factor	Tarred, All Season, Seasonal, Surfaced	±
Development	factor	Urban, Semi-urban, Rural	±
Age	Integer		+

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Variable	Unit	Remark	Apriori expectation
Sex	Dummy	Male, Female	±
Gender	factor	Adult male, adult female, elderly male, elderly female, youth	±
Marital status	factor	Married, Single, Widow(er), Divorced, Separated, Co-habiting, In a relationship	±
Educational level	factor	Tertiary, Secondary, Primary. Qur'anic. Adult/In service, Vocational/Skills acquisition, None	+
Years in formal education	Integer		+
Diversification	Dummy	If the respondent has diversified from agriculture (Yes, No)	+
Cooperatives membership	Dummy	Yes, No	+
Access to extension	factor	Always accessible, often accessible, sometimes accessible, rarely accessible, never accessible	+
Status in the family	factor	Household head ONLY, Breadwinner ONLY, Household head and breadwinner, Member	±
Religious affiliation	factor	Islam, Christianity, African traditional religion, Idol worshipper, Atheist, Other Eastern religion, None	+
Insurance package	Dummy	Whether the project/intervention is with insurance package (Yes, No)	+
Type of market	factor	Daily market, Weekly market, Rotational market, Occasional market, Seasonal market, House to house buying and selling, No market	±
Vulnerability index	index		-
Income generating capacity	factor	Very positive, Positive, Neutral, Negative, very negative	+
Resilience index	index		+
Absorptive capacity	index		+
Transformative capacity	index		+
Project adaptive capacity	index		+
Exposure	index		-
Sensitivity	index		-
Technology adoption	factor	Manual/physical means only, Traditional technology only, Improved manual or traditional technology, New/modern technology, Mix of manual/traditional/modern technologies	+
Insurance policy	factor	Always, Often, Sometimes, Rarely, nope	+
Vulnerability status	factor	Critical, High, Medium, Low, Negligible	-

$$Y_i^* = \beta_i x_{ij} + \epsilon_i \qquad \text{eq. 7}$$

Y_i is a categorized version of Y_i^* which are defined by a set of cut points or thresholds (κ_c) as $Y_i=1$ if $Y_i^* \leq \kappa_1$, $Y_i=2$ if $\kappa_1 < Y_i^* \leq \kappa_2$, $Y_i=C$ if $Y_i^* > \kappa_{C-1}$ where C is the number of categories in the ordinal variable. While for the Beta regression Y_i = Resilience capacity indices generated, and other variables are as defined in Table 1.

The explicit form of the model in the four algorithms is specified in eq. 8:

$$\begin{aligned}\text{RC or IGC} = {} & \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \\ & \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} + \beta_{15} X_{15} + \beta_{16} X_{16} + \beta_{17} X_{17} + \beta_{18} X_{18} + \\ & \beta_{19} X_{19} + \beta_{20} X_{20} + \beta_{21} X_{21} + \beta_{22} X_{22} + \beta_{23} X_{23} + \beta_{24} X_{24} + \beta_{25} X_{25} + \beta_{26} X_{26} + \epsilon_i \qquad \text{eq. 8}\end{aligned}$$

Where RC = Resilience capacity of the farmers (for Ordered logit model) or IGC = Income generating capacity index of the farmers (for Beta regression model), = Zone, = Access road, = Development level, = Sex, = Gender, = Marital status, = Educational level, = Diversification level, = Cooperative membership, = Access to extension, = Status in the family, = Religious affiliation, = Insurance package, = Type of market, = Technology adoption, = Insurance policy, = Vulnerability index, = Age, = Years in formal education, = Vulnerability

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capacity, = Resilience adaptive capacity, = Absorptive capacity, = Transformative capacity, = Project adaptive capacity, = Exposure, = Sensitivity, = intercept/constant, - = Parameters to be estimated, = Error term.

All the computations, estimations were carried with R Programming (vers. 4.5.1, R Core Team, 2025) using various packages and codes developed by Nmadu (2025) and Wickham (2016).

4. RESULTS AND DISCUSSION

After comprehensive and robust analysis of the data generated, the results of this study are presented in Fig. [3-5] as well as Table 2. The results in Fig. 3 (also Appendix I) show the popularity of the 51 projects and interventions under investigation among the beneficiaries. The findings indicated that FADAMA Development Programme (I, II, III, AF), N-Power Agro Programme, Agricultural Transformation Agenda (ATA), National Special Programme for Food Security (NSPFS), Commercial Agriculture Development Programme (CADP) and Anchor Borrowers' Programme (ABP) are the top projects that were subscribed by the beneficiaries. In the same vein, Ogun, Lagos, FCT, Kwara and Nasarawa, which are in the south and central area, are the top states that participated in the projects/intervention. However, it would be of interest to find out if beneficiaries from these states had improved welfare or resilience.

The regression results on Table 2 provide robust evidence on how adaptive capacity, vulnerability, and resilience interact to shape beneficiaries' welfare under agricultural interventions (also Fig.4). The covariates can be grouped into two broad divisions: those that gave consistent signals across the models and those with mixed or context-specific effects. In the first group, vulnerability index exhibited substantial association with fragility in ordered logit whereas in the beta model, their components, exposure and sensitivity, are significant, and the composite index term is strongly negative underscoring that higher vulnerability erodes resilience. In the same vein, those whose access to extension services are "Never" or "Rarely" accessible sharply increase the odds of fragility whereas in the beta model, "Often accessible" is positive and significant, while "Rarely accessible" is negative and significant, indicating that regular extension access enhances resilience. Risk-transfer matters in project implementation as insurance package reduces fragility but increases the resilience index. Also being a household head is associated with less fragility plausibly reflecting decision-agency and resource control. Southern zone beneficiaries show higher resilience which likely captures better infrastructure/markets and denser service ecosystems in the South. This is also a confirmation that the states with higher participation could engender better resilience as up to 3% enhancement in resilience was achieved by states in the southern zone and IGC increased by up to 0.16%. However, despite these

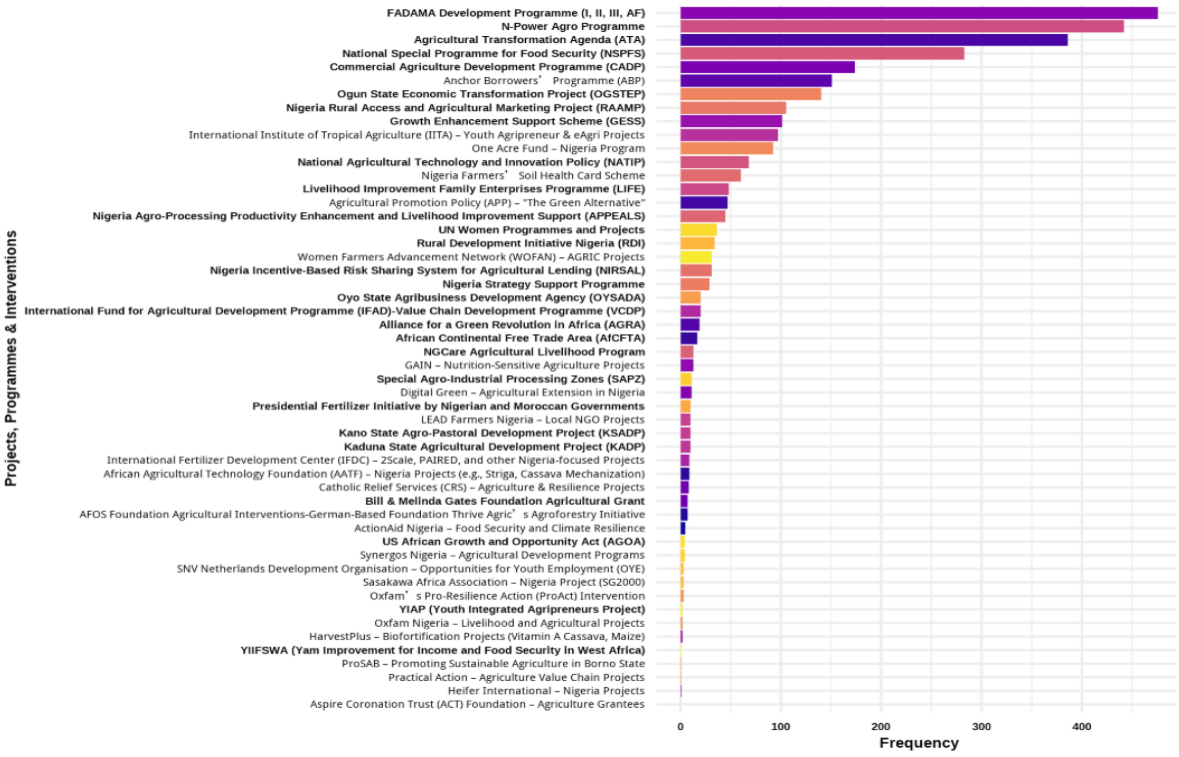


Figure 3
Awareness of projects and interventions existence by beneficiaries in the selected states of Nigeria
Source: Field survey, 2025, graphics from Wickham (2016)

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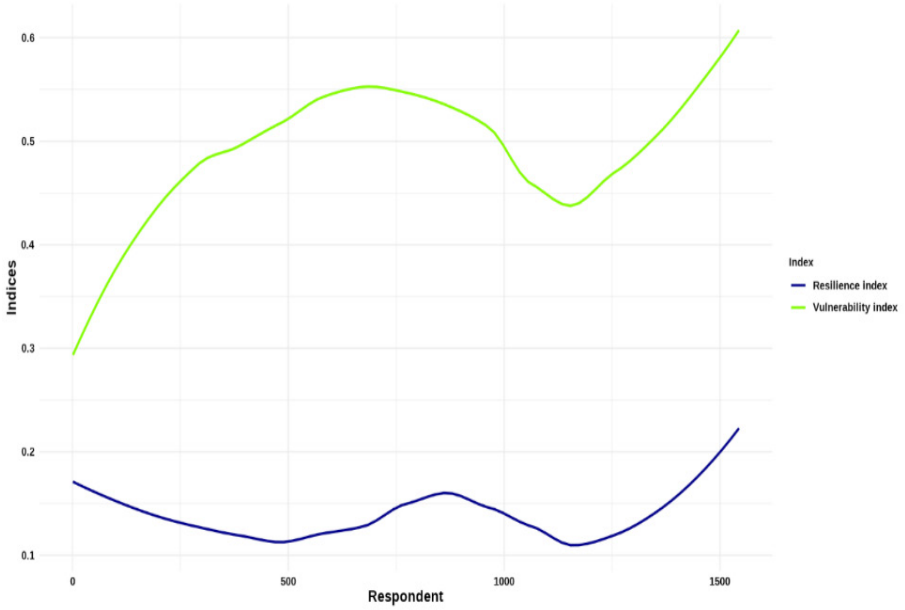


Figure 4
Relationship between resilience and vulnerability indices of respondents
Source: Field survey, 2025, graphics from Wickham (2016)

Table 5
Coefficients estimates of the Determinants of the resilience status of projects beneficiaries in the selected states under alternative models

	Ordered logit	Stepwise ordered logit	Ordered logit (income generating capacity)	Beta regression	Hypothesis
Intercepts/Cut points					
Intercept				-2.455*** (0.386)	
Resilient|High	-28.532*** (1.115)	-23.849*** (1.108)			
High|Medium	-26.452*** (1.064)	-21.774*** (1.032)			
Medium|Low	-25.555*** (1.056)	-20.883*** (1.020)			
Low|Fragile	-23.771*** (1.048)	-19.112*** (1.011)			reject
Very positive|Positive			-7.019*** (0.598)		
Positive|Neutral			-4.916*** (0.593)		
Neutral|Negative			-2.621*** (0.600)		
Negative|Very negative			-0.735 (0.639)		
Zone					
South	-2.224*** (0.338)	-2.289*** (0.303)		0.155** (0.049)	reject
Access road					
Seasonal	-0.145 (0.365)	-0.252 (0.362)		-0.016 (0.055)	
Surfaced	-1.599*** (0.360)	-1.589*** (0.356)		0.231*** (0.056)	reject
Tarred	-0.994** (0.322)	-1.065*** (0.300)		0.074 (0.051)	

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	Ordered logit	Stepwise ordered logit	Ordered logit (income generating capacity)	Beta regression	Hypothesis
Development					
Rural	-0.061			-0.129**	reject
	(0.322)			(0.045)	
Urban	-0.382			0.049	
	(0.332)			(0.053)	
Sex					
Male	1.869	1.950		-0.210	accept
	(1.251)	(1.230)		(0.150)	
Gender					
Adult male	-1.410	-1.401		0.197	reject
	(1.265)	(1.247)		(0.155)	
Elderly female	18.859***	16.961***		-0.270	
	(0.000)	(0.000)		(0.298)	
Elderly male	-2.179	-2.005		0.070	
	(1.316)	(1.296)		(0.174)	
Youth	0.491	0.424		0.068	
	(0.766)	(0.698)		(0.135)	
Marital status					
Divorced	-7.593***			-0.151	reject
	(0.440)			(0.303)	
In a relationship	-6.830***			-0.199	
	(0.739)			(0.321)	
Married	-7.751***			-0.086	
	(0.330)			(0.297)	
Separated	-8.224***			0.391	
	(1.078)			(0.370)	
Single	-7.701***			-0.059	
	(0.353)			(0.298)	
Widow(er)	-8.429***			0.076	
	(0.473)			(0.309)	
Educational level					
None	-12.741***	-15.612***		-0.089	reject
	(0.943)	(0.939)		(0.217)	
Primary	-14.855***	-17.694***		-0.102	
	(0.390)	(0.374)		(0.203)	
Qur'anic	-15.578***	-18.540***		0.003	
	(0.612)	(0.593)		(0.239)	
Secondary	-14.917***	-17.890***		-0.071	
	(0.352)	(0.348)		(0.194)	
Tertiary	-15.836***	-18.794***		0.090	
	(0.375)	(0.366)		(0.192)	
Vocational/Skills acquisition	-15.723***	-18.570***		-0.354	
	(0.589)	(0.587)		(0.226)	
Diversification					
Yes	-0.449	-0.416		0.158***	reject
	(0.260)	(0.253)		(0.042)	
Cooperatives membership					
Yes	0.187			0.021	reject
	(0.219)			(0.037)	

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	Ordered logit	Stepwise ordered logit	Ordered logit (income generating capacity)	Beta regression	Hypothesis
Access to extension					
Never accessible	0.433	0.319		-0.102	
	(0.464)	(0.448)		(0.078)	
Often accessible	-0.188	-0.268		0.210***	
	(0.275)	(0.268)		(0.054)	**reject**
Rarely accessible	0.715*	0.636*		-0.070	
	(0.332)	(0.319)		(0.060)	
Sometimes accessible	0.943**	0.910**		-0.011	
	(0.319)	(0.311)		(0.056)	
Status in the family					
Household head and breadwinner	-1.317***	-1.268***		0.078	
	(0.338)	(0.326)		(0.049)	
Household head ONLY	-1.176***	-1.110**		0.121*	reject
	(0.357)	(0.351)		(0.049)	
Member	-1.180***	-1.100**		-0.008	
	(0.351)	(0.342)		(0.054)	
Religious affiliation					
Christianity	-1.491	-1.438		0.363*	
	(0.884)	(0.876)		(0.143)	
Idol worshipper	-2.461*	-2.449*		1.282***	
	(1.074)	(1.056)		(0.180)	
Islam	-1.956*	-1.883*		0.464**	**reject**
	(0.879)	(0.868)		(0.143)	
None	144.516	13.515***		0.521	
		(0.000)		(0.462)	
Other Eastern religion	140.587	13.341***		0.847	
		(0.000)		(0.550)	
Insurance package					
Yes	-0.558*	-0.556*		0.111**	**reject**
	(0.243)	(0.233)		(0.039)	
Type of market					
House to house buying and selling	-0.102	-0.005		-0.165	
	(0.722)	(0.705)		(0.165)	
No market	0.109	-0.039		0.097	
	(1.186)	(1.152)		(0.217)	
Occasional market	0.512	0.551		-0.372	
	(1.113)	(1.101)		(0.194)	reject
Rotational market	2.344***	2.483***		-0.298***	
	(0.567)	(0.554)		(0.069)	
Seasonal market	12.631***	10.846***		-0.268	
	(0.000)	(0.000)		(0.282)	
Weekly market	1.446***	1.507***		-0.170***	
	(0.221)	(0.208)		(0.039)	
Technology adoption					
Manual/physical means only				-0.007	
				(0.048)	
Mix of manual/traditional/modern technologies				0.444***	
				(0.051)	**reject**
New/modern technology				0.068	
				(0.061)	
Traditional technology only				-0.008	
				(0.051)	

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	Ordered logit	Stepwise ordered logit	Ordered logit (income generating capacity)	Beta regression	Hypothesis
Insurance policy					
Nope				-0.159**	
				(0.058)	
Rarely				-0.089	
				(0.062)	**reject**
Sometimes				0.144*	
				(0.057)	
Sure				0.294***	
				(0.062)	
Vulnerability index					
High				0.263***	
				(0.041)	
Medium				0.255***	
				(0.064)	**reject**
Low				0.422***	
				(0.063)	
Negligible				0.214	
				(0.365)	
Non-factor variables					
Age	0.003			0.000	**accept**
	(0.013)			(0.002)	
Years in formal education	0.056*	0.064*		-0.011*	**reject**
	(0.027)	(0.026)		(0.005)	
Vulnerability index	8.832***	8.356***	-8.572***		**reject**
	(1.350)	(1.310)	(1.169)		
Resilience index			-114.286***		reject
			(11.846)		
Absorptive capacity			-6.202***		reject
			(1.872)		
Transformative capacity			108.630***		reject
			(30.480)		
Project adaptive capacity			-31.865***		reject
			(1.816)		
Exposure			25.158***		reject
			(4.712)		
Sensitivity			4.114***		reject
			(0.827)		
Number of observations	1544	1544	1544	1544	
R2				0.413	
AIC	1202.5	1189.4	3629.8	-3893.1	
BIC	1474.9	1408.4	3688.5	-3572.6	
RMSE	4.66	4.66	2.23	0.08	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: Field survey, 2025

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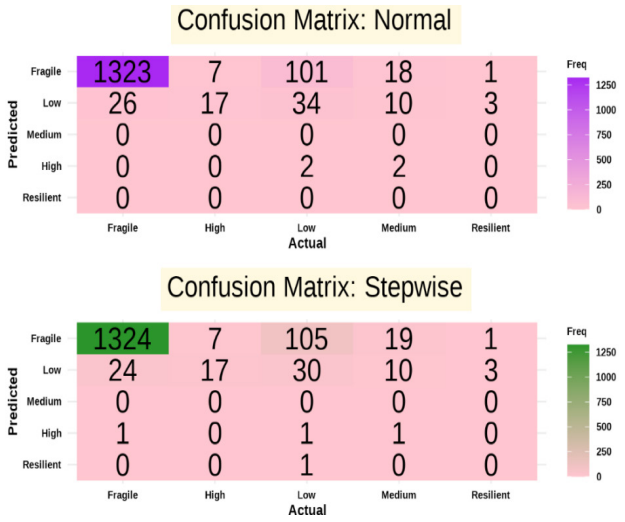


Figure 5
Confusion matrix of actual and predicted resilience capacities of respondents
Source: Field survey, 2025, graphics from Wickham (2016)

Enhancement, 94% of the respondents are still in the fragile class (Fig. 5). It therefore means that the positive development only impacted a very small number of the beneficiaries. One of the plausible causes of this dismal performance is likely due to low capacity amid preponderance of projects and interventions. From the results, at least two unrelated project/intervention are recorded per year during the 25 years period under investigation requiring beneficiaries to carry out farm level operations differently. In this regard, the beneficiary is torn between trying to imbibe new technologies under a previous intervention as a fresh one is introduced. Finally, livelihood diversification is significant in the beta model indicating portfolio breadth supports resilience even if income is volatile.

In the second category, "No formal education" raises fragility, yet more years of schooling show a small positive coefficient in the ordered logit and a negative coefficient in the beta model which is a strong indication that general schooling alone is not sufficient but practical, project-specific training and skills acquisition likely matter more. Also, weekly/rotational markets associate with more fragility in ordered logit and with lower resilience index in the beta model, this potentially reflect exposure to price/volume shocks without safeguard. Finally, "Surfaced" roads is negative in ordered logit but positive in the beta model. This can happen when road quality enables exposure to both opportunities (markets and services) and risks (competition and faster shock transmission).

The convergence between these results and prior Nigerian and SSA research is striking. Studies have consistently highlighted the importance of beneficiary capacity building, context-specific design (Oha *et al.*, 2021), and market/service access in achieving sustainable impacts (Awotide *et al.*, 2016; Adebayo & Oladele, 2013; Ekanem & Inyang, 2013, 2014; Oparinde & Hodge, 2012). Broader vulnerability and resilience syntheses also confirm Nigeria's high exposure and sensitivity, further justifying the emphasis on adaptive capacity as the pathway to resilience (Nmadu *et al.*, 2016; Shilomboleni *et al.*, 2024; Adelekan *et al.*, 2022; ND-GAIN, 2023). This study therefore adds micro-level econometric evidence that strengthens the argument for intervention models which emphasize building capacity first, then providing awareness within the context of the interventions and driving beneficiary infrastructural support initiatives in line with their capacities and level of awareness. Also, beneficiary fatigue in terms of number of projects/ interventions must be considered which may require development institutions to try and collaborate and synchronise their grants and assistance to significantly enhance resilience.

In addition, existing research results underscores recurring themes that reinforce these findings. Adebayo & Oladele (2013) and Ekanem & Inyang (2013, 2014) stress the transformative role of extension systems in bridging the agricultural knowledge divide and institutional redesign, consistent with the regression evidence on extension access. Awotide et al. (2016) empirically links agricultural technology adoption and commercialization to improved smallholder welfare, while Oparinde & Hodge (2012) and Sakeel et al. (2025 highlight conditional incentives and risk-sharing as mechanisms for enhancing resilience. At a broader scale, Adelekan et al. (2022) and Shilomboleni et al. (2024a) situates Nigerian experiences within wider African contexts, emphasizing the interaction between vulnerability and adaptive capacity. The ND-GAIN index further contextualizes Nigeria's adaptive challenges in a global comparative framework. Together, these works converge on the insight that resilience is best achieved through integrated approaches that combine capacity building, institutional strengthening, infrastructural investment, and contextual adaptation.

5. CONCLUSION AND RECOMMENDATION

This study examined adaptive capacity, vulnerability, and resilience among Nigerian farming households under agricultural interventions which show that resilience is shaped primarily by human capital, infrastructure, market access, and service provision, while vulnerability consistently undermines outcomes. Adaptive capacity, both at household and project levels, emerges as the strongest pathway to improvement. Therefore, all the hypotheses were rejected except with age and sex of the respondents. The effects were not uniform across models and factors indicating that institutional interventions influenced adaptive capacity both positively and

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negatively just as in the case of vulnerability. In the case of reduction in vulnerability, resilience is enhanced otherwise with higher vulnerability, resilience wanes. Sustainable project outcomes, such as income generating capacity remain unachieved and the moderating effects of the various contextual factors on institutional interventions, adaptive capacity and resilience are mixed. Conclusively, various projects and interventions in the last 25 years did not achieve sustainable outcomes as was envisaged.

These findings align closely with regional and global evidence, reinforcing calls for first, building capacity, then creating contextual intervention awareness, and then providing infrastructural support strategies to march capacity and awareness. In practical terms, policies that integrate education, extension services, and infrastructure development, while reducing vulnerability through risk management and diversification, offer the most promising route to long-term resilience. By combining micro-level econometric insights with broader resilience literature, this study stresses the need for integrated, multi-dimensional approaches that empower beneficiaries and secure sustainable agricultural outcomes. The regression evidence shows that resilience is not randomly distributed but shaped by human capital, infrastructure, market access, and service provision. Vulnerability consistently challenges household outcomes, while adaptive capacity both at the household and project levels offers a sustainable pathway to improvement. Importantly, the results are consistent with existing national and regional research, providing micro-level evidence that validates the broader call for diverse strategies to implement interventions.

The findings have strong implications for implementation of household level projects and interventions, and sustainability. First, interventions must prioritize reduction of exposure and sensitivity through climate-smart practices, early warning systems, and technologies that reduce risk. Second, strengthening both project-level and household-level adaptive capacity, through training, extension services, and inclusive design, will yield the largest gains. Third, infrastructural investments such as road improvements and regular market platforms directly translate into resilience gains, while promoting insurance and diversification enhances livelihood stability. Finally, targeting support toward household heads, who face higher burden constraints, and leveraging social networks embedded in religious and community affiliations can enhance program uptake and sustainability. By bridging the evidence from micro-level analysis with established insights from broader resilience literature, an integrated, multi-dimensional approaches that empower beneficiaries and ensure the sustainability of agricultural interventions is advocated.

6. LIMITATIONS AND FUTURE RESEARCH

While this study provides strong evidence, several limitations should be acknowledged. First, the cross-sectional nature of the data constrains the ability to capture dynamic processes of building resilience over time. Longitudinal studies would better illuminate causal pathways and feedback loops between adaptive capacity and vulnerability. Second, some measures such as education and extension access may mask heterogeneity in quality and relevance; future research should disaggregate service types and delivery modes. Third, cultural and institutional factors, including informal social networks, were proxied through limited variables such as religion and household role; richer qualitative or mixed-methods data could unpack these influences more deeply. Finally, this analysis focused on Nigeria, and while broadly consistent with SSA literature, cross-country comparative studies would strengthen the generalizability of findings.

Future research should therefore prioritize panel datasets, integrate qualitative and participatory approaches, and expand to regional comparisons. Such efforts will refine understanding of how adaptive capacity can be most effectively strengthened in vulnerable agricultural communities.

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APPENDIX I

State-wise distribution of projects and interventions under study*

Project/Interventions	Ogun	Lagos	FCT	Kwara	Nasara-wa	Bauchi	Ekiti	Kebbi	Osun	Oyo	Niger	Kogi	To-tal	%
FADAMA Development Programme (I, II, III, AF)	3	11	78	70	67	38	30	1	92	2	21	63	476	15.3
N-Power Agro Programme	118	25	70	74	52	15	29	6	3	7	26	17	442	14.2
Agricultural Transformation Agenda (ATA)	65	52	33	65	40	32	7	36	24	23	9	0	386	12.4
National Special Programme for Food Security (NSPFS)	9	52	8	21	38	58	33	13	10	32	6	3	283	9.09
Commercial Agriculture Development Programme (CADP)	0	23	9	15	8	34	8	33	1	33	10	0	174	5.59
Anchor Borrowers' Programme (ABP)	0	2	5	2	40	3	75	21	0	2	0	1	151	4.85
Ogun State Economic Transformation Project (OGSTEP)	109	29	0	0	0	1	0	1	0	0	0	0	140	4.5
Nigeria Rural Access and Agricultural Marketing Project (RAAMP)	7	4	1	61	5	6	2	1	0	3	15	0	105	3.37
Growth Enhancement Support Scheme (GESS)	4	50	6	1	2	6	14	12	1	5	0	0	101	3.25
International Institute of Tropical Agriculture (IITA) – Youth Agripreneur & eAgri Projects	0	31	51	1	8	1	2	1	0	1	1	0	97	3.12
One Acre Fund – Nigeria Program	46	0	1	4	1	1	0	1	17	2	2	17	92	2.96
National Agricultural Technology and Innovation Policy (NATIP)	2	14	9	0	4	3	2	0	0	5	29	0	68	2.19
Nigeria Farmers' Soil Health Card Scheme	46	3	1	0	0	2	0	4	1	1	2	0	60	1.93
Livelihood Improvement Family Enterprises Programme (LIFE)	4	31	1	1	5	4	0	1	0	1	0	0	48	1.54
Agricultural Promotion Policy (APP) – "The Green Alternative"	4	19	7	1	5	5	2	2	0	2	0	0	47	1.51
Nigeria Agro-Processing Productivity Enhancement and Livelihood Improvement Support (APPEALS)	1	5	2	0	3	5	0	2	0	4	0	23	45	1.45
UN Women Programmes and Projects	1	18	7	0	5	2	0	0	2	0	1	0	36	1.16
Rural Development Initiative Nigeria (RDI)	10	5	4	0	13	0	0	0	0	2	0	0	34	1.09
Nigeria Incentive-Based Risk Sharing System for Agricultural Lending (NIRSAL)	1	22	1	1	1	0	2	1	0	1	1	0	31	1
Women Farmers Advancement Network (WOFAN) – AGRIC Projects	11	10	1	0	3	3	1	0	1	0	1	0	31	1
Nigeria Strategy Support Programme	3	12	3	0	2	4	0	2	0	3	0	0	29	0.93
Oyo State Agribusiness Development Agency (OYSADA)	5	10	0	0	1	0	0	1	0	3	0	0	20	0.64
International Fund for Agricultural Development Programme (IFAD)-Value Chain Development Programme (VCDP)	0	4	1	0	3	1	0	7	0	1	3	0	20	0.64
Alliance for a Green Revolution in Africa (AGRA)	11	1	3	0	2	1	0	1	0	0	0	0	19	0.61
African Continental Free Trade Area (AfCFTA)	2	3	8	1	1	1	0	0	1	0	0	0	17	0.55
GAIN – Nutrition-Sensitive Agriculture Projects	3	3	3	1	3	0	0	0	0	0	0	0	13	0.42
NGCare Agricultural Livelihood Program	1	1	0	0	0	0	11	0	0	0	0	0	13	0.42
Special Agro-Industrial Processing Zones (SAPZ)	1	0	4	0	1	1	1	2	0	1	0	0	11	0.35

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Project/Interventions	Ogun	Lagos	FCT	Kwara	Nasara-wa	Bauchi	Ekiti	Kebbi	Osun	Oyo	Niger	Kogi	To-tal	%
Digital Green – Agricultural Extension in Nigeria	7	0	1	0	2	0	0	1	0	0	0	0	11	0.35
Presidential Fertilizer Initiative by Nigerian and Moroccan Governments	0	6	1	0	0	1	1	0	0	1	0	0	10	0.32
Kano State Agro-Pastoral Development Project (KSADP)	1	5	0	0	0	3	0	1	0	0	0	0	10	0.32
Kaduna State Agricultural Development Project (KADP)	3	2	0	0	1	3	0	1	0	0	0	0	10	0.32
LEAD Farmers Nigeria – Local NGO Projects	4	0	2	2	0	0	0	1	0	0	1	0	10	0.32
International Fertilizer Development Center (IFDC) – 2Scale, PAIRED, and other Nigeria-focused Projects	0	4	2	0	2	1	0	0	0	0	0	0	9	0.29
African Agricultural Technology Foundation (AATF) – Nigeria Projects (e.g., Striga, Cassava Mechanization)	1	5	0	1	0	1	0	1	0	0	0	0	9	0.29
Catholic Relief Services (CRS) – Agriculture & Resilience Projects	1	0	0	0	1	0	6	0	0	0	0	0	8	0.26
AFOS Foundation Agricultural Interventions-German-Based Foundation Thrive Agric's Agroforestry Initiative	3	0	2	1	0	0	0	1	0	0	0	0	7	0.22
Bill & Melinda Gates Foundation Agricultural Grant	4	0	0	0	1	0	1	0	1	0	0	0	7	0.22
ActionAid Nigeria – Food Security and Climate Resilience	0	0	0	0	1	0	2	0	1	0	0	1	5	0.16
Synergos Nigeria – Agricultural Development Programs	1	1	0	0	0	1	0	0	0	1	0	0	4	0.13
US African Growth and Opportunity Act (AGOA)	1	1	0	0	0	1	0	0	0	0	1	0	4	0.13
SNV Netherlands Development Organisation – Opportunities for Youth Employment (OYE)	1	1	1	0	0	0	0	0	0	0	0	0	3	0.1
Sasakawa Africa Association – Nigeria Project (SG2000)	0	0	2	0	0	0	0	0	0	0	1	0	3	0.1
Oxfam's Pro-Resilience Action (ProAct) Intervention	0	0	3	0	0	0	0	0	0	0	0	0	3	0.1
Oxfam Nigeria – Livelihood and Agricultural Projects	0	1	1	0	0	0	0	0	0	0	0	0	2	0.06
HarvestPlus – Biofortification Projects (Vitamin A Cassava, Maize)	0	0	0	0	0	0	1	1	0	0	0	0	2	0.06
YIAP (Youth Integrated Agripreneurs Project)	0	0	0	2	0	0	0	0	0	0	0	0	2	0.06
Heifer International – Nigeria Projects	0	0	0	0	1	0	0	0	0	0	0	0	1	0.03
ProSAB – Promoting Sustainable Agriculture in Borno State	0	0	0	0	1	0	0	0	0	0	0	0	1	0.03
Practical Action – Agriculture Value Chain Projects	0	0	1	0	0	0	0	0	0	0	0	0	1	0.03
YIIFSWA (Yam Improvement for Income and Food Security in West Africa)	1	0	0	0	0	0	0	0	0	0	0	0	1	0.03
Aspire Coronation Trust (ACT) Foundation – Agriculture Grantees	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	495	466	333	325	323	238	230	156	155	136	130	125	3112	99.99
%	15.9	15	10.7	10.4	10.4	7.6	7.4	5	5	4.4	4.2	4	100	

Source: Field survey, 2025
*multiple responses allowed

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APPENDIX II

Sample per LGA in the study

Local Government Area	Number of respondents	%
Karu	88	5.7
Abeokuta South	76	4.92
Ifako-Ijaye	72	4.66
Ogbomosho South	70	4.53
Kwali	67	4.34
Bogoro	66	4.27
Katagum	66	4.27
Abeokuta North	65	4.21
Bosso	65	4.21
Agege	63	4.08
Ogbomosho North	62	4.02
Adavi	61	3.95
Birnin Kebbi	61	3.95
Chanchaga	61	3.95
Edu	61	3.95
Egbedore	61	3.95
Moro	61	3.95
Okene	61	3.95
Aliero	60	3.89
Ede North	60	3.89
Gwagwalada	59	3.82
Keffi	58	3.76
Irepodun/Ifelodun	41	2.66
Gboyin	40	2.59
Ikole	39	2.53
Total	1544	100

Source: Field survey, 2025

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APPENDIX III

Socio-economic and geographic information about the states in the study

State	Location	Number of LGAs	Major tribes	Major Economic activities	Population	LGAs in the study	Communities in the Study	Annual Rainfall	Annual temperature	Major crops produced
Bauchi	9°3'-12°3'N 8°50'-11°E	20	Hausa, Fulani and Sayawa	Agriculture, livestock rearing, andtourism	8,255,946	Katagum, Bogoro	Bakin Day, Birniwa, Boi, Za'ar	700mm -1300mm	25°C to 40°C	Maize, sorghum, rice, groundnut, cotton, sesame, millet, soybean, and cassava
FCT	8°30′-9°30′N 6°30′-7°30′E	6	Gbagyi, Koro	Administration, Tourism, Farming	3,278,779	Gwagwalada, Kwali	Tungan Maje, Zuba, Dafa, Kundu	1100-1600 mm	25-28°C	Maize, Rice, Cassava, Yam, Potatoes, Sweet potatoes, Tomatoes, Peppers, Cucumbers, Vegetables
Ekiti	7°40′-7.667°N 5°15′-5.250°E	16	Yoruba	Agriculture, forestry, Tourism and Export	2,384,212	Irepodun/ Ifelodun, Ikole, Gboyin	Igede Ekiti, Are Ekiti, Ayedun Ekiti, Ijesa Isu Ekiti, Aisegba Ekiti, Ijan Ekiti	740 mm - 1220 mm	21°C - 28°C	Yams, rice, cocoa, and cassava
Kebbi	10°-13°N 3°30'-6°E	21	Hausa, Fulani	Fishing and farming	6,260,592	Birnin Kebbi, Aliero	Bago, Busawa, Aliero, Agwada	787.53-1200	18.3-40°C	Sorghum, groundnuts, millet, onions, and rice
Kogi	7°20′-8°10′N 6°20′-7°10′E	21	Igala, Ebira, Okun	Farming, Mining	5,685,864	Adavi, Okene	Kuroko, Ogaminana, Inike, Okengwen	1016-1524 mm	24-27°C	Yam, cassava, maize, cowpea, melon, bambara nut, beniseed, oil palm, castor, cashew, citrus
Kwara	8°24′-8°34′N 4°28′-4°35′E	16	Yoruba, Nupe, Fulani, and Bariba	Farming	3,660,000	Moro, Edu	Bode Sa'adu, Malete, Lafiagi, Tsaragi	800-1500mm	28.28-44.47°C	Maize, sorghum, rice, millet, beans, yam, cassava, and vegetables
Lagos	6.5244°N, 3.3792° E	20	Yoruba	Commerce and finance, manufacturing (automobiles, food & beverages, textiles, etc.), agriculture, and fishing	15,946,000	Agege, Ijaye Jokoro	Orile Agege, Dopemu, Ijaye, Alakuko	1627-1747mm	21-34°C	Cassava, maize, plantain, rice, palm oil, and coconut
Nasarawa	7°45′-9°25′N 7°-9°37′E	13	Eggon and Alago	Farming	2,886,000	Karu, Keffi	Mararaba, Masaka, Angwan Lambu, Gauta	1123-1500mm	27.6-39.3°C	Rice, yam, maize, beans, and cassava
Niger	9°00′-10°30′N 5°30′-7°10′E	25	Nupe, Gbagyi, Hausa	Farming, Fishing	6,783,300	Bosso, Chanchaga	Maikunkele, Garatu, Tunga, Kpakungu	1219 mm	26.10-30.30°C	Rice, guinea corn, maize, yam, beans, groundnut, sugarcane
Ogun	6.2°-7.8°N 3.0°-5.0°E	20	Yoruba	Farming	6,379500	Ijebu North, Ijebu Ode	Oke-Ilewo, Elega, Amolaso, Kuto	1400-1500mm	23.3-33.9°C	Cassava, rice, maize, yams, plantains, and bananas
Osun	7°30′-8°00′N 4°00′-4°45′E	30	Yoruba	Farming	4,350,800	Egbedore, Ede North	Ìrágberí, Awo, Faosun, Ẹlẹrẹ	1100-800 mm	21.10C - 31.10°C	Cocoa, kola, citrus, oil palm, maize, yam, rice, cassava, tomato, pepper
Oyo	8.1574°N, 3.6147° E	33	Yoruba	Farming, cattle rearing, mining and commercial activities	7,976,100	Ogbomosho North, Ogbomosho South	Ogbomosho, Arowomole, Idi Agba, Kajola	1050-1350mm	21-35°C	Cassava, cocoa, maize, rice, palm oil, yams, and beans

Source: Field survey, 2025

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APPENDIX IV

Factor loadings - adaptive capacity

Variable	Loadings
Membership of Community-based organisation outside community	0.749
Social networking and family support	0.742
Risk and vulnerability planning	0.743
Training for short-term changes	0.741
Local action on adaptation	0.740
Early warning service/system	0.740
Highest educational level attained	0.755
crops	0.749
Cattle (Cow/Bull/Oxen)	0.750
Sheep and goat	0.753
Broilers	0.752
Layers	0.752
Local chickens-	0.758
Turkey	0.750
Ducks	0.757
Pigeons-	0.761
Guinea fowls	0.753
Donkeys	0.761
Horses	0.760
Swine	0.754
Dogs	0.752
Primary occupation-	0.760
secondary	0.745
Radio	0.748
Television	0.746
Mobile devices	0.747
Internet connections/data services	0.746
Adoption of improved farming practices	0.742
Farmhouse	0.761
Solar power supply	0.760
Water pump	0.757
Tractor	0.755
Tractor implements	0.754
Tube well	0.763
Farm Store-	0.762
Animal cart	0.759
Permanent crops-	0.763
Plantation	0.760
Bulls/Cows or other work animals	0.757
Processing equipment	0.755
Short-term credit access	0.762
Income generation capacity	0.751
Amount of loan	0.745

Source: Field survey, 2025

APPENDIX V

Factor loadings - absorptive capacity

Variable	Loadings
Membership Cooperatives, Community-based or Farmers' organisation	0.868
Member only	0.873
Governance and policy making	0.872
Executive functions	0.870
Advisory functions	0.872
Governmental, formal or informational representation	0.874
Access to finance as important factor	0.871
Amount of loan	0.869
Farmhouse	0.873
Solar power supply	0.872
Water pump	0.871
Tractor	0.873
Tractor implements	0.872
Tube well	0.874
Farm Store-	0.874
Animal cart	0.873
Permanent crops-	0.872
Plantation-	0.873
Bulls/Cows or other work animals-	0.874
Processing equipment	0.872
Sustainable land management practices	0.866
Compost, animal and green manure	0.864
Minimum tillage, mulching and weed control	0.864
Agroforestry practices	0.863
Assistance from relatives and friends	0.868
Using a diverse workforce	0.864
Sharing of resources and technology	0.862
Rainwater harvesting techniques, storage and conservation	0.862
Use of irrigation	0.863
Collection of run-offs from flood	0.862
Constructing flood dykes and embankments	0.861
Adding new crop/changing crop species	0.862
Change timing of crop planting	0.862
Use of drought tolerant/resistance crop varieties/seeds	0.862
Pest and disease control	0.865
Farm waste disposal	0.862
Soil and erosion control	0.862
Relocating to higher grounds, non-drought or unflooded area	0.863
Social networking and family support	0.863
Adoption of improved farming practices	0.863
Insurance policy	0.867

Source: Field survey, 2025

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APPENDIX VI

Factor loadings - transformative capacity

Variable	Loadings
Seeking assistance from various organizations	0.716
Membership of Farmers' organisation outside community	0.721
Type of market in community	0.733
Public water supply/Public stand tap	0.740
Yard/public well-	0.730
Personal well-	0.732
Community borehole with reticulation/electric pump	0.736
Community borehole with manual pump-	0.730
Personal borehole-	0.732
Protected spring	0.740
Unprotected spring	0.738
Seasonal ponds	0.738
Surface Water	0.740
Cart With Small Tank-	0.741
Sachet Water-	0.727
Vendor/Tanker water supply-	0.735
Rainwater Collection-	0.729
School (primary/secondary)	0.733
Health centre	0.734
Communication mast	0.728
Bank	0.721
Water treatment plant	0.714
Broadband internet	0.714
Waste disposal system	0.720
Community centre	0.732
Radio	0.719
Television	0.725
Mobile devices	0.727
Internet connections/data services	0.728
Access to extension advisory services	0.725
Distance to extension advisory services	0.729
Meeting social and cultural obligations	0.729
Member only	0.734
Governance and policy making	0.737
Executive functions	0.732
Advisory functions	0.739
Governmental, formal or informational representation	0.740
Risk and vulnerability planning	0.717
Participating in governance	0.712
Level of technology utilised	0.739

Source: Field survey, 2025

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