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Spectral Effects of Eco-Innovations' Adoption On Sustainable Livelihoods' Resilience Among Small-Scale Wheat Farmers In Jigawa State of Nigeria

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Abstract
The adoption of eco-innovations for sustainable livelihoods among wheat farmers in Jigawa State, Nigeria, presents a pressing problem that necessitates attention and intervention. Despite the potential benefits associated with eco-friendly agricultural practices, the rate of adoption remains a significant challenge, hindering the attainment of sustainable livelihoods for wheat farmers in the region. Consequently, this research is timely as it investigates the spectral effects of eco-innovations on the sustainable livelihood resilience of small-scale wheat farmers in Jigawa State, Nigeria. Using cross-sectional data elicited through a well-structured questionnaire coupled with an interview schedule from a total of 284 farmers selected via a multi-stage sampling technique during the 2022–2023 cropping season, the research gap was analyzed using both descriptive and inferential statistics. Inspite of the accumulative livelihood strategy and high adoption of eco-innovations among the majority of farmers, the extension gap challenge hampered the landslide adoption of eco-innovations and the intention to key into crop insurance among these farmers. Nevertheless, the majority of the farmers had their farms to be sustainable, which underscores the importance of adopting eco-innovations as a climate change resilience measure, thus enabling them to achieve the accumulated livelihood strategy in the study area. Succinctly, adoption of eco-innovations has a strong endogenous effect on livelihood status en-route farm sustainability but a weak endogenous effect on livelihood status en-route willingness-to-pay (WTP). Consequently, onus lies on policymakers to address the extension gap by enhancing advisory services for effective feed-forward and feed-backward flows of information sources, risk orientation, and slight modification of the neo-conventional eco-innovations in order to suit the farms' ecological settings in the study area. This singular approach has the potential to be a single silver bullet that will enhance farmers' climate change resilience, farms' sustainability, and guarantee a prosperous sustainable farm family livelihood status in the study area.

Keywords: Eco-innovations; Adoption; Sustainability; Livelihood; Resilience; Wheat farmers; Nigeria

Introduction
An important part of Nigeria's agricultural landscape is Jigawa State, which is situated in the north. One of the main economic activities in the area is agriculture, with wheat farming having a special significance. Small-scale farming, where many families make their living from growing wheat, is the main driver of the state's economy. Nigerian wheat is a staple crop that is very important both economically and nutritionally. In Jigawa State, wheat farming is the main source of income for many people and makes a significant

contribution to both revenue generation and food security. However, a number of issues, such as soil erosion, climate variability, and conventional agricultural practices that could upset the ecological balance, pose a threat to the sustainability of wheat production.

Eco-innovations comprise a range of methods and tools intended to reduce environmental effects while fostering economic viability/feasibility (Dybikowska and Graczyk, 2019; Dudek and Wrzaszcz, 2020; Alizadeh *et al*., 2022). These advancements encompass sustainable resource management, organic farming, agro-ecological methods, and water-saving strategies (Aroonsrimorakot *et al*., 2021; Buchana, 2023). Farmers that embrace eco-innovations may be able to decrease their reliance on hazardous agrochemicals, increase the sustainability of the environment overall, and strengthen the resilience of their farming systems to climate change (Tretiak *et al*., 2021; Todorova, 2022). Like many other places in the world, Jigawa State struggles with issues related to the environment, such as irregular rainfall patterns, degraded soil, and limited water supplies. Unsustainable farming methods, including overusing chemical inputs, might make these problems worse and force a move toward eco-innovations. Although Jigawa State may have some broad studies on agriculture, there aren't many studies specifically looking at wheat farmers' adoption of eco-innovations. If any research has been done thus far, it might not fully cover the special opportunities and problems related to sustainable farming methods in the area. Therefore, a crucial field of research with significant consequences for environmentally conscious farming, sustainable farming methods, and small-scale farmers' livelihoods is the adoption of eco-innovations by wheat farmers in Jigawa State, Nigeria.

The policies and other support systems in place have an impact on the adoption of eco-innovations. Jigawa State's current agriculture laws don't have any explicit clauses or incentives to encourage wheat growers to widely implement eco-innovations. It is difficult to incorporate environmentally friendly techniques into regular agricultural operations when there are gaps in policy or poor execution. Nonetheless, Jigawa State's wheat farmers are not fully guided or encouraged to embrace sustainable practices by the policies that have been put in place. Furthermore, there is a dearth of research on wheat farmers' reasons for adopting eco-innovations, as well as their obstacles and viewpoints. Designing effective solutions therefore requires an awareness of farmers' attitudes, knowledge gaps, and sociocultural issues.

Jigawa State's wheat producers are particularly susceptible to the negative effects of climate change, which is a danger to agricultural productivity. The need for sustainable and environmentally friendly farming methods is growing as worries about climate change and environmental sustainability spread around the world (Durán-Romero *et al*., 2020; Leszek and Grzegorz, 2021; Yordanova, 2023). Under these conditions, implementing eco-innovations becomes an essential means of reducing environmental deterioration, strengthening climatic resilience, and guaranteeing the sustainability of agricultural practices. Consequently, investigating eco-innovations becomes essential for determining methods that can improve climate resilience, reduce environmental hazards, and support wheat farming's long-term sustainability. Furthermore, wheat cultivation in Jigawa State plays a vital role in the financial stability of many families. Understanding the uptake of eco-innovations is vital for assessing their potential to boost farmers' income, cut production costs, and contribute to overall livelihood sustainability.

Even with the potential advantages of eco-innovations, further research is needed to determine how widely adopted they are among Jigawa State's wheat growers. Comprehending the variables impacting the implementation of sustainable practices is imperative in order to formulate focused interventions, formulate efficacious policies, and endorse environmentally conscious farming techniques that conform to the distinct socio-economic and environmental milieu of Jigawa State.

Succinctly, the need to solve environmental issues, strengthen climate resilience, and promote small-scale farmers' social and economic well-being is what drives this research. This study is to close knowledge gaps and offer insightful information to the farming community, academic institutions, policymakers, and agricultural extension services in order to ensure the long-term sustainability of wheat growing in Jigawa State and to encourage sustainable practices. Research on the particular nuances of these problems in the context of Jigawa State, however, will be crucial for developing strategies that encourage wheat farmers to adopt eco-innovations, which will ultimately help the region achieve sustainable livelihoods. Consequently, the following specific research objectives were carefully designed to:

i) assess the current adoption status of eco-innovations among wheat farmers;
ii) identify the key drivers and barriers influencing the adoption of eco-innovations practices;
iii) determine sustainability of wheat farm in the study area; assess willingness-to-pay (WTP) for crop insurance in the study area;
iv) evaluate the environmental and economic impacts of eco-innovations adoption on wheat farming sustainability and livelihoods' of the farmers; and,
v) provide insights for policymakers, extension services, and farmers to enhance the adoption of eco-friendly practices.

Research Methodology

One of Nigeria's 36 states, Jigawa State is situated in the northwest of the nation. The state is bordered to the west by Kano State, to the east by Bauchi State, to the northeast by Yobe State, and to the northwest by Katsina State. The state is approximately 23,154 square kilometres in total area on land. Jigawa State is primarily made up of plateaus and level plains, with a few isolated hilly places. The climate in Jigawa State is predominantly Sudan savanna, with a dry season from November to April and a rainy season from May to October. Temperatures can be high, especially during the dry season. There are, nevertheless, a few forest reserves and wooded regions. Jigawa State's principal rivers include its tributaries and the Hadejia River, which passes through the state's eastern region. Fishing, irrigation, and other agricultural endeavours depend on these rivers. Jigawa State is blessed with a wealth of natural resources, including mineral deposits (such as kaolin and gypsum), lush agricultural land, and water supplies for hydroelectric power generation and irrigation. Jigawa State's main industry is agriculture, which includes the cultivation of crops such millet, sorghum, rice, maize, and cowpea. Along with trade and small-scale industry, livestock farming is important.

Data from a farm survey were collected from 283 active wheat farmers who were chosen using a multi-stage sample procedure. Initially, since wheat production spans the state's agricultural strata, a saturated sampling frame of the stratified Jigawa State Agricultural and Rural Development Agency (JARDA) zones-Zone 1 (Birnin-Kudu), Zone II (Hadejia), Zone III (Gumel), and Zone IV (Kazaure)-was drawn. Second, each zone's primary producing Local Government Areas (LGAs) were deliberately chosen. The chosen LGAs in Zones I, II, III, and IV were, in that order, Hadejia, Kazaure, Ringim, and Jahun. Thirdly, three villages were chosen at random from each of the chosen LGAs, a total of twelve villages. Finally, the representative sample size for the study was determined using the Krejcie and Morgan formula (Equation 1), which was based on the sampling frame derived from the JARDA and Reconnaissance survey (Table 1). Thus, 283 heat growers that were currently in operation were chosen at random. A well-structured questionnaire and an interview schedule were used to extract farm survey data for the 2022 wheat crop season using an easy cost-route technique. The adoption index, confirmatory factor analysis (CFA) in conjunction with composite index, farm sustainability index, contingent valuation approach, and CFA (formative and reflective models) were utilised in decreasing order to accomplish the aims.

Table 1: Sampling frame of wheat farmers in the study area

Zones	LGAs	Villages	Population	Sample size
Birnin Kudu Zone (Zone I)	Jahun	Harbo Tsohuwa	134	16
		Harbo Sabuwa	149	18
		Jama'a	137	17
Gumel Zone (Zone II)	Ringim	Ringim Town	130	16
		Gabarin	143	18
		Dabi	198	24
Hadejia Zone (Zone III)	Hadejia	Sunamu	178	22
		Mai Alkama	258	31
		Hago	184	23
Kazaure Zone (Zone IV)	Kazaure	Farin Daba	321	39
		Gada	230	28
		Tudun Wayo	250	31
Total 4	4	12	2312	283

Source: Reconnaissance survey, 2021; Jigawa State Agricultural and Rural Development (JARDA), 2021

$$n_P = \frac{N(X)}{X+(N-1)} \quad \ldots\ldots (1)$$

$$X = \frac{Z^2 * P(1-P)}{e^2} \quad \ldots\ldots (2)$$

n = Sample size; N = Population size; e = Acceptable sampling error; X= Finite sample size; and, P = Proportion of the population

Model Specification

1. Adoption Index:

Using a numerical strength, the adoption index is given as follows (Table 2a):

$$ADPI = \frac{Adopted\ technology(s)}{Total\ available\ technologies} \quad \ldots\ldots (3)$$

Where, ADPI is Adoption index

2. Eco-innovation Attributes:

Following Alizadeh *et al*.(2022), the six attributes of eco-innovations statuses viz. awareness (AW), attitude (AT), knowledge (KN), information access (IN), willingness to creativity (WC), and risk orientation (RT) were assessed using composite index (Appendix A). Adapted from Sadiq *et al*.(2023), the following are the formulae used to achieve the composite index:

$$I_s = \frac{I_i - I_{min}}{I_{max} - I_{min}} \quad \ldots\ldots (4) \text{ (Minimization normalization index)}$$

$$I_s = \frac{I_{max} - I_i}{I_{max} - I_{min}} \quad \ldots\ldots (5) \text{ (Maximization normalization index)}$$

Where, I_s is the sub-indicator index, I_i is the value of the i^{th} sub-indicator; I_{min} is the minimum value of the i^{th} sub-indicator; and, I_{max} is the maximum value of the i^{th} sub-indicator.

$$I = \sum_{i=1}^{n=0} \left(\frac{w_{si} * I_{si} + \dots\dots\dots + w_{sn} I_{sn}}{w_{si} + \dots\dots\dots + w_{sn}} \right) \dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(6) (Composite index)}$$

Where, *I'* is the indicator/dimension index of i^{th} farmers and *w* is the weight of i^{th} sub-indicator index.

3. Farm Sustainability Assessment Index:

In measuring farm sustainability index, three dimensions of farm sustainability vis-à-vis economic (ES), social (SS) and environmental (ENS) sustainability indicators were aggregated (Nazir *et al*., 2017; Ranasinghe *et al*., 2021) (Appendix B). The economic, social and environmental sustainability were measured using economic efficiency index, social security index and environmental security index respectively. Given below is the model; succinctly, the composite index of the sustainability indicators were first subjected to normalization (minimum and maximum) (see equations 4 and 5 for the normalization formula). Presented below are the sub-sustainability and sustainability composite indexes.

$$S_s = \sum_{i=1}^{n=0} \left(\frac{w_{si} * S_{si} + \dots\dots\dots + w_{sn} S_{sn}}{w_{si} + \dots\dots\dots + w_{sn}} \right) \dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(8) (Composite index)}$$

Where, S_s is the sub-dimension (ESI/SSI/ENSI) index of i^{th} farmer(s) and *w* is the weight of i^{th} sub-dimension index.

$$S_i = \frac{ES + SS + ENS}{w_{ES} + w_{SS} + w_{ENS}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(9)}$$

Where, S_s is the farm sustainability index of i^{th} farmer(s).

Note: S= sustainable (>= 2.00); SS= somewhat sustainable (>=1.00); IN= intermediate (>=0.00); PU= possibly unsustainable (>= -1.00); PQU= possibly quite unsustainable (>= -2.00); PVU= possibly very unsustainable (< -2.00) (Adopted categorized names by Shamsudin *et al*., 1994; Sultana *et al*., 2021).

4. Contingent valuation method (CVM)

The contingent valuation method (CVM) is a survey-based economic technique used to estimate the economic value that individuals place on environmental goods, services, or non-market resources. It is particularly useful in situations where there is no observable market for the resource being valued, such as clean air, endangered species preservation, or the preservation of natural habitats.

$$WTP = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots\dots\dots + \beta_n X_n + \varepsilon \dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(10)}$$

Where, WTP = Willingness to pay (dependent variable); X = independent variable(s): AG = Age (years); GEN = Gender (male =1, otherwise =0); ED = Education (year(s)); HHS = Household size (number of person(s)); FEXP = Farming experience (year(s)); AGH = Agricultural holding (hectare); OPH = Operational holding (hectare); LAIN = Logarithm income (Naira); LS Livestock ownership (Tropical livestock unit (TLU)); EXT = Extension contact (yes =1, otherwise= 0); CR = Credit access (yes =1, otherwise= 0); COP = Co-operative membership (yes=1, otherwise= 0); IAW = Insurance awareness (yes =1, otherwise =0); IK = Insurance knowledge (yes =1, otherwise =0); and, CFI = Confidence in financial institutions designated as fund managers for crop insurance

Results and Discussion

Eco-innovations' Adoption Status

A perusal of the results showed that the majority (80.9%) of the farmers adopted the eco-innovations, possible as resilience and adaptation measures against weather-induced changes (Figure 1). However, only a handful of the farmers (4.6%) didn't adopt the eco-innovation, and this is likely to have happened among the laggard farmers owing to their reservations about the non-conventional or indigenous technologies. Nevertheless, few of the farmers moderately (11.7%) and less (2.8%) adopted the eco-innovation, and this might be largely attributed to capital paucity and poor knowledge on these technologies, especially the non-conventional eco-innovations.

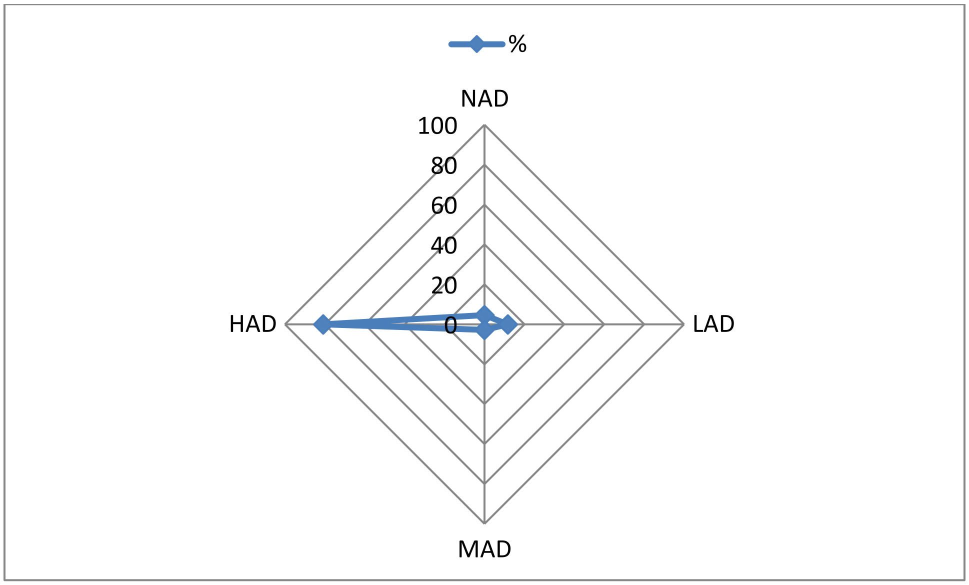

Figure 1: Adoption status of the farmers
Source: Field survey, 2022
Note: NAD = Non-adoption; LAD = Less adoption; MAD = Moderate adoption; HAD = High adoption

Furthermore, the individual-wise results vis-à-vis the eco-innovation indicators showed that the majority of the farmers had moderate awareness (AW) about the eco-innovations; likewise, moderate knowledge (KN), access to information sources (IN) and creativity willingness (WC) on eco-innovations (Figure 2). Besides, the attitude (AT) towards eco-innovation was established to be high among the majority of the farmers in the study area. However, the majority of the farmers had poor risk orientation (RT) on eco-innovation for sustainable wheat production.

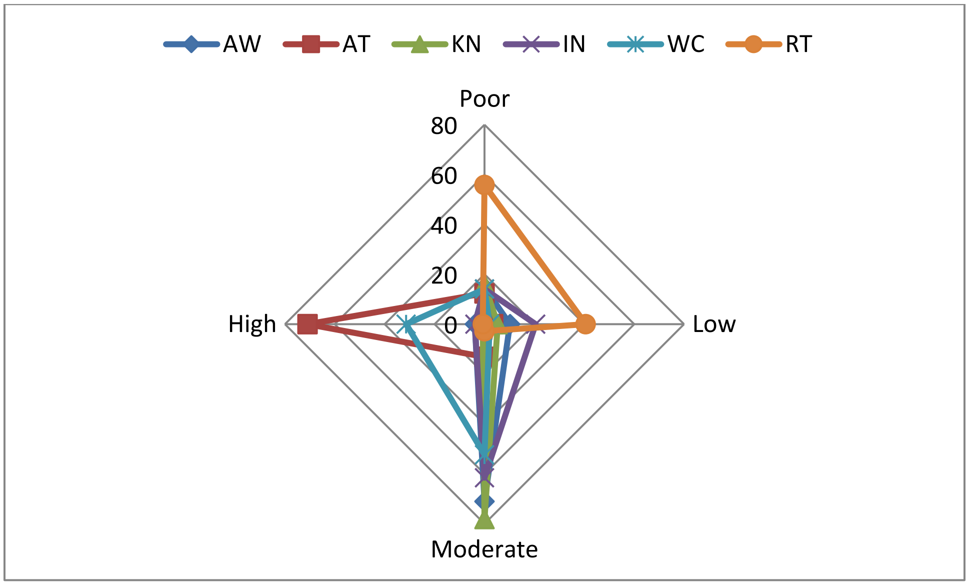

Figure 2: Individual-wise perceptions on eco-innovations' indicators
Source: Field survey, 2022

Nevertheless, average-wise, the farmers were moderately aware about eco-innovations; had moderate creativity willingness on the innovation; moderate knowledge on the innovation; and a moderate attitude towards adoption of the eco-innovation (Figure 3). However, the low access to information sources and risk orientation on eco-innovation might be attributed to the extension gap and poor cosmopolitan link of the farmers; likewise, risk aversion due to fear of capital loss, a limiting factor in a subsistence agrarian setting, is a portend/significant contributory factor. Consequently, it can be inferred that the duo of the foregoing indicators were the challenge to adequate adoption of eco-innovation for sustainable wheat farming in the study area.

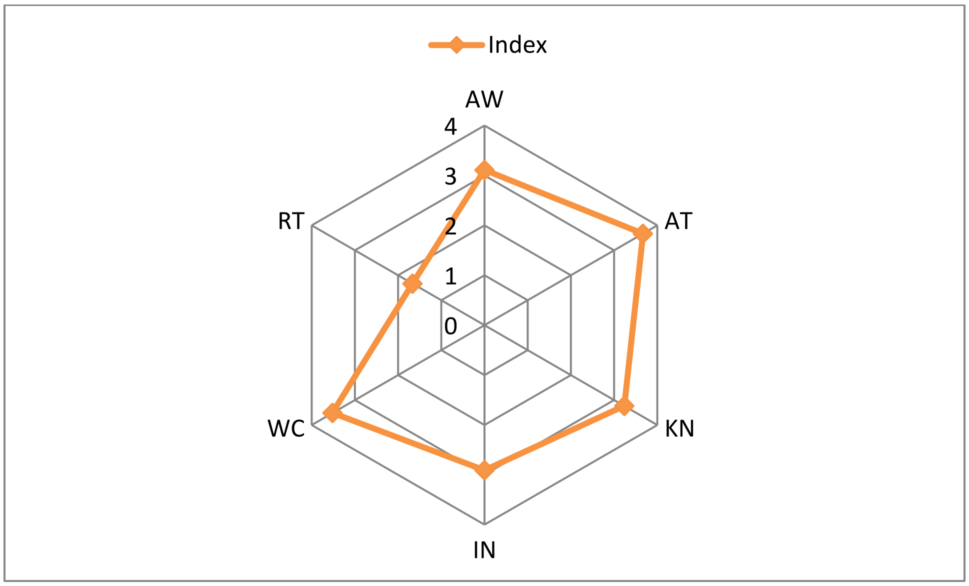

Figure 3: Average-wise perceptions on eco-innovations' indicators
Source: Field survey, 2022

Furthermore, the CFA results after satisfying the diagnostic validity of model fit showed all the indicators, except creativity willingness (WC), to have significantly influenced adoption of eco-innovation, as evident by their respective coefficients, which were within the acceptable error margin of 1% probability level (Table 2a). Empirically, the inelastic of awareness (AW), knowledge (KN), and risk orientation (RT) coefficients implied they are necessities for eco-innovation adoption. The elastic of attitude (AT) coefficient means it is a superfluity for eco-innovation adoption; while, the perfect inelastic of access to information sources (IN) coefficient implied it has a secondary effect on eco-innovation adoption (Table 2b and Figure 4). Thus, the implication is that the farmers had a keen interest in awareness, knowledge and risk orientation in the adoption of eco-innovations. However, the less interest in the sources of information might be attributed to the fact that most of these farmers fall into the early majority adoption category, characterized by a non-cosmopolitan nature and relying heavily on information from contact farmers/lead farmers. Consequently, the perfect inelastic and non-significant of the willingness creativity (WC) coefficient implied that most of these farmers had little or no intent of being creative in their adoption of these eco-innovations, i.e., modification of the technologies that proved to be stereotyped to the farming ecology of the study area. Generally, the positive significant of AW, KN, RT and AT coefficients means that farmers with adequate awareness, knowledge, risk orientation and positive attitude toward these eco-innovations are likely to adopt these technologies. However, farmers with little or no access to information sources on eco-innovations are less likely to adopt these technologies in the study area, as evident by the negative significant of 'IN' coefficient. Therefore, an increase in awareness, knowledge, risk orientation and favourable attitudes towards eco-innovations has the likelihood of increasing adoption of these innovations by 0.882, 0.619, 0.464 and 2.078% respectively (Table 2c). However, an increase in the information sources on these innovations has the likelihood of decreasing the adoption of eco-innovations by 2.326%.

Table 2a: Model fit summary

Category name	Index name	Obtained	Recommended
Absolute fit	CMIN	17833.23	-
	DF	1764	-
	P	0	p<=0.05
	RMSEA	0.18	< 0.08
	RMR	0.631	<0.02
	GFI	0.289	> 0.90
Incremental fit	AGFI	0.238	> 0.90
	NFI	0.486	> 0.90
	RFI	0.467	> 0.90
	TLI	0.493	> 0.90
	CFI	0.511	> 0.90
	IFI	0.512	> 0.90
	PGFI	0.269	> 0.90
	FMIN	63.238	> 0.90
Parsimonious fit	CMIN/DF	10.11	< 5.0

Source: Field survey, 2022

Table 2b: Effects of adoption's attributes on eco-innovation's adoption

Variable (⟵)		**Estimate (US)**	**S.E.**	**C.R.**	**P**	**Estimate (S)**	**R^2**
AW1	AW	1	-	-	-	0.973	0.947
AW2	AW	1.24	0.018	68.693	***	0.999	0.997
AW3	AW	1.257	0.025	50.634	***	0.974	0.949
AW4	AW	1.238	0.035	35.131	***	0.924	0.853
AW5	AW	0.504	0.08	6.315	***	0.354	0.125
AW6	AW	0.764	0.053	14.289	***	0.656	0.431
AW7	AW	0.735	0.033	22.017	***	0.81	0.656
AW8	AW	0.606	0.024	25.415	***	0.851	0.725
AW9	AW	0.011	0.06	0.184	0.854	0.011	0
AW10	AW	0.25	0.06	4.154	***	0.241	0.058
AT1	AT	1.992	0.077	26.028	***	0.983	0.967
AT2	AT	2.368	0.09	26.237	***	0.987	0.973
AT3	AT	1.838	0.077	23.838	***	0.948	0.898
AT4	AT	1.968	0.077	25.447	***	0.974	0.95
AT5	AT	1.891	0.111	17.048	***	0.795	0.632
AT6	AT	0.658	0.119	5.517	***	0.319	0.102
AT7	AT	0.872	0.097	8.997	***	0.496	0.246
AT8	AT	0.863	0.065	13.183	***	0.67	0.449
AT9	AT	0.788	0.05	15.87	***	0.76	0.578
AT10	AT	1	-	-	-	0.852	0.726
RT1	RT	1	-	-	-	0.95	0.903
RT2	RT	1.11	0.03	37.329	***	0.968	0.936

RT3	RT	0.723	0.054	13.466	***	0.647	0.418
RT4	RT	0.771	0.025	30.327	***	0.92	0.847
RT5	RT	0.408	0.071	5.718	***	0.329	0.108
RT6	RT	0.258	0.063	4.079	***	0.24	0.058
RT7	RT	-0.032	0.052	-0.621	0.535	-0.038	0.001
RT8	RT	0.025	0.049	0.512	0.609	0.031	0.001
RT9	RT	0.242	0.057	4.281	***	0.252	0.063
RT10	RT	0.079	0.048	1.65	0.099	0.099	0.01
KN1	KN	2.443	0.14	17.404	***	0.973	0.947
KN2	KN	2.849	0.16	17.83	***	0.994	0.989
KN3	KN	2.071	0.122	16.997	***	0.953	0.908
KN4	KN	2.155	0.128	16.811	***	0.944	0.891
KN5	KN	1.702	0.138	12.364	***	0.714	0.509
KN6	KN	1.287	0.12	10.742	***	0.625	0.391
KN7	KN	1.052	0.115	9.122	***	0.535	0.286
KN8	KN	1.015	0.08	12.684	***	0.731	0.534
KN9	KN	1.011	0.08	12.657	***	0.729	0.532
KN10	KN	1	-	-	-	0.732	0.535
WC1	WC	1	-	-	-	0.951	0.904
WC2	WC	1.198	0.027	44.927	***	0.985	0.97
WC3	WC	1.222	0.029	41.553	***	0.974	0.948
WC4	WC	1.015	0.035	28.645	***	0.9	0.811
WC5	WC	0.885	0.023	37.77	***	0.958	0.918
WC6	WC	0.927	0.023	39.45	***	0.966	0.932
WC7	WC	0.209	0.035	5.985	***	0.339	0.115
WC8	WC	0.358	0.033	10.733	***	0.549	0.302
WC9	WC	0.518	0.036	14.524	***	0.672	0.451
WC10	WC	0.563	0.037	15.016	***	0.685	0.469
IN1	INF	2.095	0.344	6.081	***	0.915	0.838
IN2	INF	2.494	0.409	6.098	***	0.932	0.868
IN3	INF	2.46	0.402	6.118	***	0.951	0.905
IN4	INF	2.777	0.452	6.137	***	0.973	0.947
IN5	INF	2.402	0.402	5.971	***	0.824	0.679
IN6	INF	2.251	0.379	5.938	***	0.801	0.642
IN7	INF	1.457	0.297	4.914	***	0.44	0.194
IN8	INF	1.044	0.234	4.453	***	0.362	0.131
IN9	INF	0.901	0.22	4.093	***	0.313	0.098
IN10	INF	1	-	-		0.348	0.121
ADPI	AW	0.882	0.091	9.705	***	0.375	0.595
ADPI	INF	-2.362	0.471	-5.009	***	-0.332	
ADPI	KN	0.619	0.176	3.516	***	0.138	
ADPI	WC	-0.28	0.09	-3.115	0.002	-0.12	

ADPI	AT	2.078	0.178	11.677	***	0.496
ADPI	RT	0.464	0.071	6.495	***	0.254

Source: Field survey, 2022

Note: ***, **, * & NS mean significant at 1, 5, 10% and non-significant respectively; US= Unstandardized; S= Standardized; SE= Standard error: CR= Critical ratio; P= Probability; R^2= Squared multiple correlation; → = relationship; and, INF/IN.

Table 2c: Total, direct and indirect effects of adoption's attributes on eco-innovation's adoption

Item	INF	WC	KN	RT	AT	AW
ADPI			Total effect (unstandardized)			
	-2.362	-0.28	0.619	0.464	2.078	0.882
			Standardized			
	-0.332	-0.12	0.138	0.254	0.496	0.375
			Direct effect (unstandardized)			
	-2.362	-0.28	0.619	0.464	2.078	0.882
			Standardized			
	-0.332	-0.12	0.138	0.254	0.496	0.375
			Indirect effect (unstandardized)			
	0	0	0	0	0	0
			Standardized			
	0	0	0	0	0	0

Source: Field survey, 2022

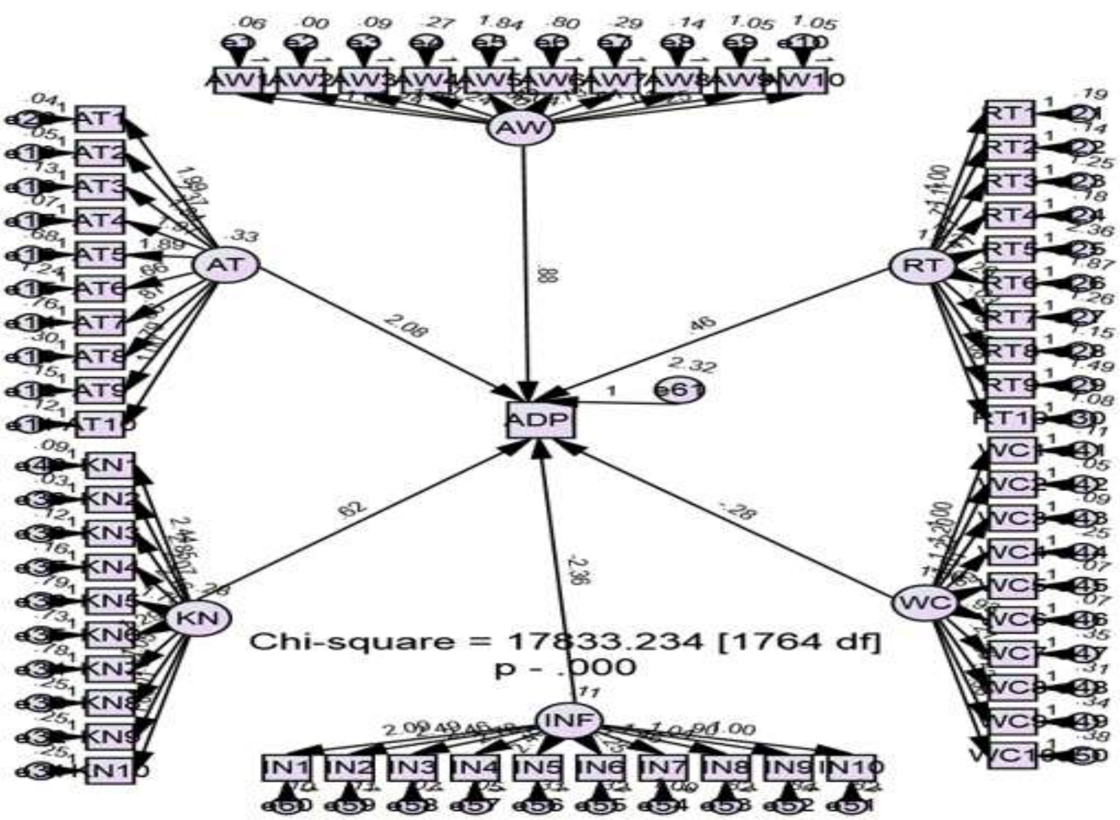

Figure 4: Structural modeling of the effect of eco-innovations indicators on eco-innovation's adoption

Sustainability Assessment of Wheat Farming

A perusal of sustainability index showed that majority (78.8%) of the farmers had their farms to be sustainable while an insignificant of the sampled population had their farms to be unstainable (Figure 5). Nevertheless, indicator-wise results showed that only 10.6, 46.3 and 83.4% of the farmers, respectively, had their farms to be economically, socially and environmentally sustainable. Thus, the heightened index of environmental sustainability is a possible reason for the robust farm sustainability achieved by the majority of the farmers in the study area. Consequently, the study calls on the few farmers whose wheat farms are unsustainable to enhance their economic and social sustainable farm practices. Therefore, it can be inferred that the farmers were conscious of the effects climate change on their farms, thus used climate change adaptive strategies. Though in a different enterprise, this finding is contrary to the findings of Ranasinghe *et al*.(2021) and Sultana *et al*.(2021), who in their various study areas found the majority of paddy rice farmers not to have sustainable farms, thus recommending the need to enlighten and inculcate good agricultural practices (GAP) to these farmers.

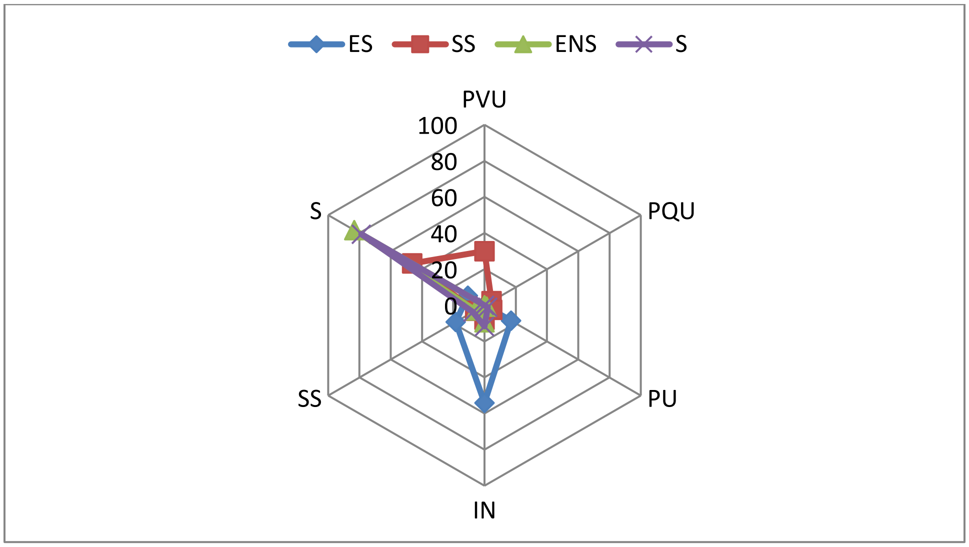

Figure 5a: Farm sustainability assessments of wheat farmers
Source: Field survey, 2022

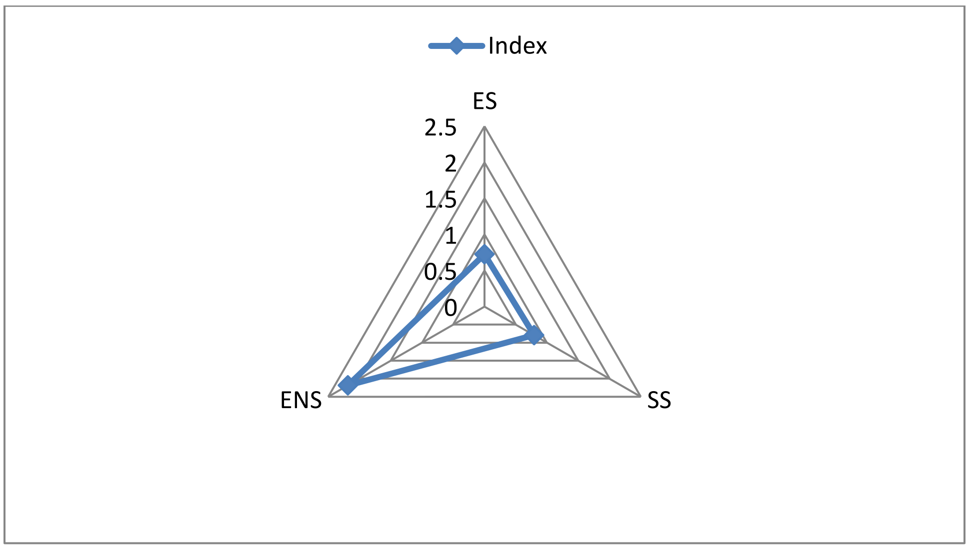

Figure 5b: Aggregate indicator level of farm sustainability
Source: Field survey, 2022

Willingness to Pay (WTP) for Crop Insurance

A cursory review of the WTP results showed that the majority (55.8%), though just marginally above the average of the sampled population, were willing to pay for crop insurance while barely close to the average (44.2%) of the sampled population were not willing to pay for crop insurance (Table 3). The possible reason for this slight marginal difference between the farmers willing to pay and not willing to pay be attributed to adequate awareness and knowledge about crop insurance coupled with capital paucity, which is a common phenomenon in a typical agrarian setting. However, government incentives on risk de-escalation adopted by the Nigerian incentive-based risk sharing system for agricultural lending (NIRSAL) cannot be overruled in influencing most of the farmers who keyed into the idea of crop insurance in the study area. Consequently, at an initial bid (IBID) of 5% of the annual income, though still the majority, the percentage of farmers willing to insure their crop plummeted by 8.78%, thus justifying the challenge of economic capital paucity among most of these farmers in the study area (Table 4). As a rider, there was a slight increase in the percentage of farmers who were not willing to pay for crop insurance at an initial bidding. Nevertheless, at the initial IBID, the minimum and maximum cum average premiums the farmers were willing to pay are ₦ 13750 ($39.29), ₦ 170000 ($485.71) and ₦ 39129.17 ($111.80) respectively.

Table 3: Willingness to pay and IBID of the farmers

Items	Frequency	Percent
	WTP	
No	125	44.2
Yes	158	55.8
Total	283	100.0
	IBID	
Total	283	100.0

Source: Field survey, 2022

Note: $1= ₦350 at the time of the study: 2022

Nexus between Eco-innovation's Adoption and Livelihood Status via WTP and Sustainability

The nexus between eco-innovation's adoption and livelihood status via WTP and sustainability was verified using CFA, and the diagnostic test results proved the model to be fit for the specified equation as evident by its test statistics that are within the recommended thresholds (Table 4a). Thus, the SEM is reliable for future prediction with accuracy, efficiency, certainty and consistency. Empirically, eco-innovation's adoption has significant twin influence on WTP and sustainability; likewise, it transcends a significant influence on livelihood status via sustainability as a mediating variable (Table 4b and Figure 6). However, the effect of eco-innovation becomes elusive on livelihood status through WTP and sustainability as mediating factors. Generally, sustainability has a significant effect on the livelihood status of farmers. The significant effect of eco-innovation's adoption on WTP and sustainability might be attributed to the need for climate change resilience among farmers, thus a catalyst for livelihood resilience. However, the negative sign and non-significant of the WTP coefficient might be attributed to risk aversion due to fear of capital loss, a limiting factor in a small operational holding, a common phenomenon among most of these farmers. Furthermore, the total effect of ADPI on WTP, SI and LV respectively, is 0.023, 0.077 and 0.267; the total effect of WTP on SI and LV is -0.017 and -0.060; whilst the total effect of SI on LV is 3.484 (Table 4c). Therefore, for a robust eco-innovation's adoption, a catalyst for livelihood's vulnerability resilience, the study calls for an effective utilization of the social capital pool, i.e., co-operative associations, as a complement in addressing capital paucity; likewise, a holistic implementation of the risk sharing system project of NIRSAL coupled with a wider scope of coverage in the study area.

Table 4a: Model fit summary

Category name	Index name	Obtained	Recommended
Absolute fit	CMIN	5012.68	-
	DF	299	-
	P	0.00	p<=0.05
	RMSEA	0.023	< 0.08
	RMR	0.020	<0.02
	GFI	0.954	> 0.90
Incremental fit	AGFI	0.941	> 0.90
	NFI	0.911	> 0.90
	RFI	0.942	> 0.90
	IFI	0.921	> 0.90
	TLI	0.950	> 0.90
	CFI	0.918	> 0.90
	PGFI	0.301	> 0.90
	FMIN	17.775	> 0.90
Parsimonious fit	CMIN/DF	4.765	< 5.0

Source: Field survey, 2022

Table 4b: Nexus between eco-innovation's adoption and livelihood status via WTP and farm sustainability

Variable (←)		**Estimate (US)**	**S.E.**	**C.R**	**P**	**Estimate (S)**	**R^2**
ADPI	AW	1.311	0.079	16.638	***	0.464	0.781
ADPI	AT	1.673	0.079	21.128	***	0.589	
ADPI	KN	0.341	0.08	4.236	***	0.118	
ADPI	INFO	-1.399	0.096	-14.543	***	-0.406	
ADPI	WC	-0.293	0.078	-3.759	***	-0.105	
ADPI	RISK	-0.488	0.081	-6.002	***	-0.167	
WTP	AG	0.004	0.001	3.367	***	0.111	0.692
WTP	GEN	0.021	0.035	0.587	0.557	0.019	
WTP	ED	0.001	0.003	0.306	0.76	0.01	
WTP	HHS	-0.003	0.003	-0.954	0.34	-0.032	
WTP	FEXP	-0.004	0.002	-1.694	0.09	-0.056	
WTP	AGH	-0.047	0.014	-3.419	***	-0.113	
WTP	OPH	0.084	0.019	4.322	***	0.143	
WTP	LAIN	0.02	0.037	0.556	0.578	0.018	
WTP	LS	-0.07	0.007	-10.429	***	-0.345	
WTP	EXT	0.17	0.035	4.823	***	0.159	
WTP	CR	-0.284	0.075	-3.761	***	-0.124	
WTP	COP	0.026	0.029	0.895	0.371	0.03	
WTP	IBID	0.536	0.026	20.221	***	0.668	
WTP	IAW	0.054	0.036	1.508	0.132	0.05	
WTP	IK	-0.018	0.037	-0.491	0.624	-0.016	
WTP	CFI	0.016	0.03	0.531	0.595	0.018	

WTP	ADPI	0.023	0.004	5.368	***	0.177	
SI	ADPI	0.077	0.003	22.972	***	0.814	0.657
SI	WTP	-0.017	0.026	-0.658	0.51	-0.023	
LV	SI	3.484	0.103	33.825	***	0.896	0.802

Source: Field survey, 2022

Note: INFO/IN, Risk/RT, LV = livelihood status, SI = farm sustainability index; for the other acronyms, check the appendix table

Table 4c: Total, direct and indirect effects of eco-innovation's on livelihood status via WTP and SI

Variable	ADPI	WTP	SI
	Total effect (unstandardized)		
WTP	0.023	0	0
SI	0.077	-0.017	0
LV	0.267	-0.06	3.484
	Standardized		
	0	0	0
WTP	0.177	0	0
SI	0.81	-0.023	0
LV	0.726	-0.021	0.896
	Direct effect (unstandardized)		
	0	0	0
WTP	0.023	0	0
SI	0.077	-0.017	0
LV	0	0	3.484
	Standardized		
	0	0	0
WTP	0.177	0	0
SI	0.814	-0.023	0
LV	0	0	0.896
	Indirect effect (unstandardized)		
	0	0	0
WTP	0	0	0
SI	0	0	0
LV	0.267	-0.06	0
	Standardized		
	0	0	0
WTP	0	0	0
SI	-0.004	0	0
LV	0.726	-0.021	0

Source: Field survey, 2022

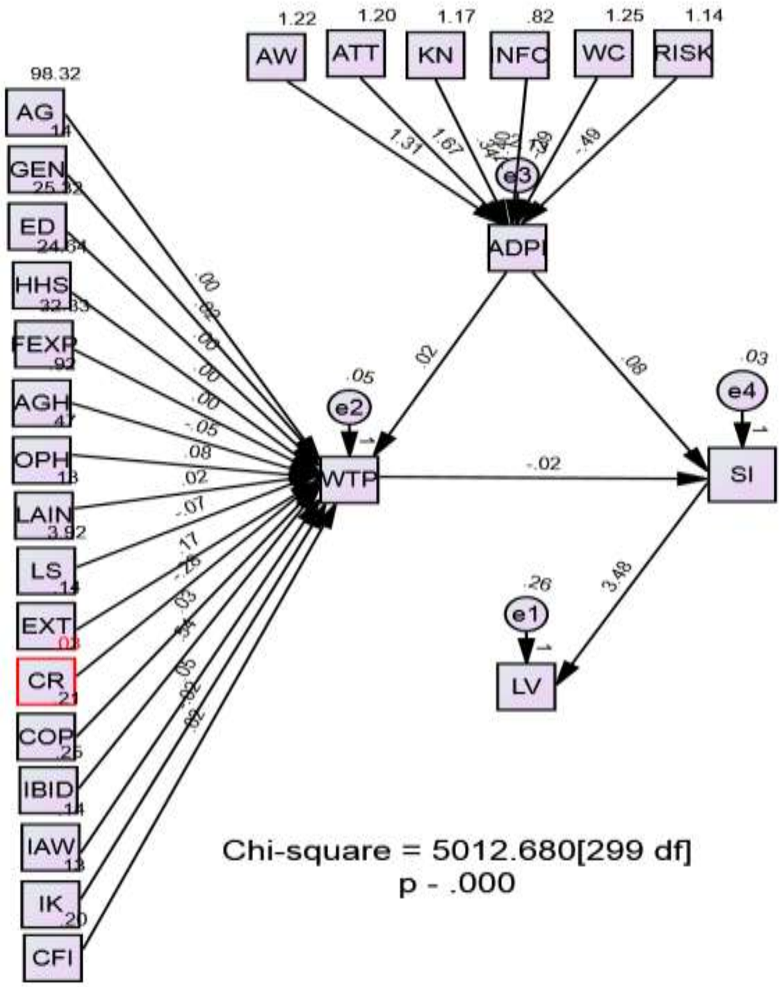

Figure 7: Structural modeling of nexus between eco-innovation's adoption and livelihood status via WTP and farm sustainability

Conclusion and Recommendations

Empirically, there is high adoption of eco-innovation in the study area which owed to livelihood accumulation status of majority of the farmers. However, adoption of eco-innovation is hindered by an extension gap owing to low access to information and poor risk orientation. Consequently, this extension gap marred the intention of almost all of the average sampled farmers, who were not willing to key into the idea of crop insurance, a precursor against risk and uncertainty that are largely driven by weather-induced vagaries, a threat to farm families' livelihood status. Nevertheless, it was just marginally above the average sampled population, though the majority accepted the idea of crop insurance, and this was due to skeletal reach of the risk sharing system of the NIRSAL programme in the study area. Furthermore, the majority of the farmers had their farms to be sustainable, which underscores the importance of adopting eco-innovation as a climate change resilience measure, thus enabling the majority of the farmers to achieve the accumulated livelihood strategy in the study area. Generally, adoption of eco-innovation has a strong endogenous effect on livelihood status en-route sustainability but a weak endogenous effect on livelihood status en-route WTP. Therefore, the study recommends the need for enhancement of extension services as a measure to address the extension gap that marred effective feed forward-backward flows of information sources and risk orientation on the technologies. Besides, good advisory services will enable the farmers to adapt the eco-innovations, especially non-conventional ones, in a manner that suits their farms' ecological settings, thus enhancing the farmers' climate change resilience, farms' sustainability, and a guarantee of prosperous, sustainable livelihood status.

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