ESTIMATING URBAN FARM HOUSEHOLDS' WILLINGNESS TO PAY FOR SUSTAINABLE WASTEWATER MANAGEMENT AND RENEWABLE ENERGY SERVICES IN SOUTHEAST NIGERIA: A CONTINGENT VALUATION APPROACH

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ABSTRACT
The study evaluated urban farm households' willingness to pay (WTP) for sustainable wastewater management and renewable energy services in Southeast Nigeria. It focused on urban farm households in five states within the region. A multi-stage random sampling technique was used to select 600 households, and data collection was conducted through face-to-face structured interviews using a pre-tested questionnaire. The Contingent Valuation Method (CVM) was employed to estimate households' WTP for government-proposed wastewater treatment, renewable energy production, and public health monitoring services. The hypothetical scenario presented a government-led initiative that would treat wastewater for irrigation, produce biogas for energy, generate bio-based fertilizers, and implement public health monitoring through wastewater-based epidemiology (WBE). Findings revealed that, in terms of willingness to pay, 36.83% of urban farm households were willing to pay for sustainable wastewater management and renewable energy services, while 80% expressed unwillingness. (Note: These figures seem inconsistent and may require clarification; see below.) Regarding the maximum amount households were willing to pay, the majority (23.98%) indicated a willingness to pay between ₦12,001 and ₦15,000, followed by 19.46% who were willing to pay between ₦3,001 and ₦6,000. The Tobit regression model identified significant socio-economic determinants of WTP. Variables such as gender, age, marital status, household size, years of schooling, and access to credit significantly influenced the amount households were willing to pay for these services. Additionally, results from the multivariate probit regression model showed that access to credit, market distance, awareness of sustainable practices, and off-farm income were key factors influencing households' choices among the proposed services. Specifically, access to credit significantly increased the likelihood of choosing wastewater treatment but decreased the probability of adopting bio-based fertilizers. Awareness of sustainable practices had contrasting effects—positively influencing fertilizer adoption while reducing the likelihood of adopting bioenergy and wastewater services. Furthermore, land tenure insecurity consistently reduced the probability of adoption across all service types. These findings underscore the multidimensional factors shaping household behavior and highlight the need for integrated policy approaches. Based on the results, it is recommended that the Federal Government of Nigeria collaborate with financial institutions to improve access to affordable credit facilities for urban farm households.
Keywords: Urban, Farm Households, Willingness to Pay, Sustainable Wastewater Management, Renewable Energy Services

INTRODUCTION
In recent years, Southeast Nigeria has faced mounting environmental and developmental challenges, particularly as urbanization accelerates and agricultural practices evolve. Urban farm households, which play a vital role in the region's economy, increasingly struggle with issues such as inadequate wastewater management, water pollution, and unreliable energy sources. Wastewater, often left untreated or improperly managed, poses serious environmental threats by contaminating water bodies and soil, directly impeding farming productivity (Deh-Haghi et al., 2020). Simultaneously, these households continue to depend on traditional, inefficient energy sources that contribute to environmental degradation and fail to meet their growing needs (Ali et al., 2020). To address these interconnected issues, sustainable wastewater management and the generation of renewable energy from treated wastewater present promising opportunities. Reusing wastewater for agricultural purposes could help alleviate water scarcity and reduce environmental pollution, while harnessing renewable energy from treated effluent offers a reliable and eco-friendly alternative to conventional energy sources (Byambadorj & Lee, 2019; Cheng et al., 2022). However, the success of these innovative solutions depends significantly on the willingness of urban farm households to pay for such services. Their financial commitment is essential for ensuring the economic viability and long-term sustainability of these technologies (Berry et al., 2019; Borzykowski et al., 2018).

Despite the clear potential, a critical gap remains in understanding the determinants of willingness to pay (WTP) for sustainable wastewater and energy services among urban farm households in Southeast Nigeria. Few studies have investigated how these households perceive and value such services, especially in terms of their capacity and readiness to bear the costs (Cheng et al., 2022; Baron, 2017). Socio-economic factors—such as income, education, access to resources, and farming experience—are likely to influence these preferences and decisions significantly (Desvousges et al., 2017; Frontuto et al., 2017). Without empirical insights into these dynamics, it becomes challenging for policymakers and development actors to craft effective and inclusive interventions. This study aims to fill this knowledge gap by surveying urban farm households to assess their willingness to pay for sustainable wastewater treatment and renewable energy services. It will quantify the perceived value of these services and identify key socio-economic drivers shaping household decisions. The findings will offer valuable guidance for policymakers, environmental agencies, and development practitioners seeking to implement sustainable infrastructure solutions that are both economically feasible and socially acceptable. Ultimately, the research seeks to contribute to the broader goal of achieving sustainable development and environmental resilience in Southeast Nigeria (Ali et al., 2020; Berry et al., 2019).

Objectives of the study

The broad objective of the study is to evaluate urban farm households' willingness to pay for sustainable wastewater management and renewable energy services in Southeast Nigeria. Specifically, the study seeks to:

i. ascertain urban farm households' willingness to pay decision for sustainable wastewater management and renewable energy services;
ii. evaluate urban farm households' maximum willingness to pay for sustainable wastewater management and renewable energy services;
iii. estimate socio-economic factors influencing urban farm households' maximum willingness to pay for sustainable wastewater management and renewable energy services.
iv. estimate factors influencing choice for sustainable wastewater management and renewable energy services

METHODOLOGY

The study focused on farm households in Southeast Nigeria, specifically targeting urban communities engaged in agricultural activities. A multi-stage random sampling technique was used to select 600 households across the five states in the region: Abia, Anambra, Ebonyi, Enugu, and Imo. Data collection was conducted through face-to-face structured interviews using a pre-tested questionnaire. Enumerators were trained to ensure consistency and reliability in data collection. The questionnaire included items on household demographics, farm size, income, sources of irrigation, energy use, types of fertilizers used, and health monitoring practices. The central focus of the instrument was to assess households' willingness to pay (WTP) for the government's proposed wastewater program, which includes treated wastewater for irrigation, biogas for energy, bio-based fertilizers, and public health monitoring. The Contingent Valuation Method (CVM) was employed to estimate households' WTP. The hypothetical scenario is presented thus:

Hypothetical Scenario

The Federal Government is introducing an innovative programme to transform wastewater into valuable resources for farm households while promoting environmental sustainability and public health. This initiative focuses on three core areas: wastewater treatment and safe reuse, bioenergy and biochemicals from wastewater, and public health monitoring through wastewater-based epidemiology (WBE). Farm households will directly benefit from treated water for irrigation, renewable energy for household use, bio-based fertilizers to enhance soil productivity, and early disease monitoring systems to safeguard their health and livelihoods.

Key technologies underpin this programme to ensure efficiency and sustainability. Constructed wetlands and decentralized biofilters will treat wastewater for irrigation, while anaerobic digesters will convert wastewater into biogas for cooking and heating. Specialized units will extract nutrients from treated wastewater to produce organic fertilizers, and automated sampling equipment will support disease surveillance under WBE systems. These technologies will be implemented by government-appointed engineering firms, agro-chemical companies, and public health agencies, ensuring technical expertise and reliability. To make the programme accessible and sustainable, farm households will share the costs through affordable payments collected via Catholic religious communities. Payments cover one-time setup costs for infrastructure installation, including wastewater treatment systems and biogas digesters, as well as recurring fees for ongoing services such as water delivery, fertilizer supply, and public health monitoring. Training sessions and printed guides will be provided to educate households on using the technologies and interpreting health updates. The Table 1 below summarizes the programme package, clearly outlining what farm households are paying for, the technologies and services provided, the implementing agencies, and the frequency of service delivery:

Component	What Farm Households Pay For	Technology/Service Provided	Who Implements It	Frequency
Wastewater Treatment & Safe Reuse	Treated wastewater for irrigation, including system setup and maintenance costs.	Installation of constructed wetlands or decentralized biofilters to treat wastewater.	Government-contracted engineering firms and NGOs.	Weekly delivery of treated water.
Bioenergy Production	Access to renewable energy (biogas) for cooking and heating, including equipment.	Installation of anaerobic digesters to convert wastewater into biogas.	Wastewater treatment plants managed by specialists.	Monthly supply of biogas cylinders.
Bio-Based Fertilizers	Supply of organic fertilizers derived from wastewater treatment processes.	Fertilizer production units that extract nutrients from treated wastewater.	Agro-chemical companies contracted by the government.	Monthly supply of fertilizers.
Public Health Monitoring (WBE)	Disease monitoring services, lab testing, and health alerts.	Automated wastewater sampling units and lab-based epidemiological analyses.	Public health agencies and research labs.	Quarterly health alerts and reports.
Training & Capacity Building	Practical training sessions on using technologies and interpreting health updates.	On-site workshops and printed guides for handling biofertilizers, biogas systems, and safe irrigation practices.	Agricultural extension services and health agencies.	Annually and during new installations.

Respondents were asked if they would be willing to pay ₦20,000 per month for 5 years for the full package of services. The survey also included variations in price points to gauge the households' responsiveness to different payment amounts. For instance, households were asked if they would accept a higher (₦15,000) or lower (₦5,000) monthly payment, based on different scenarios for service provision. The data collected from the household survey were analysed using the Tobit regression model, which is suitable for dealing with censored data, as it accounts for the fact that some respondents may report zero willingness to pay or may have limited responses due to budget constraints.

1. Tobit Regression Model

The Tobit model is appropriate in this context because it can handle the left-censored nature of the dependent variable (WTP), where respondents who are unwilling to pay any amount report a zero value. The Tobit model allows for the estimation of both the probability of a positive WTP and the amount a respondent would be willing to pay if they have a positive WTP. The output will provide both the marginal effects of the explanatory variables on the probability of WTP being positive and on the amount of WTP. The analysis will also include checking for multicollinearity among the independent variables, and goodness-of-fit tests will be performed to ensure the reliability of the model. The results from the Tobit model will help identify key factors that influence farm households' WTP for the wastewater programme, providing valuable insights into the programme's potential for implementation and sustainability. The model is specified as follows:

Implicit Tobit Model

The implicit form of the Tobit model accounts for the censoring of the dependent variable (Maximum WTP) at zero (for respondents who are unwilling to pay).

$$WTPi* = \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6X6 + \beta7X7 + \beta8X8 + \ldots\ldots\ldots + \beta15X15 + \boldsymbol{\epsilon i} \quad \text{.....Eq.1}$$

Where:

$WTPi$ is the latent (unobserved) variable representing the maximum willingness to pay for household i

$X1, X2, \ldots, X15$ are the independent variables (such as gender, age, marital status, etc.).

$\beta0$ is the intercept term.

$\beta1, \beta2, \ldots, \beta15$ are the coefficients to be estimated.

ϵi is the error term.

The observed dependent variable $WTPi$ is censored at zero:

$$WTP_i = \begin{Bmatrix} \frac{WTP_i^*}{0} & \frac{if\ WTP_i^*>0}{if\ WTP_i^* \leq 0)} \end{Bmatrix} \text{..........Eq.2}$$

Explicit Tobit Model

The explicit form of the Tobit model provides a clear interpretation of the relationship between the independent variables and the observed willingness to pay (WTP). The relationship between the independent variables ($X1\ to\ X15$) and the dependent variable (Maximum WTP) is expressed as:

$$WTP_i = \begin{Bmatrix} \frac{\beta_o + \beta_1\, Gender + \,\ldots\ldots + \beta_o\ Crop\ yield + \epsilon i}{0,} & \frac{if\ WTP_i^*>0}{if\ WTP_i^* \leq 0)} \end{Bmatrix} \text{..........Eq.3}$$

Where: the measurement and apriori expectations of the independent variables X1-Xn are as follows

Variables	Measurement	Apriori Expectations
Gender (X1)	Binary (0 = Female, 1 = Male)	Male may have higher WTP due to greater control over farming decisions.
Age (X2)	Continuous (age of the respondent)	Older individuals may have higher WTP due to greater experience and financial stability.
Marital Status (X3)	Categorical (0 = Single, 1 = Married, etc.)	Married individuals may have higher WTP due to family considerations and responsibilities.
Household Size (X4)	Continuous (number of people in the household)	Larger households may have lower WTP due to resource constraints.
Years Spent in School (X5)	Continuous (number of years the respondent spent in school)	Higher education may increase WTP due to greater awareness of environmental and health issues.
Primary Occupation (X6)	Categorical (e.g., 1 = Farmer, 2 = Trader, etc.)	Farmers may show higher WTP for agricultural-related services.
Farming Experience (X7)	Continuous (years of experience in farming)	More experienced farmers may have higher WTP due to their reliance on farming for livelihood.
Annual Farm Income (X8)	Continuous (income from farming per year)	Higher income farmers may have higher WTP due to greater financial capacity.
Access to Credit (X9)	Binary (0 = No, 1 = Yes)	Those with access to credit may have higher WTP due to financial stability and ability to invest in services.
Membership of Organization (X10)	Binary (0 = Not a member, 1 = Member)	Members of agricultural organizations may have higher WTP due to collective benefits and support.
Type of Organization (X11)	Categorical (e.g., 1 = Cooperative, 2 = Farmers' group, etc.)	Membership in cooperatives may lead to a higher WTP due to organized support and resources.
Access to Extension Services (X12)	Binary (0 = No, 1 = Yes)	Access to extension services may increase WTP due to the perceived benefit from expert guidance.

Frequency of Extension Services (X13)	Continuous (number of times extension services are provided per year)	Higher frequency of extension services may increase WTP due to continuous learning and improvement.
Farm Size (X14)	Continuous (size of the farm in hectares)	Larger farm sizes may correlate with higher WTP due to greater resource availability.
Crop Yield (X15)	Continuous (amount of crop harvested per hectare)	Higher crop yields may increase WTP due to greater profitability and interest in improving farm conditions.

2. Multivariate Pobit Regression Model

The multivariate probit regression is a supervised machine learning algorithm involving multiple data variables for analysis. This model is based on the principle that the urban farm household heads will choose the practice that will maximize his or her utility. It is particularly appropriate for modelling discrete choice decisions such as sustainable wastewater management and renewable energy services (SWMRES) (wastewater treatment and safe reuse, bioenergy production and bio-based fertilizers) because it is an indirect utility function where an individual with specific characteristics associates an average utility level with each alternative SWMRES in a choice set. This model is based on the principle that the farm household head will choose the conservation practices that will maximize his/her utility.

The farm household head will make a comparison of marginal benefits and costs based on the utility gained from combining different sustainable wastewater management and renewable energy services (SWMRES), aiming to maximize overall utility. Although utility itself is not directly observable, the choices made by the farm household head reveal which combination of SWMRES provides the greatest perceived utility (Berry et al., 2019; Hanley & Czajkowski, 2019). Hence, the utility will be decomposed into deterministic (Vij) and random (εij) part:

$Uij = Vij + \mathcal{E}ij$ Eq.4

Since it is not possible to observe εij and predict exactly the choice of SWMRES, the probability of any particular SWMRES choice will be used in which a farm household head selects a SWMRES j = 1 if:

$Uik > Ui\,Vj \neq k$ Eq.5

Where Uik represents a random utility associated with the SWMRES j = k, V_{ij} represents an index function denoting the decision-makers' average utility associated with this alternative, and εij represents the random error. However, in this study, SWMRES choice are not mutually exclusive, considering the possibility of simultaneous choices of practices and the potential correlations among the choice decisions of these SWMRES. Multivariate probit model was used to estimate several correlated binary outcomes jointly because it simultaneously captures the influence of the set of explanatory variables on each of the different choice of SWMRES, while allowing for the potential correlations between unobserved disturbances, as well as the relationships between the choices of different SWMRES ((Berry et al., 2019; Hanley & Czajkowski, 2019). The net benefit (Y^*_{ik}) that the farm household head derives from choosing a SWMRES is a latent variable determined by observed explanatory variable (Xi) and the error term (εi):

$Y^*_{ik} = X'_i\beta k + \varepsilon_i$ (k = Y_1; Y_2; Y_3) ....Eq. 6

Thus, the econometric approach for this study is by using the indicator function; the unobserved preferences in Eq. (3) translate into the observed binary outcome equation for each choice as follows

$Y_{ik} = 1$ if $Y^*_{ik} > 0$, 0 Otherwise ....Eq. 7

K = Y_1; Y_2; Y_3 farmers' choice of SWMRES

Choices	SWMRES
Y1	Wastewater Treatment & Safe Reuse
Y2	Bioenergy Production
Y3	Bio-Based Fertilizers

The measurement and apriori expectations of the independent variables X1-Xn are presented in the Table below:

Variables	**Measurement**	**Apriori Expectations**
X1: Access to Credit	Dummy (1 = Has access, 0 = No access)	+ (Access to credit can improve the ability to invest in sustainable technologies.)
X2: Cost of Water/Energy per Month	Continuous (Monetary value in currency)	+/- (Higher costs may encourage investment in sustainable alternatives, but could also deter low-income households.)
X3: Awareness of Sustainable Practices	Dummy (1 = Aware, 0 = Not aware)	+ (Awareness increases the likelihood of adoption.)
X4: Farm Waste Output	Continuous (Kg of waste generated per month)	+ (Higher waste output may incentivize investment in wastewater recycling.)
X5: Land Tenure Security	Dummy (1 = Secure tenure, 0 = Insecure)	+ (Farmers with secure land tenure are more likely to invest in long-term sustainability.)
X6: Access to Extension Services	Dummy (1 = Has access, 0 = No access)	+ (Extension services provide knowledge and technical support for adoption.)
X7: Off-Farm Income	Continuous (Monetary value in currency)	+ (Higher off-farm income can increase financial capacity to invest.)
X8: Market Distance	Continuous (Kilometres to nearest major market)	− (Longer distances may reduce incentives due to high transportation costs and low profitability.)
X9: Access to Government/NGO Support	Dummy (1 = Receives support, 0 = No support)	+ (Subsidies or incentives can boost adoption of sustainable practices.)

RESULTS AND DISCUSSION

1. Urban Farm households Willingness to pay decision for Sustainable Wastewater Management and Renewable Energy Services in Southeast Nigeria

The figure reveals a critical insight into the willingness of urban farm households in Southeast Nigeria to pay for certain environmental services, such as wastewater management and renewable energy. According to the result, 36.83% of the respondents are willing to pay for these services, while a significant 80.00% are not. This distinction offers valuable perspectives on the barriers and potential facilitators for the adoption of sustainable environmental practices in this region.

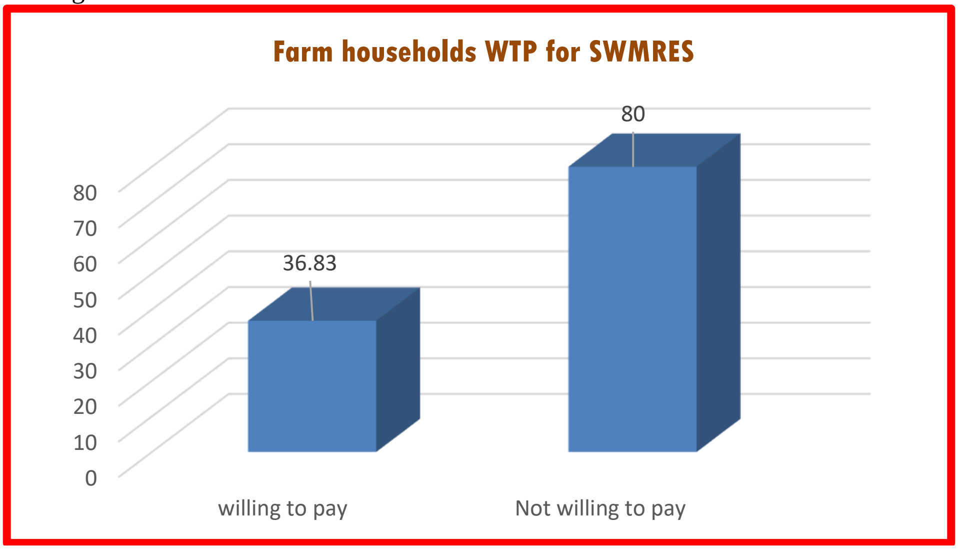

Figure 1: Urban Farm households Willingness to pay for Sustainable Wastewater Management and

Renewable Energy
A relatively small percentage of the respondents (36.83%) expressed a willingness to pay for wastewater management and renewable energy services. This could be attributed to several factors, with the first being awareness and perceived value of these services. When households understand the long-term benefits of sustainable wastewater management—such as improved water quality for irrigation or the reduction of waterborne diseases—they are more likely to invest in these services. However, awareness in many urban areas remains low, and often, households do not perceive immediate or direct benefits, especially if these services are not effectively communicated. As noted by Haque et al. (2022) and Cheng et al. (2022), the success of such services often hinges on how well the community perceives their value. For instance, if a household cannot clearly recognize the impact of cleaner water or energy sources on their daily lives, they may be hesitant to pay for these services.

Moreover, the economic feasibility of such services plays a role. Desvousges et al. (2017) highlighted that households with limited income—common in urban farming areas—often struggle to allocate resources for additional services, even when those services yield long-term benefits. Berry et al. (2019) further supported this, noting that even when environmental services have the potential to improve quality of life, financial limitations can constrain a household's ability to commit to paying for them. The respondents willing to pay may be those who have previously experienced the benefits of similar services or who have greater disposable income, enabling them to prioritize sustainable options such as renewable energy or treated wastewater for agriculture. The overwhelming majority of respondents (80.00%) indicated that they are not willing to pay for wastewater management and renewable energy services. This substantial resistance can be attributed to several factors, primarily economic constraints and perceived cost-benefit trade-offs. Many urban households face significant financial limitations, making them unable to afford the additional costs associated with adopting these services. In a study by Fitzpatrick et al. (2017), it was found that in areas with low income, households are less likely to invest in environmental services, even when they stand to benefit in the long term. The high percentage of respondents unwilling to pay may reflect a broader pattern of financial prioritization among urban farm households, where immediate needs for food, water, and basic living expenses take precedence over long-term environmental investments.

Another factor contributing to this reluctance is skepticism and trust issues regarding the efficacy of these services. Deh-Haghi et al. (2020) noted that farmers' acceptance of wastewater reuse for irrigation depends heavily on their trust in the technology and its perceived safety and efficiency. If respondents are unfamiliar with how these systems work or if they have had negative experiences with similar projects, they may be hesitant to invest. Verlicchi et al. (2018) also suggested that mistrust in the effectiveness of these technologies can significantly influence willingness to pay. For instance, if urban farm households view wastewater treatment or renewable energy systems as unreliable or ineffective, they may not see sufficient value to justify payment. Lastly, cultural and behavioral factors influence willingness to pay. Many urban households in Southeast Nigeria may be more familiar with traditional farming and energy-use practices, which they perceive as more reliable. As argued by Frontuto et al. (2017) and Giguere et al. (2020), adopting new environmental technologies not only requires financial resources but also behavioral shifts and changes in perception. If the community does not fully grasp or accept the need for wastewater treatment or renewable energy systems, reluctance to pay will remain high. In such cases, the challenge lies not only in economic barriers but also in altering long-established habits and beliefs.

These findings are consistent with more recent studies examining willingness to pay for environmental services in urban and developing contexts. Haque et al. (2022) and Cheng et al. (2022) observed that willingness to pay for services like waste and wastewater management is typically low in areas where financial pressures are high and awareness of benefits is limited. Similarly, Fitzpatrick et al. (2017) and Deh-Haghi et al. (2020) found that in communities with limited resources, households prioritize short-term survival over long-term environmental improvements, even when those improvements offer future gains. Moreover, studies like those of Hanley and Czajkowski (2019) and Khan et al. (2022) show that willingness to pay is influenced by socio-economic factors such as income, education, and access to services—all of which are relevant to the decisions of urban farm households in Southeast Nigeria.

Urban Farm Households Maximum Willingness to pay for Sustainable Wastewater Management and Renewable Energy Services in Southeast Nigeria
The result presented in Table 1 outlines the distribution of urban farm households in Southeast Nigeria based on their maximum willingness to pay (WTP) for sustainable wastewater management and renewable energy services. This table provides critical insights into how much these households are willing to invest in such services, revealing varied responses across different income brackets. The first category, with a WTP range between ₦1,000 and ₦3,000, has 13.57% of respondents. While this proportion is relatively small, it still indicates a significant

number of households willing to contribute modest amounts towards sustainable services. This low range may reflect a group of households that have limited disposable income but still recognize the potential benefits of wastewater management and renewable energy. According to Haque et al. (2022) and Cheng et al. (2022), such households may see these services as important but can only afford minimal contributions due to financial constraints.

Table 1: Distribution of Urban Farm households based on their Maximum Willingness to pay for Sustainable Wastewater Management and Renewable Energy Services in Southeast Nigeria

(Maximum Amount WTP) Naira	Frequency	Percentage
1000 - 3,000	30	13.57
3001- 6,000	43	19.46
6,001 - 9000	20	9.05
9,001 - 12,000	32	14.48
12,001 - 15000	53	23.98
15,001 - 19,000	12	5.43
18,001 - 21,000	15	6.79
21,000 - 25,000	9	4.07
25,001 - 28,000	5	2.26
28,000 - 30,000	2	0.90

Source: Field Survey (2024).

A more substantial percentage of respondents, 19.46% in the ₦3,001–₦6,000 range and 9.05% in the ₦6,001–₦9,000 range, represent households that are willing to pay moderate amounts for sustainable services. These figures suggest that a considerable portion of the urban farm population is more open to paying for wastewater management and renewable energy, possibly due to the perceived benefits of these services in improving farming productivity and reducing energy costs. According to Khan et al. (2019b), such moderate WTP may indicate that households perceive a fair value in ecosystem or environmental services and are willing to invest when they foresee tangible improvements in livelihoods. A noteworthy portion—14.48% in the ₦9,001–₦12,000 range and 23.98% in the ₦12,001–₦15,000 range—is willing to contribute higher amounts. This represents a significant willingness to pay for environmental services, likely from households with better economic conditions or higher perceived benefits of wastewater management and renewable energy. These households might have sufficient income to afford higher contributions and possibly have seen direct or indirect benefits from similar services. Ndambiri et al. (2017) and Deh-Haghi et al. (2020) suggest that households with relatively higher incomes are more inclined to support sustainable technologies and investments, particularly when these are linked to perceived improvements in quality of life or productivity.

The remaining categories, with WTP amounts ranging from ₦15,001 to ₦30,000, show a total of 19.87% of respondents. This includes 5.43% in the ₦15,001–₦19,000 range, 6.79% in the ₦18,001–₦21,000 range, 4.07% in the ₦21,000–₦25,000 range, 2.26% in the ₦25,001–₦28,000 range, and 0.90% in the ₦28,000–₦30,000 range. These figures demonstrate that only a small percentage of urban farm households are willing to pay very high amounts for these services, suggesting that although there is some willingness to pay at higher levels, it is concentrated in a minority of the population. As noted by Berry et al. (2019), this might reflect a disparity in income and the broader economic realities of urban areas, where only a few can afford substantial contributions for environmental services. The distribution of WTP amounts indicates a diverse economic landscape among urban farm households in Southeast Nigeria. While a majority of respondents are inclined to pay moderate amounts, there is a notable drop in the willingness to contribute higher sums. This pattern is consistent with findings from Suryawan & Lee (2023), who observed that while a segment of urban populations is willing to pay for improved waste services, many households are constrained by income and cost-related concerns. It also reflects the economic constraints of urban households, where many are living on subsistence agriculture and may prioritize immediate survival needs over long-term investments in environmental sustainability. Lu et al. (2020) similarly observed that access to sustainable technologies is often limited by economic factors, even when long-term environmental and agricultural gains are evident. However, the significant percentage of households willing to pay moderate amounts for these services suggests that there is potential for adopting sustainable practices if the cost is manageable. The findings from Khan et al. (2022) and Khan et al. (2019a) support this view, highlighting the importance of designing financial and institutional frameworks (e.g., subsidies, spatial targeting, or microfinancing) that encourage broader participation in sustainable ecosystem service markets.

Farm households Willingness to pay determinants for Sustainable Wastewater Management and Renewable Energy Services in Southeast Nigeria

The results presented in Table 2 provide valuable insights into the determinants of urban farm households' willingness to pay (WTP) for sustainable wastewater management and renewable energy services in Southeast Nigeria, as estimated through a Tobit regression model. This analysis captures the relationship between several socio-economic and demographic factors and the likelihood of urban farm households committing to payments for these services.

Table 2: Tobit regression model of Farm Households Willingness to pay determinants for Sustainable Wastewater Management and Renewable Energy Services in Southeast Nigeria

Variables	Coefficient	Std. Error	z-Statistic	Prob.
Constant	-5214.100	3459.720	-1.507087	0.1318
Gender	-3849.332***	1224.247	-3.144245	0.0017
Age	156.5826***	47.68453	3.283719	0.0010
Marital status	2155.509**	932.5368	2.311446	0.0208
Household size	484.3527***	157.2811	3.079535	0.0021
Years spent in school	505.4831***	132.5566	3.813339	0.0001
Primary occupation	-760.9138	567.1931	-1.341543	0.1797
Farming experience	-126.5732**	53.71633	-2.356325	0.0185
Annual farm income	-0.002717	0.002078	-1.307792	0.1909
Access to credit	5042.727***	1561.801	3.228791	0.0012
Membership of organization	-2765.846	3790.655	-0.729649	0.4656
Type of organization belonged to	5305.852***	1862.176	2.849276	0.0044
Access to Extension services	-2809.409***	1105.355	-2.541635	0.0110
Frequency of extension services	-5632.133***	2079.734	-2.708103	0.0068
Farm size	-725.7426***	128.4328	-5.650758	0.0000
Crop yield	0.280483***	0.061149	4.586881	0.0000
Mean dependent variance	4090.833	S.D. dependent variance		5342.143
S.E. of regression	3285.694	Akaike info. Criterion		13.78996
Sum squared residual	1.11E+09	Schwarz criterion		14.18485
Log likelihood	-810.3974	Hannan-Quinn criterion		13.95033
Avg. log likelihood	-6.753312			

Source: Field Survey (2024).

One of the most significant factors influencing WTP is gender, with a negative coefficient of -3849.332 and a p-value of 0.0017, indicating that male-headed households are less likely to be willing to pay for these services compared to female-headed households. This finding is supported by recent research such as that of Haque et al. (2022), which suggests that socio-demographic characteristics, including gender, influence investment decisions related to environmental services, with women often demonstrating a higher concern for household and community well-being, thereby enhancing their willingness to pay. Another key determinant is age, which has a positive and significant effect on WTP, with a coefficient of 156.5826 and a p-value of 0.0010. This implies that older urban farm household heads are more likely to pay for sustainable services. Age is often associated with a greater understanding of the long-term benefits of sustainability, as older individuals may have seen the negative effects of environmental degradation over time and may thus be more inclined to invest in services aimed at mitigating these issues. This finding aligns with Deh-Haghi et al. (2020), who observed that older individuals often show more readiness to adopt environmental innovations due to heightened environmental awareness.

Marital status also plays a significant role, with a positive coefficient of 2155.509 and a p-value of 0.0208. Married household heads are more likely to express a willingness to pay for these services, likely due to the collective decision-making process that prioritizes the welfare of the entire family, which often includes improving living conditions through sustainable practices. This supports the findings of Byambadorj and Lee (2019), who noted that marital status affects household-level investment decisions, especially those concerning long-term infrastructure or welfare improvements. The household size variable, with a positive and significant coefficient of 484.3527 (p-value of 0.0021), suggests that larger households are more willing to pay for sustainable services. This could be because larger households may experience more direct benefits from these services, such as improved water quality or energy access, which can help meet the needs of multiple family members. This result is in line with the findings of Cheng et al. (2022), which demonstrated that household size significantly influences willingness to pay due to increased resource consumption and benefits derived from improved environmental services.

Years spent in school is another significant determinant, with a coefficient of 505.4831 and a p-value of 0.0001, indicating that individuals with higher levels of education are more likely to pay for sustainable services. Education typically leads to a better understanding of environmental issues and the long-term benefits of sustainable practices, making educated individuals more receptive to new technologies and investments. This is consistent with the work of Hanley and Czajkowski (2019), who found that education enhances the ability to assess long-term value propositions in environmental investments. Interestingly, the variable primary occupation did not show a significant effect on WTP (p-value of 0.1797). This suggests that the type of primary occupation does not have a strong influence on urban farm households' willingness to pay for wastewater management and renewable energy services. It contrasts with earlier assumptions, but similar to Baron (2017), this result might reflect inconsistencies or context-specific influences in contingent valuation outcomes, especially when socioeconomic or geographic variation is high.

Farming experience has a negative and significant coefficient of -126.5732 (p-value of 0.0185), meaning that households with more years of farming experience are less likely to pay for these services. This may reflect the fact that long-standing farmers may have developed traditional, less-costly ways of managing their farms and could be skeptical about adopting new technologies. Ali et al. (2020) support this interpretation, suggesting that familiarity with conventional methods can reduce openness to monetized ecosystem services, especially when those services appear to disrupt established farming routines. Access to credit shows a positive and significant effect, with a coefficient of 5042.727 (p-value of 0.0012), indicating that households with access to credit are more likely to be willing to pay for these services. Access to credit provides the financial means to invest in sustainable solutions, making it an important determinant of WTP. This finding is supported by Berry et al. (2019), who emphasized that access to financing options can significantly enhance households' capacity to invest in environmental technologies.

Moreover, the variable membership of organizations did not significantly influence WTP, with a p-value of 0.4656. This suggests that simply being part of an organization does not directly affect the willingness to pay for sustainable services. However, the type of organization a household belongs to had a significant impact, with a positive coefficient of 5305.852 (p-value of 0.0044), suggesting that belonging to certain types of organizations, possibly those focused on environmental or community welfare, increases the likelihood of WTP. Access to extension services and the frequency of extension services both show negative coefficients, with significant p-values (0.0110 and 0.0068, respectively), indicating that households with better access to extension services and those receiving more frequent services are less likely to pay for sustainable services. This counterintuitive result may indicate that these households already receive sufficient knowledge and support from extension services, making them less inclined to pay for additional external services. Deh-Haghi et al. (2020) observed that households heavily reliant on free or subsidized services may be less willing to invest financially in similar services outside of those provided by governmental or NGO channels.

Lastly, farm size and crop yield have significant effects on WTP. The negative coefficient for farm size (-725.7426) suggests that larger farms may be less likely to pay for these services, possibly due to the higher costs associated with providing these services to larger operations. On the other hand, crop yield has a positive and significant effect, with a coefficient of 0.280483, indicating that households with higher crop yields are more likely to be willing to pay for sustainable services, possibly because they are more likely to see the direct benefits of such services in improving agricultural productivity.

2. Factors Influencing Choice for Sustainable Wastewater Management and Renewable Energy Services

Table 3 presents the results from Multivariate Probit (MVP) regression model used to identify the factors influencing farm households' choices among three sustainable services: wastewater treatment and safe reuse, bioenergy production, and bio-based fertilizers.

Table 3: Factors Influencing Choice for Sustainable Wastewater Management and Renewable Energy Services

	Wastewater Treatment & Safe Reuse		Bioenergy Production		Bio-Based Fertilizers	
	Coefficient (Sig.)	T value	Coefficient (Sig.)	T value	Coefficient (Sig.)	T value

Constant	2.466	5.38	1.913	15.09	3.048	21.43
Access to Credit	1.508 (0.000)***	6.45	0.092 (0.155)	1.43	-1.174 (0.000)***	-16.16
Cost of Water/Energy	-0.014 (0.010)**	-2.62	0.001 (0.408)	0.83	0.009 (0.000)***	5.16
Sustainable Practice Awareness	-0.591 (0.002)***	-3.09	-0.162 (0.003)***	-3.05	1.032 (0.000)***	17.38
Farm Waste Output	-0.065 (0.359)	-0.92	0.044 (0.028)**	2.22	-0.167 (0.000)***	-7.58
Land Tenure Security	-0.255 (0.000)***	-12.88	-0.007 (0.211)	-1.25	-0.072 (0.000)***	-11.63
Access to Extension Services	0.006 (0.293)	1.05	-0.001 (0.576)	-0.56	-0.018 (0.000)***	-9.97
Off-Farm Income	1.5e-07 (0.000)***	6.96	-4.6e-08 (0.000)***	-7.93	-9.8e-08 (0.000)***	-15.11
Market Distance	1.336 (0.000)***	9.99	0.102 (0.006)***	2.75	-0.349 (0.000)***	-8.41
Gov./NGO Support Access	0.080 (0.000)***	8.34	0.007 (0.012)**	2.53	-0.020 (0.000)***	-6.85
Observations	240		240		240	
RMSE	0.7806		0.2159		0.2423	
R-Sq	0.5812		0.3561		0.7321	

Source: Field Survey (2024) * = p < 0.05, ** = p < 0.01, *** = p < 0.001

Access to credit emerged as a highly significant determinant for both wastewater treatment and bio-based fertilizers, though with opposite effects. For wastewater treatment, access to credit had a strong positive coefficient of 1.508 ($p = 0.000$), indicating that financial empowerment significantly enhances households' capacity to invest in infrastructure-intensive solutions. This finding aligns with Khan et al. (2022), who emphasized the role of financial instruments in promoting access to environmental services. Conversely, for bio-based fertilizer adoption, access to credit exerted a strong negative effect with a coefficient of –1.174 ($p = 0.000$), reflecting a substitution effect. Households with credit access are more likely to prefer conventional or technologically advanced alternatives, viewing bio-based fertilizers as lower priority or less urgent. The cost of water and energy had contrasting effects across services. It negatively influenced wastewater treatment with a coefficient of –0.014 ($p = 0.010$), implying that rising utility costs is likely to discourage investments in water treatment systems due to the associated operational burden. In contrast, it positively influenced the adoption of bio-based fertilizers, showing a coefficient of 0.009 ($p = 0.000$), suggesting that higher conventional input costs motivate households to adopt affordable, locally produced alternatives. This supports the findings of Lu et al. (2020), who observed similar trends among resource-constrained farmers.

Awareness of sustainable practices played a nuanced role across service options. It had a negative and significant effect on wastewater treatment (–0.591, $p = 0.002$) and bioenergy production (–0.162, $p = 0.003$), reflecting skepticism about feasibility, safety, or costs of these technologies. However, it showed a strong positive correlation with bio-based fertilizer adoption (1.032, $p = 0.000$), indicating that increased awareness promotes acceptance of simpler, lower-risk solutions. This supports conclusions by Suryawan and Lee (2023) on the role of public understanding in driving sustainable adoption. Farm waste output had service-specific implications. It significantly and positively affected bioenergy adoption (0.044, p = 0.028), suggesting households with higher organic waste volumes are more likely to see energy generation as a viable reuse option. Conversely, it had a significant negative effect on bio-based fertilizers (–0.167, p = 0.000), which may point to labor concerns or waste management challenges. This aligns with Khan et al. (2020b), who highlighted the varied perceptions of waste reuse among farmers.

Land tenure security consistently showed a negative and significant effect across all services: –0.255 (p = 0.000) for wastewater, –0.072 (p = 0.000) for bio-based fertilizers, and non-significant for bioenergy. This counterintuitive result may indicate that households with insecure tenure are more likely to engage in short-term, subsidized services due to uncertainty about future land access. This behavior is echoed by Ndambiri et al. (2017), who observed higher participation in externally supported environmental programs among insecure landholders.

Off-farm income presented a complex pattern. It had a positive and significant effect on wastewater treatment (1.5e-07, p = 0.000), but negative effects on bioenergy (–4.6e-08, p = 0.000) and bio-based fertilizers (–9.8e-08, p = 0.000). This suggests that households with diversified income streams favor capital-intensive services like wastewater infrastructure, while deprioritizing labor-demanding or lower-return options like bioenergy and organic fertilizers. These patterns mirror those found in Khan et al. (2019a). Market distance had significant but varied effects. It was positively associated with wastewater treatment (1.336, p = 0.000) and bioenergy production (0.102, p = 0.006), suggesting that more remote households may prefer decentralized reuse options. In contrast, it negatively affected fertilizer use (–0.349, p = 0.000), likely due to logistical constraints in input procurement or distribution. These findings are consistent with Khan et al. (2019b), who discussed how market distance influences household preferences. Finally, access to government or NGO support had significant effects across services. It positively influenced wastewater treatment (0.080, p = 0.000) and bioenergy adoption (0.007, p = 0.012), indicating that external institutional backing encourages participation by reducing risk. However, it had a significant negative effect on fertilizer adoption (–0.020, p = 0.000), reflecting farmers' preference for autonomy in fertilizer use. This supports Verlicchi et al. (2018), who emphasized the importance of aligning policy interventions with perceived household needs and traditions.

CONCLUSION AND RECOMMENDATIONS

In conclusion, the study's findings on urban farm households' willingness to pay (WTP) for sustainable wastewater management and renewable energy services in Southeast Nigeria highlight significant insights into the financial and socio-economic factors that influence their adoption of such services. A considerable proportion of households expressed a willingness to pay, although a larger portion showed reluctance, indicating the presence of barriers to acceptance and adoption. The distribution of maximum willingness to pay indicates that while there is some level of financial capacity to support these services, affordability remains a critical factor that could impact overall participation. The results from the Tobit regression analysis further demonstrate that socio-economic factors such as gender, age, household size, education, access to credit, and farming experience play substantial roles in determining willingness to pay. These factors indicate that households with better access to financial resources and higher levels of education are more likely to invest in sustainable practices, whereas factors like farming experience and farm size may reduce the likelihood of adoption. Further insights from the multivariate probit regression analysis underscore the differentiated influence of specific variables across the types of services. Access to credit significantly increased the likelihood of adopting wastewater treatment but negatively influenced adoption of bio-based fertilizers. Awareness of sustainable practices had a mixed effect, reducing the adoption likelihood of wastewater treatment and bioenergy production while strongly increasing the likelihood of bio-based fertilizer adoption. Land tenure insecurity emerged as a strong deterrent across all services, while off-farm income and access to government or NGO support consistently facilitated adoption. Based on the findings of this study, the following recommendations are made:

i. The Federal Government, through the Central Bank of Nigeria (CBN) and other financial institutions, introduce and promote specialized credit facilities targeted at urban farm households to support investments in sustainable wastewater management and renewable energy systems. Access to affordable loans and financial products can mitigate the financial barriers identified in the study, empowering households to adopt these technologies. Additionally, the government should partner with agricultural extension services to raise awareness about these credit options.

ii. The Federal Ministry of Agriculture and Rural Development (FMARD), in collaboration with the Ministry of Environment, should prioritize the development and implementation of educational programs and campaigns aimed at raising awareness about the benefits of sustainable wastewater management and renewable energy. These initiatives should target urban farm households, particularly those with lower education levels, to enhance their understanding of the long-term financial and environmental benefits of adopting such services.

iii. To encourage the adoption of renewable energy and sustainable wastewater management systems, the Federal Government, through agencies like the Nigerian Energy Support Program (NESP), should offer subsidies or grants to urban farm households. These incentives could reduce the initial investment costs, making the technologies more accessible to households with limited financial resources. This would particularly support lower-income households that are currently unwilling or unable to pay for such services.

iv. It is crucial that the Federal Ministry of Agriculture, in collaboration with state and local agricultural extension services, strengthens the delivery of technical support and training to urban farm households on the proper installation, operation, and maintenance of sustainable wastewater and renewable energy systems. Regular and consistent extension services can enhance knowledge and build trust in these technologies, increasing their adoption. Additionally, the frequency of these services should be improved to ensure that more households receive continuous guidance.

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APPENDIX

Dependent Variable: Y_MAXIMUM_WTP
Method: ML - Censored Normal (TOBIT) (Newton-Raphson / Marquardt steps)
Date: 01/07/25 Time: 17:04
Sample: 1 600
Included observations: 600
Left censoring (value) at zero
Convergence achieved after 6 iterations
Coefficient covariance computed using observed Hessian

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-5214.100	3459.720	-1.507087	0.1318
X1_GENDER	-3849.332	1224.247	-3.144245	0.0017
X2_AGE	156.5826	47.68453	3.283719	0.0010
X3_MARITAL_STATUS	2155.509	932.5368	2.311446	0.0208
X4_NO_OF_PEOPLE_IN_YOUR_	484.3527	157.2811	3.079535	0.0021
X5_NO_OF_YEARS_SPENT_IN_	505.4831	132.5566	3.813339	0.0001
X6_PRIMARY_OCCUPATION	-760.9138	567.1931	-1.341543	0.1797
X7_HOW_LONG_HAVE_YOU_BEE	-126.5732	53.71633	-2.356325	0.0185
X8_ANNUAL_FARM_INCOME	-0.002717	0.002078	-1.307792	0.1909
X9_ACCESS_TO_CREDIT	5042.727	1561.801	3.228791	0.0012
X10_BELONG_TO_AN_ECONOMI	-2765.846	3790.655	-0.729649	0.4656
X11_TYPE_OF_ECONOMIC_ASS	5305.852	1862.176	2.849276	0.0044
X12_ACCESS_TO_AGRICULTUR	-2809.409	1105.355	-2.541635	0.0110
X13_NUMBER_OF_AGRICULTUR	-5632.133	2079.734	-2.708103	0.0068
X14_FARM_SIZE	-725.7426	128.4328	-5.650758	0.0000
X15_YOUR_AVERAGE_CROP_YI	0.280483	0.061149	4.586881	0.0000
	Error Distribution			
SCALE:C(17)	4080.987	336.1586	12.14007	0.0000

Mean dependent var	4090.833	S.D. dependent var	5342.143
S.E. of regression	3285.694	Akaike info criterion	13.78996
Sum squared resid	1.11E+09	Schwarz criterion	14.18485
Log likelihood	-810.3974	Hannan-Quinn criter.	13.95033
Avg. log likelihood	-6.753312		
Left censored obs	480	Right censored obs	0
Uncensored obs	221	Total obs	600