

# Social Protection, Agro-Environmental Innovation, and Carbon Sequestration Management as Pathways to Climate-Resilient Development: Empirical Evidence from Rural Kogi State, Nigeria.

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*Abstract- The effects of climate change on rural development outcomes in Nigeria is severely adverse, yet responses are still piecemeal and context insensitive. This study Examines how the combination of carbon Sequestrations, agro-environmental Innovations and social protection systems can enhance climate resilience in rural Kogi Imo State. In particular, it: (i) Evaluates the perceptions of households on cross-sectoral synergies; (ii) utilizes an Integration Index in assessing the level of Resilience and integration; (iii) identifies Institutional and governance barriers; and (iv) suggests an evidence-based Framework for implementation at the States level. Data were collected through 217 households and eight Key Informant Interviews by utilizing a concurrent Mixed-methods design across four LGAS-Lokoja, Ajaokuta, Dekina and Kabba/Bunu. Descriptive statistics and ANOVA were used to analyze the quantitative data while qualitative data were analyzed using a thematic analysis. The findings indicate significant differences in resilience over levels of integration ( $F(3, 213) = 47.62, p < .001$ ). Households with full integration had a significantly higher average resilience score (4.18 out of 5), compared to single domain users who had an average score of (3.12) and those without intervention(2.58). Only 17.1% of respondents were fully integrated. This indicates a significant gap in policy relevance. Such failures were largely due to governance-related issues including institutional blind spots, weak extension systems, and program designs excluding women. The framework proposed by this study is the Kogi Integrated Resilience Strategy (KIRS) Model, which aims to implement integrated resilience pathways and is aligned with Nigeria's climate change act (2021) and the updated Nationally Determined Contributions. The findings provide realistic and empirical insights for improving climate-resilient systems-oriented development.*

*Index Terms- Agro-environmental innovation, carbon Sequestrations, integrated development, social protection systems.*

## I. INTRODUCTION

The unpredictability of agricultural calendars along the Niger-Benue confluence in Kogi state is increasingly alarming. The unreliability of the onset and duration of rainy seasons, coupled with extended drought has left so much to be desired. This has severely disrupted most traditional farming cycles as what used to be a predictable seasonal order of planting and harvesting has now become case of overlapping shocks, where one climate shock occurs before a recovery from the previous one. This challenge transcends environment concerns as it portends a serious development crisis. Furthermore, the steady degradation of the agricultural systems that feed millions of Nigerians due to climate change is adding to the existing poverty as well as weak institutions and declining resources (Ijachi et al., 2023; Mustapha, Abubakar & Joseph, 2021).

As such, Nigeria is at a crucial crossroads in its development. The increased irregularity of rainfall, the droughts, flooding and deteriorating soil quality has not only caused a profound negative effect on the livelihoods of rural people but also destabilize the national economy. This situation is even more critical for smallholder farmers in Kogi and some other states that are vulnerable due to their ecological exposure as well as limited support from the government (Folorunso, 2024; Shibesh & Nagabhatla, 2025). These forces not only jeopardize the livelihoods of individuals but also create pressure on social protection systems that are already under strain to alleviate vulnerability.

This study addresses this gap by examining the integration of three critical domains of social protection systems, agro-environmental innovations, and carbon sequestration management, and how they can work together to help development that can withstand climate change.

The study is guided by the following objectives: (1) to evaluate the perception of rural household farmers on the synergistic benefits of integrating the three intervention domains; (2) to analyze the relationship between integration levels and resilience outcomes using an Integration Index; (3) to identify governance and institutional determinants of integration; and (4) to develop an evidence-based framework for implementing integrated climate-resilient strategies. Correspondingly, the study tests hypotheses regarding differences in resilience outcomes, relationships between governance quality and integration, and comparative benefits of multi-domain access.

## II. LITERATURE REVIEW

In recent times, scholarly research has focused on strategies for climate-resilient development. These include social protection, agro-environmental innovation, and carbon sequestration management. Social protection is a combination of public policies and institutional programs that serve as a safety net aimed at mitigating and reducing vulnerability so as to enhance a household's capacity to manage economic and social risks throughout its life cycle (Erondu & Uzoma, 2024). Agro-environmental innovation on the other hand, is broadly defined as the technological and institutional innovations aimed at reducing environmental impact on agriculture and strengthening the sector's resilience to climate change (Koivuranta et al., 2023). These innovations include improved seed varieties, conservation agriculture, and water-efficient irrigation that boost agricultural productivity while reducing environmental degradation (Omotosho & Omotayo, 2024; Naazie et al., 2023). Carbon sequestration is the process of trapping atmospheric CO<sub>2</sub> to mitigate climate change. Techniques such as agroforestry, conservation tillage, and biochar application can increase soil carbon storage, enhance long-term soil fertility, and position

smallholders for potential participation in the new carbon market (Loria and Lal, 2025; 2022; Olaniyi et al., 2023).

While each of these pathways demonstrates measurable benefits in isolation, the evidence increasingly shows that when they are integrated, the resilience outcomes is more durable and scalable than any single intervention (Ulrichs et al., 2019; Schipper et al, 2022). In Nigeria's Agriculture, Forest and other land use sector (AFOLU) for instance, integrated practices combining agroforestry, biochar, and carbon credits were able to show compounding gains in productivity, soil health, and carbon which underscores the course domain dividend approach that a siloed dividend cannot achieve. This outcome is particularly significant given that soils constitute the largest terrestrial carbon reservoir and are highly sensitive to climate change-induced degradation (Zhang et al., 2025; Ren et al., 2024).

Achieving these benefits, however, is dependent on enabling conditions that remain structurally weak across much of rural Nigeria. The social, economic, biophysical, and institutional characteristics shape the adaptive capacity (Chapagain et al., 2025). In the absence of educational opportunities and financial and extension services, agro-environmental innovations seem to widen rather than narrow inequality, mostly benefiting better-off households (Incoom et al., 2025). Effective political systems are just as important; the absence of coordinated and adaptive governance systems impedes the uptake of programmes; and wherever these systems are weak, outcomes will be systematically undermined, regardless of the quality of the intervention (Bucheli et al, 2024).

Adaptive Social Protection extends this argument by repositioning cash transfers and insurance from passive safety nets but proactive, risk-informed adaptive mechanisms to create long-term resilience. However, Nigeria's system is poorly aligned with climate and agricultural policy frameworks, thereby constraining its potential (Holmes et al., 2020; World Bank, 2022).

Across Sub-Saharan Africa, ASP Programs produce the best outcomes when adapted to agricultural calendars, climate shocks, and reach women and marginalised farmers, which is still not the case in Kogi State. (FAO, 2024; Scarpin, 2024).

Integrated planning frameworks that align adaptation, mitigation, and development goals are necessary for operationalising climate-resilient development. Recent studies have identified governance quality as the critical determinant of whether frameworks translate into lived outcomes (Schipper et al., 2022; Taylor et al., 2023). Nigeria’s Climate Change Act (2021) and its updated Nationally Determined Contributions set out ambitious integrated goals, yet their delivery at subnational levels is fragmented, under-resourced, and technically constrained. Kogi State suffers from ecological fragility, governance deficits, and household poverty. Yet there is a dearth of relevant empirical evidence for integrated climate programming in the state (Anyanwu et al., 2023; Climate Watch, 2023). This research effort directly tackles that gap.

### III. METHODS

This study adopted a mixed-methods approach to examine how integrated interventions support climate-resilient development in rural Kogi State. To obtain quantitative information regarding intervention domains and key resilience indicators, structured questionnaire was used to collect data while the study also used Key Informant Interviews for the collection of qualitative data. Key Kogi stakeholders were interviewed for this study. These included agric extension agents, social protection officers, NGOs workers, and rural Community leaders. Both sets of data were collected during the same period but analyzed separately and integrated during the last analysis.

A multistage sampling method was used for the study. Four local government areas in Kogi State were purposively selected due to their climate risk and ecological diversity. Local government areas include Lokoja, Ajaokuta, Dekina, and Kabba/Bunu. A systematic random sampling technique was used to select participants. The study obtained 217 valid

questionnaires. Data was analysed by descriptive statistics and ANOVA to check the significant outcome of resilience on three levels of intervention integration.

## IV. RESULTS

### 4.1 Socio Demographic Profile

Table 1: Socio-Demographic Profile of Respondents

Variable	Category	Frequency (n)	Percentage %
Gender	Male	128	59.0
	Female	89	41.0
Age	18-25 Years	38	17.5
	26-35 Years	61	28.1
	36-45 Years	68	31.3
	46-55 Years	34	15.7
	56 Years +	16	7.4
Educational Level	No formal	28	12.9
	Primary	47	21.7
	Secondary	73	33.6
	Tertiary	69	31.8
Household size	1-3 Persons	29	13.4
	4-6 Persons	88	40.6
	7-9 Persons	72	33.2
	10 above	28	12.9
Farming Experience	1-5 Years	31	14.3
	6-10 Years	57	26.3
	11-15 Years	63	29.0
	16-20 Years	44	20.3
	20 Years +	22	12.1
Primary Occupation	Crop Farming	112	51.6
	Livestock	43	19.8
	Mixed Farming	38	17.5
	Others	24	11.1

Source: Field Survey, 2025

Table 1 Shows The demographic information of the participants. The male respondents constituted 59.0% (n=128) while the female respondents, 41.0% (n=89) indicating the gender distribution of the smallholder households. The 36–45 years age group represented the cohort most (31.3%, n=68), followed by 26–35 years old (28.1%, n=61). 28 (12.9%) had no education and 73 (33.6%) had secondary education.

The mean household size for the North-Central Nigeria reference range was 6.2 people (SD=2.1). The most prevalent primary occupation was crop farming (51.6%, n=112), with 11-15 years of farming experience being the most common (29.0%, n=63).

4.2 Respondents Perception of Cross Domain Synergies

Table 2: Respondents Perception of Cross Domain Synergies

Statement	SA %	A %	U %	D %	Mean	Remark
Carbon Sequestrations + Agro-innovations improve farm yields.	34.1	37.8	13.8	14.3	3.86	High
SP + Agro innovations reduce shock vulnerability.	41.0	36.4	12.5	10.1	4.05	High
Carbon Sequestration +SP jointly stabilize Livelihoods.	29.0	40.6	17.5	12.9	3.82	High
All three domains jointly build Resilience.	46.5	37.3	10.1	6.1	4.27	Very High
Integration is stronger than any single domain.	49.8	35.0	8.8	6.4	4.26	Very High
GRAND MEAN					4.09	High

Source: Field Survey, 2025

Table 2 shows respondents Perceptions of synergies between the three intervention domains which were analyzed. Every item had mean scores higher than 3.70, indicating a high degree of perceived cross-domain complementarity. The results show that Integration is stronger than any single domain as recorded by M=4.26. The highest mean (M=4.27, SD=0.89) was recorded showing perception of

respondents that the three domains jointly build resilience. The overall grand mean of 4.09 indicates that rural households in Kogi State strongly value integration.

4.3 Integration Levels and Household Resilience Outcomes

Table 3: Integration Levels and Household Resilience

Integration Level	Description	(n)	%	Mean Resilience	SD
Full integration (3 domain)	SP + Agro-innovation + Carbon Sequestration	37	17.1	4.18	0.61
Partial Integration ( 2 domain)	Any two of the three	57	26.3	3.74	0.72
Single domain	One domain only	79	36.4	3.12	0.84
No formal intervention	No access to any domain	44	20.3	2.58	0.91
TOTAL		217	100.		

Source: Field Survey, 2025

Table 3 shows responses according to domain integration levels. Despite making up only 17.1% (n = 37) of the sample, households with complete integration had the highest resilience (M = 4.18, SD = 0.61). Conversely, 26.3% showed partial integration (M = 3.74, SD = 0.72), 36.4% accessed a single domain (M = 3.12, SD = 0.84), and 20.3% had no access (M = 2.58, SD = 0.91). A one-way ANOVA with a large effect size ( $\eta^2 = 0.40$ ) showed statistically significant differences between the groups ( $F(3, 213) = 47.62, p <.001$ ). Significant pairwise differences between integration levels were found using Tukey's HSD post-hoc test ( $p <.05$ ). The evidence shows that even though full integration produces better results, its uptake is still restricted.

#### 4.4 Governance conditions

Table 4: Institutional enabling conditions and Governance gaps

Governance condition	Mean	SD	Interpretation
Inter-ministry collaboration for climate action	2.09	1.07	Very low-critical
Program coordination	2.17	1.02	Very low-critical
SP aligned to agricultural calendar	2.28	0.98	Very low-critical
Climate warnings received on time	2.31	1.08	Very low-critical
Community trust in institutions	2.44	1.11	Low – High priority
Extension services regularly available	2.54	1.13	Moderate – High priority
Women and youth included in decisions	2.63	1.07	Moderate – High priority
NGO donor support to govt.	3.22	1.05	Moderate
Grand Mean	2.46	—	Low Overall

Source: Field Survey, 2025

Table 4 shows Respondents' evaluations of eight institutional and governance items on a five-point rating scale. Weak enabling conditions across the study area were reflected in the majority of governance coordination indicators scoring below the 2.50 midpoint. The only item that reached a moderate level was NGO and donor support ( $M = 3.22$ ,  $SD = 1.05$ ), while interministry cooperation for climate action received the lowest score ( $M = 2.09$ ,  $SD = 1.07$ ). The overall grand mean of 2.46 indicates a generally low level of institutional effectiveness. This contrasts sharply with the respondents' high

evaluation of integration ( $M = 4.09$ ), indicating a clear mismatch between perceived needs and existing institutional support.

#### 4.5 Social Protection Program Access rates and Effectiveness Rating

Table 5: Social Protection Access and Effectiveness

Program Type	Access Rate (%)	Beneficiaries (n)	Mean Effectiveness	Interpretation
Food Assistance	41.0	89	3.68	Moderate
Cash Transfer	28.3	61	3.74	Moderate
Public works program	22.1	48	3.81	High
Adaptive SP training.	17.5	38	4.01	High

Source: Field Survey, 2025

Table 6 shows a striking finding from the social protection analysis. Adaptive SP training programmes recorded both the highest effectiveness rating among beneficiaries ( $M=4.01$ ) and the lowest access rate (17.5%). This contrasted with food assistance programmes which were the most widely accessed (41.0%) but had lower effectiveness ( $M=3.68$ ). This inverse relationship indicates a systemic imbalance in programme reach, in which the most transformative interventions do not reach priority areas, which is a finding with direct implications for reform priorities.

#### 4.6 Qualitative data

A report from an Agricultural Extension Officer in Lokoja (KII-01). "When we distributed climate-resilient maize seeds to communities in the safety net programme, it made a lot of difference. The program boosted their confidence to try the new seeds in their farms so they can maximize yield in the event the rains failed". This captures the integration dividend in the sense that social protection removes the risk-aversion barrier that prevents adoption of more agro-productive innovations.

A female farmer in Ajaokuta (KII-05) described her experience of single-domain support: “*Sometimes last year, I got the subsidised fertiliser which helped a lot. But the rains delayed this year and it was tough because I couldn't access support.*” Her account illustrates how isolated interventions generate temporary relief without building durable adaptive capacity. On governance, a coordinator with the Kabba, Kogi Agricultural Development Programme (KII-03) said: “*Although extension workers are working, the recent security challenges have limited their reach.*” Moreover, many of them require retraining to include current climate-smart practices.” This account illustrates how isolated interventions can give short-term relief without helping people adapt in the long term.

## V. CONCLUSION AND RECOMMENDATION

Using data from 217 rural households in Kogi State's four Local Government Areas. This study shows that there's significant increase in climate Resilience when interventions are integrated compared to single strategies. The findings show a strong integration advantage, with statistically significant group differences supporting the considerably higher resilience outcomes of fully integrated households. Despite this, only very few farming households record full integration, which is a sign of serious institutional and governance barriers. Some of which include, lack of extension capacity, poor program alignment, and insufficient interministerial coordination which hinders effective implementation. Additionally, low educational attainment and gender inequality further impede access and adoption. The results show a huge gap between the advantages of integration and the current methods of providing interventions.

Policy makers should formalize the creation of legally backed inter-ministerial pathways that will serve as cross-sectoral platforms for climate Resilient program coordination for development. Dedicated budget lines and integrated planning should be prioritized for better implementation. Furthermore, investment in extension systems, gender inclusive program and rural education should be strengthened to enhance adoption, equity and scalability of integrated climate resilience interventions.

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