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Advancing Sustainable Development Goals through Nature-based Solutions in Nigeria

Onyinye Ifeoma Ochuba, P*h*.D.

Department of Economics,
University of Africa, Toru-orua, Bayelsa State, Nigeria.
Email: daluochuba@gmail.com; Phone: 08034171766

ABSTRACT
This study explores the contribution of Nature-based Solutions (NbS) to achieving Sustainable Development Goals (SDGs), with a particular focus on SDG 2 (Zero Hunger) in Nigeria. Drawing on data from 297 rural households collected through a structured questionnaire, the analysis utilizes the Endogenous Switching Regression (ESR) model to examine the effects of NbS adoption on household food security. The findings indicate that although adopting NbS alone did not yield an immediate or statistically significant improvement in food security, longer-term use had a strong and significant positive effect, especially among households that had adopted NbS. Key socioeconomic factors, including education, income, farm size, and the use of climate-resilient crop varieties also had a significant impact on food security, particularly among non-adopters. The study further reveals that adoption decisions were not significantly influenced by observable climate-related variables, pointing to potential unmeasured constraints such as limited institutional support or lack of information. Based on these insights, the study recommends sustained policy interventions, enhanced farmer education, and targeted support mechanisms to encourage long-term NbS adoption. Addressing these structural barriers is essential for maximizing the potential of NbS in promoting sustainable agriculture, enhancing food security, and building climate resilience in Nigeria.
Keywords: Sustainable Development Goals, Nature-based Solution, climate change, food security.

1. INTRODUCTION

The Sustainable Development Goals (SDGs) are globally accepted indicators for ensuring the continuity of humanity and all its supporting systems. This entails that nature is at the heart of the SDGs. Economies rely on nature's ability to perform its sink and flow services. As important as this realization is, nature has continuously been altered, making it almost impossible for it to effectively perform these functions. Johnson, et al., (2021) found that humans' activities have altered 75% of the Earth's uniced land surface.

This signals a significant threat to the well-being and continuous sustainability of economies and their operators. The same study found that if economic operators fail to synchronize economic activities with nature, there will be a collapse of some ecosystem functions, such as the provision of food from marine fisheries, timber from native forests, and wind pollination, among others, by 2030. This collapse, if unaverted, will cost 2.3% of global GDP. More alarming is the fact that poorer countries will be worse off as a result of the collapse. Johnson et al. (2021) pointed out that countries in Sub-Saharan Africa and South Asia will get the worst blow with estimated GDP losses of -9.5% and -6.5%, respectively.

Global response to these threats, among other considerations, birthed the SDGs. Interestingly, Fisher, (2019) found that nature is capable of advancing multiple SDGs. The study found that forest cover reduces the prevalence of 3 childhood deadly conditions: Anaemia, Diarrhoea, and Stunting among children of the poorest households in 35 countries. It also confirmed a link between fisheries decline and deficiencies in nutrients and deforestation with malaria.

In the face of these findings, actualizing the tenets of the SDGs remain evasive for most countries of the world, especially middle and low-income countries. Global achievement indicators have placed so many countries, especially low-income countries, at the rear. For instance, a study of Nigeria's progress with the achievement of SDGs, (Emah, 2023) found that Nigeria moved from its initial position of 160 out of 166 countries in 2020 to 146 in 2023. As significant as this progress seems, Nigeria is still very far from achieving the targets of the SDGs. This flows from poor funding of SDG projects to persistent harmful environmental practices ranging from gas flaring, urban build-up, excessive timber logging, and deforestation, among others. These direct attacks on nature can only be addressed by nature-centered remedies. This informs the urgent need for a nature-based economic development model. This model is captured in the Nature-based Solution (NbS) to economic-biospheric interactions. NbS refers to actions that are aimed at addressing societal challenges by working in harmony with nature (Asamoah, et al., 2025).

Scholars have invested in the study of nature-based solutions in conjunction with various variables and at different times and locations. Pereira, et al., (2023) and Carvalho, et al., (2022) in their studies of NbS in Europe and some parts of Asia found a promising outlook, emphasising scalability to maximize benefits. In Africa, Nyika and Dinka, (2022) and Acreman, et al., (2021) found that Africa's quest to embrace nature-based solutions is confronted with the challenges of land tenure systems, inadequate resources to foster implementation, and poor planning. Studying nature-based solutions for urbanization and environmental build-ups, Boateng, et al.,(2023) and Holden, et al., (2022) found that NbS provides services that enhance the overall well-being of urban dwellers while enabling natural resilience to climate change impacts. Interrogating the possibility of using NbS to achieve SDGs, Fisher, (2019) confirmed that NbS holds the potential of achieving certain components of the SDGs at very impressive magnitudes. Narrowing down on NbS and food security, Acevedo-ortiz, et al., (2024); Nguyen, et al., (2024) and Kalmpourtzidou, et al., (2023) found that due to increased urban land use, practices such as green roof, urban gardening, etc, have proven an efficient way of enhancing the supply of vegetables and fruits, which improves overall food security. In Nigeria, scholars have repeatedly indicted the state for its failure to implement effective climate change actions, which will encompass NbS despite rectifying a lot of protocols to that effect. This was the unanimous finding of Hia and Achinge, (2023) and Ayuba and Oruonye, (2022).

A careful look at the studies above reveals that there is a lacuna in the subject matter of using NbS to achieve specific SDG goals in Nigeria. Deliberate studies aimed at establishing the clarity of employing NbS as a tool for achieving zero hunger (SDG 2) in Nigeria has not been extensively dealt with. This is the gap that this study intends to fill. To actualize this, the study aims to examine the possibility of using NbS as one of the tools for achieving SDGs goals 2 – zero hunger; through enhanced food security in Nigeria. Consequently, this study aims to; assess the impact of Nature-based Solutions on achieving food security and reducing hunger (SDG 2) in Nigeria.

This study is will provide a sound policy direction by narrowing down on the effectiveness or otherwise of NbS in addressing food security in Nigeria. This is especially important as Nigeria is still at infancy in terms of technological advancement, so subsistent farming with crude implements/inputs remains the reality of Nigeria. A tailored study on NbS and zero hunger will be very directional towards the attainment of SDG 2 in Nigeria.

2. Literature Review

2.1. Conceptual Literature

2.1.1. Nature-based Solutions

Nature-based Solutions are sets of tools at the disposal of the population that use nature to mitigate or, where possible, eradicate the damaging effects of global warming and climate change. It is that advancement which encompasses developmental synergy among economic variables and biospheric elements (Asamoah, et al., 2025). Simply put, it is a model that involves a simultaneous development of the physical, economic, and natural environments. Inter-American Development Bank (2019) described NbS as a cost-effective way to build infrastructure resilience in response to a changing climate, while also delivering a range of other societal benefits. Examples of NbS are: Agroforestry, Mulching, Green roofs, coastal wetlands, mangroves, salt marshes, gardening with climate resilient crop varieties, etc. These hold the advantage of lowering carbon footprint, improved management of natural capital, maintenance of greenhouse gas sink, higher plant and animal diversity, low cost of investment and maintenance of infrastructure, and enhanced resistance to external shocks to ensure the continued availability of food (Johnson, et al., 2021).

2.1.2. SDG Goal 2; Zero Hunger

SDGs are sets of globally agreed-upon indicators for measuring various countries' positions in terms of variables that have global consequences. The SDG has a total of 17 goals; the second of which is zreo hunger. This goal aims to end hunger and ensure the attainment of food security and sustainable agriculture by the year 2030 (Fisher, 2019). To achieve the set goal, there must be adequate and sustained investment in agriculture which will culminate in ending hunger and malnutrition. This will be evidenced by improved nutrition, reduction in the number of stunted children under 5 years of age and affordable food prices globally. Adequate attention is required in the areas of adressing economic and gender inequality, commual, regional and international conflicts, land tenure systems and climate change realities among others will ensure the achievement of food security (IPCC, 2023). Food security is said to exist when people at all times have access to adequate and quality food that matches their food preferences without compromising their social and cultural beliefs (WFP, 2025). Mashanye, (2025) found that there is a direct realtionship between food security and nature, because all the classes of food have their origin in nature.

2.2. Empirical Literature: NbS and Food Security

The quest for economic advancement and structural development exerts considerable pressure on nature's ability to sustain living organisms. This pressure on nature's capacity, nevertheless, can be addressed using adequate investment in the ecosystem (Wagner, et al., 2023). Munang, et al., (2013), confirmed that sustainable investment in ecosystem-based adaptation will not only enhance food production, which is the key to achieving food security, but will also increase agricultural productivity, increase farmers' profit, and make food affordable to the poor. Achieving affordable food for the poor and indeed humanity will increase the demand placed on planetary resources. To counter this, Beltran-Pena, et al., (2020) ; Mashanye, (2025) suggested the intensification of sustainable agriculture to ensure adequate food supported by a healthy ecosystem. Onaolapo et al. (2015); Akinola, et al., (2020); Shweta, et al., (2023); Kidane & Makonnen, (2024) are unanimously of the view that traditional agricultural system and growing indigenous food hold the ability to foster agricultural productivity. Boosting agricultural production without damaging the ecosystem requires careful alignment of production processes and procedures that are ecosystem-friendly (Asamoah, et al., 2025; Carvalho, et al., 2022; Acevedo-ortiz, et al., 2024). This system is captured by nature-based solutions to food security Asamoah, et al., (2025) and IDB. , (2019). When food security is adequately taken care of using this strategy, SDG 2 would have been achieved Fisher, et al., (2019); Johnson, et al., (2021) ; (Telwala, 2023). The empirical review above culminates in study's Objective : assessing the impact of NbS on achieving food security and reducing hunger in Nigeria.

An in-depth analysis of the literature reviewed above reveals a dearth of NbS literature for Nigeria and a quantitative analysis of NbS and climate change. This is the vacuum that this study intends to fill with the second objective of evaluating the effectiveness of Nature-based Solutions in enhancing climate resilience and mitigating climate change impacts in Nigeria.

3 METHODOLOGY

3.1 Research Design

The study adopted a cross-sectional survey design, gathering primary data from rural farming households through a structured questionnaire. This design was well-suited for obtaining a snapshot of respondents' experiences with Nature-Based Solutions (NbS), as well as their levels of food security and climate resilience at a single point in time. It allowed for the examination of associations between key variables such as NbS adoption, household socioeconomic conditions, and food security status using advanced econometric tools like the Endogenous Switching Regression (ESR) model. Overall, the cross-sectional design served as a solid framework for evaluating the impact and relevance of NbS in advancing Nigeria's progress toward the Sustainable Development Goals (SDGs).

3.2 Population of the Study

The study focused on rural farming households in Bayelsa state, Nigeria as its target population, particularly those actively involved in agricultural activities and at risk of experiencing climate-related shocks like floods and droughts. These households were chosen due to their vulnerability to climate impacts and their critical role in achieving food security and sustainable development. The research aimed to assess how the adoption of Nature-Based Solutions (NbS) influences their food security outcomes. By examining this group, the study sought to produce evidence-based insights to inform policies that enhance rural livelihoods and support progress toward Sustainable Development Goal (SDG) 2, Zero Hunger.

3.3 Sample Size Determination and Sampling Techniques

The sample size for the research was chosen to ensure both statistical reliability and adequate representation of rural farming households. A total of 297 respondents were selected, offering a robust dataset for the econometric models applied in the analysis. The study employed a multistage sampling technique: initially, rural areas that are particularly vulnerable to climate-related events were purposively selected; then, within these areas, farming households were randomly sampled. This approach helped to reflect the range of climate experiences and the varying levels of Nature-based Solutions (NbS) adoption among respondents, while also reducing selection bias and improving the general applicability of the study's conclusions.

3.4 Method of Data Analysis

Objective One is examined using the Endogenous Switching Regression (ESR) model. This model is appropriate because, in survey-based studies, adoption of Nature-based Solutions (NbS) is not random; some respondents adopt NbS while others do not, and this decision is often influenced by factors such as education level or household wealth. The ESR model helps account for this non-random selection by estimating outcomes separately for adopters and non-adopters. Similar to Instrumental Variable (IV) models, ESR corrects for potential selection bias introduced by the adoption decision. This makes it possible to make fair comparisons between the two groups by controlling for their underlying differences. The key variables in the analysis include: food security as the outcome variable (measured by a household food security index), NbS adoption as a binary treatment variable (1 = adopter, 0 = non-adopter), and sets of explanatory variables for both the outcome and the adoption equations.

The ESR model comprises two regimes: one for NbS adopters and another for non-adopters, alongside a selection equation that models the adoption decision. Consider the following functional form:

$$FS_i = f(D_i, X_i, Z_i) \qquad 1$$

Where FS_i is household food security index for household i, D_i is a Dummy variable indicating NbS adoption (1 = adopter, 0 = non-adopter), X_i is vector of explanatory variables influencing food security, and Z_i is a vector of explanatory variables influencing the adoption decision (including instruments not in X_i). The selection equation (NbS Adoption Decision) is:

$$D_i^* = Z_i\alpha + v_i \qquad 2$$

$$D_i = \begin{cases} 1 \; if \; D_i^* > 0 \; (adopter) \\ 0 \; otherwise \; (non-adopter) \end{cases}$$

Where D_i^* is a latent variable representing the propensity to adopt NbS, and α is a vector of parameters, while $v_i \sim N(0,1)$. The outcome equations (food security index) is:

Regime 1: For NbS Adopters $(D_i = 1)$

$$FS_{1i} = X_{1i}\varphi_1 + \varepsilon_{1i} \qquad 3$$

Regime 0: For non-adopters $(D_i = 0)$

$$FS_{0i} = X_{0i}\varphi_0 + \varepsilon_{0i} \qquad 4$$

Where FS_{1i} and FS_{0i} are respectively food security outcomes for adopters and non-adopters. φ_1 and φ_0 are vectors of coefficients, while the error terms (ε_{1i} and ε_{0i}) are assumed to follow a trivariate normal distribution with zero mean and non-zero covariances, that is;

$Cov(\varepsilon_{1i}v_i) = \sigma_{1v}, Cov(\varepsilon_{0i}v_i) = \sigma_{0v}$

Estimation of the Endogenous Switching Regression (ESR) model is carried out using the Full Information Maximum Likelihood (FIML) technique, which jointly estimates both the selection and outcome equations, thereby correcting for selection bias. This approach allows the ESR model to produce reliable estimates of the Average Treatment Effect on the Treated (ATT) and the Average Treatment Effect on the Untreated (ATU).

3.5 Construction of the Food Security Index

The Food Security Index was constructed using the Principal Component Analysis (PCA) technique. The process involved several steps. First, the food security indicators obtained from the questionnaire such as worrying about not having enough food, skipping meals due to food shortage, running out of food before having money to buy more, eating less than needed because of insufficient food, and going an entire day and night without eating were standardized using z-scores to ensure all variables were measured on a common scale. Next, PCA was applied to the standardized variables to extract the eigenvalues (which indicate the amount of variance explained by each component) and the component loadings (which represent the weights of each variable). The Food Security Index was then computed using the first principal component, as it captured the most variation in the data, with higher scores reflecting better food security. Then, the index was normalized to a 0 – 1 scale to enhance interpretability, where 0.00 – 0.24 indicates severely food insecure, 0.25 – 0.49 indicates moderately food insecure, 0.50 – 0.74 indicates mildly food insecure, and 0.75 – 1.00 indicates food secure.

4 RESULTS

4.2 Demographic Characteristics

The demographic characteristics of the respondents are reported on Table 1.

Table 1: Descriptive profiles of the respondents

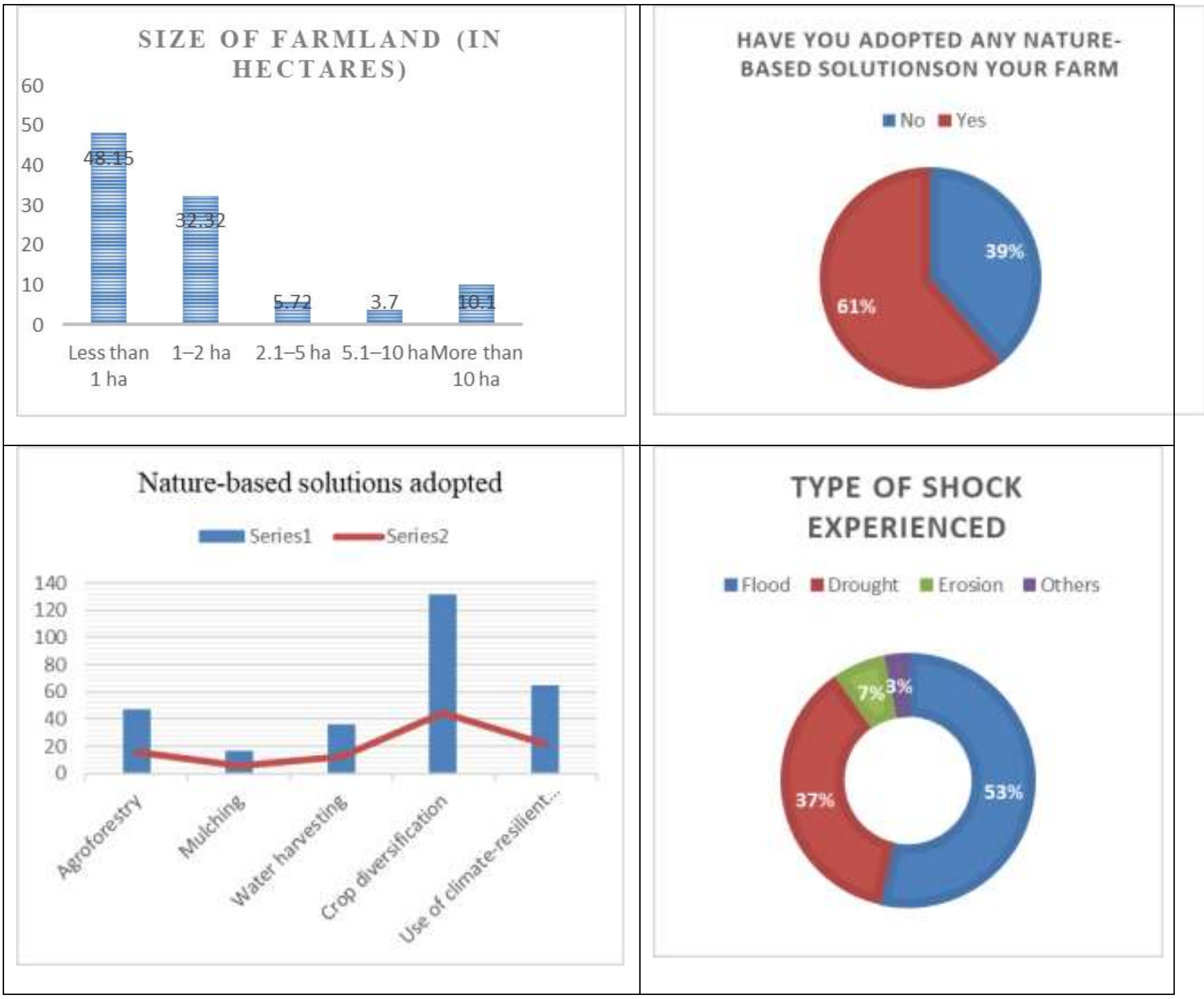
	Frequency	%
Gender of the Respondent		
Male	181	60.94
Female	116	39.06
Total	**297**	**100.00**
Age of the Respondent		
Below 30 years	11	3.70
30 – 34 years	17	5.72
35 – 39 years	102	34.34
40 – 44 years	138	46.46
45 years and above	29	9.76
Total	**297**	**100.00**
Educational Attainment		
No formal education	4	1.35
Primary	77	25.93
Secondary	106	35.69
Tertiary	110	37.04
Total	**297**	**100**
Household Size		
Below 5 persons	134	45.12
5 – 9 persons	128	43.10
10 – 14 persons	25	8.42
15 persons and above	10	3.37
Total	**297**	**100**

Source: Researchers' computation.

The demographic characteristics of the respondents offer valuable insights into the nature of rural households surveyed in the study. Regarding gender, a larger proportion of the respondents were male, making up 60.94% (181 individuals), while females comprised 39.06% (116 individuals). This male dominance in the sample may reflect prevailing gender norms in rural agricultural settings, where men typically assume leadership roles in farming and household decision-making.

In terms of age distribution, the majority of respondents fell within the middle-aged category. The largest proportion, 46.46% (138 individuals), were between 40 and 44 years old, followed by 34.34% (102 individuals) in the 35 to 39 age range. A small percentage, 3.7%, were below 30 years, while 9.76% were 45 years or older. This pattern suggests that most respondents are in their prime working years, which may positively influence the availability of labor and the willingness or ability to adopt innovative agricultural practices like Nature-based Solutions.
Regarding educational attainment, most respondents had received some level of formal education. Specifically, 37.04% (110 individuals) attained tertiary education, 35.69% (106) completed secondary school, and 25.93% (77) had primary education. Only a small fraction, 1.35% (4 individuals), reported having no formal education. This generally high level of education among the participants is a positive indicator, as it may enhance their capacity to understand and adopt innovative agricultural practices and sustainable technologies.
Household sizes among respondents showed some variation. About 45.12% (134 households) had fewer than five members, and 43.10% (128 households) reported having between five and nine members. Larger households, with 10 to 14 members, made up 8.42% (25 households), while only a small portion 3.37% (10 households) had 15 or more members. This pattern indicates that the majority of households are of moderate size, which may have implications for household labor availability, food consumption demands, and overall food security outcomes.
Other characteristics were examined and the result is presented on Figure 1

Figure 1: Other characteristics



Source: Plotted by the author

The results indicated that the majority of respondents were small-scale farmers, with 48.15% cultivating less than 1 hectare and an additional 32.32% farming on 1–2 hectares. In total, over 80% of the households operated on 2 hectares or less, highlighting the prevalence of subsistence farming. Conversely, only 10.1% of respondents had access to more than 10 hectares of land, pointing to a limited presence of large-scale farming. This pattern of land distribution reflected the constrained production capacity of most farmers and underscored the need for policies and support programs such as Nature-based Solutions that were tailored to the specific conditions and challenges of smallholder agriculture.

The results showed that 61.28% of respondents (182 individuals) had adopted Nature-based Solutions (NbS) on their farms, while 38.72% (115 individuals) had not. This demonstrated a relatively high level of adoption and increasing awareness of sustainable agricultural practices among farmers. However, the significant proportion of non-adopters suggested that barriers such as limited access to information, insufficient resources, or weak institutional support may have continued to impede broader uptake. Overcoming these challenges through targeted outreach, education, and support programs could have further promoted the implementation of NbS.

The findings revealed that among farmers who had adopted Nature-based Solutions (NbS), crop diversification was the most widely practiced, reported by 44.44% (132 respondents). This was followed by the use of climate-resilient crop varieties at 21.89%, and agroforestry at 15.82%. Water harvesting was adopted by 12.12%, while mulching had the lowest adoption rate at 5.72%. These results suggested that farmers tended to favor NbS practices with a more immediate and noticeable impact on productivity and climate resilience. On the other hand, the relatively lower uptake of practices like mulching and water harvesting might have been due to barriers such as limited knowledge, higher labor requirements, or lack of necessary resources.

The data showed that floods were the most frequently reported climate-related shock, experienced by 53.54% (159) of the respondents, followed by drought, which affected 36.70% (109 individuals). Erosion was reported by a smaller proportion (6.73%), while other types of shocks accounted for just 3.03%. These findings indicated that flooding and drought were the dominant climate threats faced by farmers in the study area, underscoring the critical need for adaptive measures such as Nature-based Solutions to reduce their impacts and strengthen resilience.

4.3 Impact of Nature-based Solutions on Achieving Food Security and Reducing Hunger

Table 2 presents the results of the impact of nature-based solutions on achieving food security and reducing hunger.

Table 2: Endogenous Switching Regression estimates of the impact of Nature-based Solutions on achieving food security and reducing hunger

Variable	Coefficient	Standard error	z-value	P-value
Foodsec_Index0 (Non-adopters of Nature-based Solutions)				
Nature-based Solutions	-0.0068	0.0105	-0.65	0.514
How long NbS is practiced	0.1063	0.0233	4.57	0.000
Age	0.0277	0.0126	2.20	0.028
Education	0.0338	0.0169	2.00	0.045
household size	0.0760	0.0212	3.58	0.000
Income	0.0351	0.0141	2.49	0.013
Farm Size	0.0517	0.0139	3.70	0.000
Crop Diversity	-0.0086	0.0144	-0.60	0.548
Resilient Crops	0.0585	0.0279	2.10	0.036
Climate Shocks	0.0017	0.0237	0.07	0.944
Constant	-0.2131	0.2083	-1.02	0.306
Foodsec_Index1 (Adopters of Nature-based Solutions)				
Nature-based Solutions	0.0064	0.0098	0.65	0.515
How long NbS is practiced	0.1400	0.0226	6.18	0.000
Age	-0.0041	0.0096	-0.43	0.666
Education	0.0109	0.0153	0.72	0.474
Household Size	0.0305	0.0198	1.54	0.124

Income	0.0172	0.0111	1.55	0.122
Farm Size	0.0274	0.0125	2.19	0.029
Crop Diversity	0.0066	0.0131	0.51	0.612
Resilient Crops	0.0377	0.0248	1.52	0.129
Climate Shocks	-0.0038	0.0191	-0.20	0.840
Constant	0.0284	0.0832	0.34	0.733
Selection Equation				
Access to early warning systems	-0.0869	0.3090	-0.28	0.778
Experience major climate shock	-0.2708	0.2010	-1.35	0.178
Perceived effectiveness of NbS	-0.0264	0.1335	-0.20	0.843
Constant	0.5264	0.3388	1.55	0.120
/lns0	-1.9127	0.2009	-9.52	0.000
/lns1	-1.6129	0.1343	-12.01	0.000
/r0	0.2069	1.3919	0.15	0.882
sigma0	0.1477	0.0296		
sigma1	0.1992	0.0268		
rho0	0.2041	1.3339		
rho1	-0.7593	.1704		
Wald chi2(10)	173.58 (p = 0.0000)			
LR test of indep. eqns. :	1.32 (p = 0.5181)			

Source: Computed by the author

The effect of Nature-based Solutions (NbS) adoption on household food security was statistically insignificant for both non-adopters (Coef = -0.0068, p = 0.514) and adopters (Coef = 0.0064, p = 0.515). This implies that the adoption status alone did not have a significant impact on food security outcomes. In other words, simply adopting NbS is not enough to produce measurable improvements in household food security, highlighting that the intensity or duration of adoption likely plays a more critical role in generating meaningful effects.

The duration of Nature-based Solutions (NbS) use had a positive and statistically significant effect on food security for both non-adopters and adopters. For non-adopters (Coef = 0.1063, $p < 0.001$), the significant effect indicated spillover benefits at the community level, where prolonged implementation of NbS improves food security even for households that had not adopted them directly. Among adopters (Coef = 0.1400, $p < 0.001$), the effect was even more pronounced, suggesting that longer-term engagement with NbS significantly enhances food security, likely through cumulative improvements in agricultural productivity, soil health, and resilience to climate shocks.

Age had a positive and statistically significant effect on food security among non-adopters (Coef = 0.0277, p = 0.028), indicating that older household heads are more likely to experience better food security possibly due to greater agricultural experience or risk management skills. In contrast, the effect of age on food security among adopters was negative and statistically insignificant (Coef = -0.0041, p = 0.666), suggesting that age did not have a significant influence on food security outcomes for households already implementing Nature-based Solutions.

Education had a positive and statistically significant effect on food security among non-adopters (Coef = 0.0338, p = 0.045), suggesting that individuals with higher educational attainment were more likely to make informed decisions regarding farming practices and food consumption. Among adopters, however, the effect of education was positive but statistically insignificant (Coef = 0.0109, p = 0.474), indicating that education did not have a meaningful influence on food security in this group—possibly due to similar education levels among adopters or reduced marginal effects of education once Nature-Based Solutions were already in use.

Household size had a positive and highly significant effect on food security among non-adopters (Coef = 0.0760, $p < 0.001$), suggesting that larger households likely contributed more labor to agricultural activities, thereby improving food access. For adopters, the effect of household size was also positive but statistically insignificant (Coef = 0.0305, p = 0.124), implying that household size played a less critical role in food security outcomes when Nature-based Solutions were already in place.

Income had a positive and statistically significant effect on food security among non-adopters (Coef = 0.0351, p = 0.013), emphasizing the crucial role of financial resources in securing adequate food.

Among adopters, the effect of income remained positive but was statistically insignificant (Coef = 0.0172, $p = 0.122$), suggesting that after adopting Nature-based Solutions, the marginal effect of income on food security may have diminished.

Farm size had a positive and statistically significant effect on food security in both groups. Among non-adopters (Coef = 0.0517, $p < 0.001$), larger landholdings significantly enhanced food access and production. Likewise, among adopters (Coef = 0.0274, $p = 0.029$), farm size had a significant positive effect, underscoring the vital role of land availability in improving food security outcomes across different farming systems.

Crop diversity had an insignificant effect on food security in both groups. For non-adopters, the effect was negative and statistically insignificant (Coef = -0.0086, $p = 0.548$), while for adopters, it was positive but also insignificant (Coef = 0.0066, $p = 0.612$). These results suggested that increasing the number of crop types grown did not significantly improve food security, possibly due to factors such as market limitations, reliance on staple crops, or suboptimal implementation of diversification strategies.

Among non-adopters, the use of climate-resilient crop varieties had a positive and statistically significant effect on food security (Coef = 0.0585, $p = 0.036$), indicating that cultivating hardier crops contributed meaningfully to improved food outcomes even in the absence of broader NbS adoption. In contrast, among adopters, the effect was also positive but statistically insignificant (Coef = -0.0086, $p = 0.548$), suggesting that other components of Nature-based Solutions—such as soil and water conservation—may have played a more dominant role in enhancing food security within that group.

Exposure to climate shocks had an insignificant effect on food security for both non-adopters (Coef = 0.0017, $p = 0.944$) and adopters (Coef = -0.0038, $p = 0.840$). This indicated that climate shocks did not exert a statistically meaningful influence on household food security outcomes. The lack of significant effect may have reflected effective short-term coping mechanisms, the relative infrequency of major shocks during the study period, or the possibility that their impacts were already captured by other variables such as income levels or resilience practices.

The constant terms had statistically insignificant effects in both equations, indicating that when all independent variables were held at zero, the baseline level of the food security index did not significantly differ from zero for either group.

The selection equation of the endogenous switching regression model estimated the factors that affected households' decisions to adopt Nature-based Solutions (NbS). In this study, none of the explanatory variables in the selection equation had a statistically significant effect. Specifically, access to early warning systems (Coef = -0.0869, $p = 0.778$), experience of major climate shocks (Coef = -0.2708, $p = 0.178$), and perceived effectiveness of NbS (Coef = -0.0264, $p = 0.843$) all showed insignificant effects on the likelihood of adoption. These findings suggested that observable characteristics related to climate risk or perception did not significantly influence NbS adoption decisions. The insignificant effects may have reflected deeper underlying issues such as limited access to information, institutional constraints, or sociocultural barriers not accounted for in the model. Additionally, the constant term was also insignificant ($p = 0.120$), reinforcing the likelihood that unobserved or complex behavioral factors had a more substantial influence on adoption choices.

The model diagnostics offered additional insights into the estimation results. The standard deviations of the error terms (σ_0) = 0.1477 for non-adopters and $\sigma_1 = 0.1992$ for adopters reflected the presence of variability due to unobserved factors influencing food security outcomes. The correlation coefficients between the error terms of the selection and outcome equations ($\rho_0 = 0.2041$ for non-adopters and $\rho_1 = -0.7593$ for adopters) suggested a moderately strong negative selection bias among adopters; however, these effects were not statistically significant. The likelihood ratio (LR) test for the independence of the selection and outcome equations yielded a p-value of 0.5181, indicating that the model did not suffer from significant selection bias. In contrast, the Wald chi-squared test for the joint significance of the regressors in the food security equations was highly significant ($p < 0.001$), confirming that the model was statistically valid and that several explanatory variables had a significant effect on food security. Overall, the results supported the use of the ESR model while highlighting the need for further research into unobserved factors that may influence the decision to adopt Nature-based Solutions.

4.4 DISCUSSION OF THE FINDINGS

The results from the Endogenous Switching Regression analysis offer important economic insights for shaping food security policy in Nigeria. The study found that simply adopting Nature-based Solutions (NbS) did not have an immediate or statistically significant effect on household food security. However, the length of time NbS practices were used had a significant and positive impact, indicating that the benefits of practices such as soil conservation, agroforestry, and the use of climate-resilient crops accumulate over time to improve productivity and resilience. Furthermore, among non-adopters, key factors like household income, education level, farm size, and the use of resilient crops had significant effects on food security. This suggests that households with better access to resources and knowledge are more likely to be food secure, even without adopting NbS. These findings highlight the need for policies that not only promote NbS adoption but also address broader structural inequalities that limit poorer households' ability to improve their food security.

From a policy standpoint, the findings emphasize the need for sustained investment in raising awareness and encouraging the long-term adoption of Nature-based Solutions (NbS), rather than relying on short-term interventions. Policymakers should prioritize expanding agricultural extension services that not only promote NbS practices but also offer continuous technical support to ensure their effective and lasting use. Given that the benefits of NbS take time to materialize, governments and development partners should create incentives such as subsidies, input assistance, or land tenure reforms to encourage farmers' long-term commitment. In addition, since factors like education and income significantly influence food security, policies that link NbS adoption with broader poverty alleviation, education, and rural development initiatives are likely to have greater impact. Overall, the findings point to the need for a comprehensive, multi-sectoral approach that supports sustainable agriculture while tackling the underlying socioeconomic challenges that hinder food security.

The results from the selection equation have important economic and policy implications. The absence of statistically significant factors influencing the adoption of Nature-based Solutions (NbS) suggests that households' decisions to adopt these practices are not strongly shaped by observable climate-related factors like past exposure to climate shocks, access to early warning systems, or even their perception of how effective NbS are. This indicates that adoption may be limited by unobserved barriers such as lack of technical knowledge, weak institutional support, limited access to credit, or prevailing social norms. From an economic standpoint, this reveals a critical challenge: households that are vulnerable to climate risks may still not adopt beneficial practices unless there are deliberate efforts to support them. Therefore, policymakers need to implement more proactive and targeted strategies such as locally tailored extension services, farmer education initiatives, financial support, and institutional reforms to raise awareness and lower barriers to adoption. Without addressing these underlying constraints, efforts to promote NbS adoption are unlikely to succeed, even in high-risk communities.

5 CONCLUSION AND RECOMMENDATION

This study examined how Nature-based Solutions (NbS) can support the achievement of sustainable development goals in Nigeria. The findings indicate that while simply adopting NbS does not lead to immediate or statistically significant improvements in household food security, sustained use over time has a strong and positive effect. Socioeconomic factors such as education, income, farm size, and the use of climate-resilient crops also had a significant impact on food security, especially among households that had not adopted NbS. However, the choice to adopt NbS did not appear to be influenced by observable climate-related factors like prior shock exposure or access to early warning systems. This suggests that other barriers such as lack of information, institutional weaknesses, or behavioral constraints may be limiting adoption. To fully harness the potential of NbS in achieving Sustainable Development Goal 2 (Zero Hunger), policymakers need to go beyond promoting adoption. They must ensure long-term support, address underlying structural inequalities, and embed NbS within broader strategies for rural development and climate resilience.

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