Agricultural Sciences, 2025, 16(9), 1016-1035
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Household Willingness to Pay for the Control of *Ipomoea* Plant Species and Its Influencing Factors: Evidence from Kajiado Central Sub-County, Southern Kenya

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How to cite this paper: Mersha, K.A., Ngigi, M. and Gitau, R. (2025) Household Willingness to Pay for the Control of *Ipomoea* Plant Species and Its Influencing Factors: Evidence from Kajiado Central Sub-County, Southern Kenya. *Agricultural Sciences*, **16**, 1016-1035.
https://doi.org/10.4236/as.2025.169058

Received: August 12, 2025
Accepted: September 20, 2025
Published: September 23, 2025

Abstract

Communal grazing lands are essential for livelihood and food security in pastoralist regions like Kajiado County, Kenya, where communities heavily depend on livestock production. However, with progressive land-use change, biological invasions have increased over the past decade. The invasive *Ipomoea* plant species in Kajiado County has led to the loss of grazing land, threatening the long-term livelihood and food security of the community. This study aimed to (1) characterize households' willingness to pay for the control of the *Ipomoea* species, (2) estimate households' mean willingness to pay, and (3) determine the factors influencing households' willingness to pay. Data from 267 households were collected using a multistage sampling procedure across three wards in Kajiado Central Sub-county: Purko, Dalalekutuk, and Illdamat, that were later cleaned and analysed using SPSS version 27 and STATA version 17, respectively. The data were analysed using descriptive statistics, and a double-bounded dichotomous choice under the CVM approach with a Seemingly Unrelated bivariate probit model was employed to estimate mean WTP and the factors influencing households' WTP. Out of 260 valid responses, 81.15% expressed willingness to pay cash in Kenyan shilling. The model results showed that the mean willingness to pay was 9541.44 KES per year. The results showed that initial and follow-up bid amounts, livestock ownership, access to extension services, the household's primary livelihood activities, and family size were significant variables that influence WTP. The study recommends that policymakers should consider these variables and community participation when designing effective strategies for managing the spread of invasive plant species and enhancing the resilience of pastoral systems.

Keywords

Contingent Valuation Method, Double Bounded Dichotomous Choice Method, *Ipomoea*, Kajiado, Seemingly Unrelated Bivariate Probit Model

1. Introduction

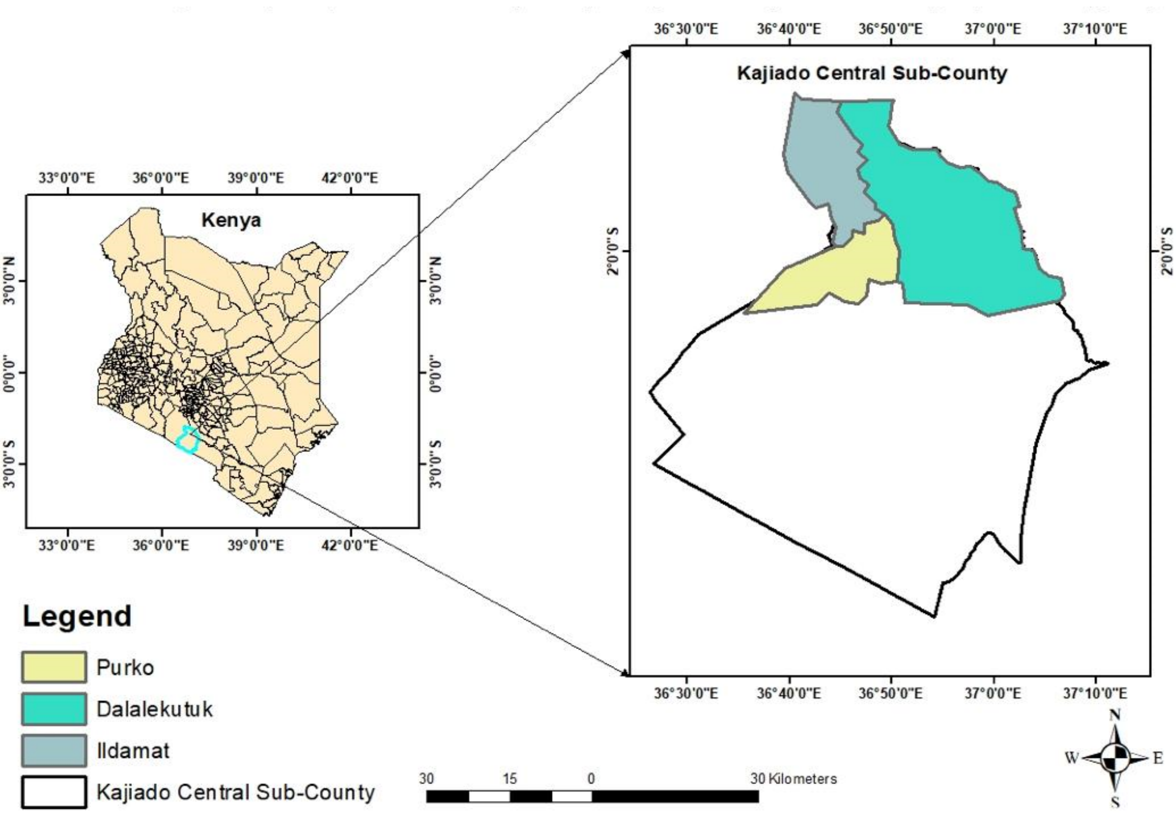
The livestock sector in Kenya is a crucial component of agriculture, contributing 3.6% to the national GDP [1]. According to the State Department of Livestock Statistics (2023) [2], Kenya's livestock population includes 21,882,008 cattle, 23,208,541 sheep, 34,989,347 goats, 67,043,771 chickens, and 840,160 pigs. This sector provides income, employment, and enhances food security. The government of Kenya is transforming its livestock sector through policies like the Kenya Climate-Smart Agriculture Strategy KCSAS (2017-2026) [3] and the Agricultural Sector Transformation and Growth Strategy ASTGS (2019-2029) [4], focusing on productivity, climate resilience, and commercialization, especially in Arid and Semi-Arid Lands (ASALs), where 60% of the country's livestock is held. These areas, however, are affected by climate change, drought, and the biological invasion of weeds, all of which have degraded communal grazing lands [5].

Invasive alien species (IAS) have caused significant global economic damage, estimated at a minimum of US$1.288 trillion (2017 USD) over the past 50 years, with costs steadily rising [6]. In Central and South America, IAS incurred USD 102.5 billion in damages from 1975 to 2020, with 90% concentrated in Brazil, Argentina, and Colombia. In Africa, costs ranged between US$18.2 billion and US$78.9 billion from 1970 to 2020 [7]-[9]. In East Africa, IAS, such as weeds in semi-arid regions, compete with native grasses for resources, hindering pasture establishment and livestock production, with some species posing toxicity risks [7]. For instance, *Prosopis juliflora* in Ethiopia's Afar region consumes 3.1 - 3.3 billion cubic meters of water annually, equivalent to irrigating 460,000 hectares of cotton and 330,000 hectares of sugarcane, with potential net benefits of US$320 million and US$470 million per season, respectively [10]. In Kajiado County, Kenya, an arid and semi-arid region heavily reliant on livestock production, the invasion of *Ipomoea* species has affected approximately 3 million acres of pasture, threatening food security and livelihoods [11]. Livestock production, which employs 75% of the population and supplies 40% of the country's food, has been impacted, with chevon (goat meat) value increasing from 300.3 million KES in 2018 to 1.07 billion KES in 2022, while beef production declined slightly from 1.69 billion KES to 1.51 billion KES [12]. Despite limited research on *Ipomoea*'s economic impacts in Kenya, its aggressive spread in Maasai pastoral lands of Kenya and Tanzania has been documented [13] [14].

The Kajiado County government has prioritized coordinated community efforts to control *Ipomoea* through physical uprooting and proper disposal to mitigate its effects on livestock and food security. Addressing these challenges related to grazing lands requires collective action and effective management of common pool resources (CPRs). Previous studies recommended that community participation and multi-stakeholder collaboration are essential for sustainable environmental resource management [15]-[18]. While previous studies have provided recommendations, no empirical research has specifically assessed households' willingness to pay (WTP) for controlling *Ipomoea* plant species in the study area. As a result, the value that local communities place on managing this invasive species remains unknown. Thus, this study aimed to contribute to the limited literature by (1) characterizing households' willingness to pay for the control of *ipomoea* plant species, (2) estimating households' mean willingness to pay, and (3) determining the factors affecting household WTP for the control of *ipomoea* plant species in Southern Kenya, which is crucial for restoring the health of grazing lands and ensuring the sustainability of pasture livelihoods.

2. Materials and Methods

2.1. Study Area



Source: Own construction, 2025.

Figure 1. Map of the study area.

The study was based in the southern part of Kenya, mainly in Kajiado County. The county borders Kiambu and Nakuru counties to the north, Narok County to the west, and Machakos and Makueni counties to the northeast and east, respectively. To the southeast lies Taita Taveta County, while Tanzania forms the southern boundary. Geographically, the county spans approximately 21,871.1 square kilometers, positioned between latitudes 1˚0'S and 3˚0'S and longitudes 36˚5'E and 37˚5'E [12]. The geographical scope of the study, limited to three wards within Kajiado Central Sub-County, is illustrated in **Figure 1**. According to the 2019 census, the number of households in the Kajiado Central sub-county was 37,059, with a total land area of 4239 square kilometers and a density of 38 persons per square kilometer [19]. Livestock farming in the sub-county mainly consists of cattle, sheep, and goats. The trade of these animals and their products, such as beef, milk, goat meat (chevon), sheep meat (mutton), along with hides and skins, serves as a vital source of household earnings, enhances dietary needs, and generates employment for local residents [20].

2.2. Sampling Procedure

The study employed a multi-stage sampling approach to collect data from livestock-keeping households in the target sub-county. Initial selection focused on Kajiado County due to its status as the region most significantly affected by Ipomoea plant invasions nationwide. Subsequently, Kajiado Central Sub-County was chosen as the study area as it experiences the highest infestation levels within the county. From this sub-county, three wards (Purko, Dalalekutuk, and Illdamat) were selected. The study employed [21] sample size formula to determine the minimum required sample size, which is the best formula for determining sample size when the variable of interest is a proportion, which is the percentage of households willing to contribute. The study assumed a degree of variability of 0.5, a confidence level of 95%, and a 6% level of precision, as a 6% margin provides a slightly relaxed precision level while ensuring reliable results, making it a practical balance between accuracy and resource constraints.

$$\boldsymbol{n} = \frac{\boldsymbol{Z}^2\mathbf{pq}}{\boldsymbol{e}^2} \tag{1}$$

where: n- Sample rural households required

Z^2 is the desired confidence interval.

e- is the margin of error

p- is the estimated proportion of households who are willing to pay

q- the proportion of households who are not willing to pay

Therefore, the sample size for this study was $\boldsymbol{n} = \frac{(1.96)^2\, 0.5(1-0.5)}{(0.06)^2}$ **n =** 266.777 ≈ 267.

2.3. Types, Sources, and Methods of Data Collection

This research employed a mixed-methods approach for data collection. Primary data, which formed the basis for both descriptive and empirical analysis, were gathered through semi-structured questionnaires administered to selected households in Kajiado Central Sub-County. To complement the findings, secondary data were obtained from diverse sources, including agricultural offices at the sub-county level, national population census records, peer-reviewed journal articles, and book chapters. The survey questionnaire designed for this research aimed to collect data on various household characteristics and, additionally, it included a contingent valuation scenario in the form of a double-bounded dichotomous choice elicitation method with an open-ended follow-up question, which overcomes the complexity associated with questionnaire design and implementation [22]-[24]. While some risk of hypothetical bias remains, this study employed a double-bounded dichotomous choice design to mitigate it. The follow-up question prompts households to think more critically and ground their willingness to pay in a realistic financial context, which helps reduce overstatements and refine the valuation estimates.

Prior to the full-scale data collection, the questionnaire underwent a pilot test involving 22 randomly chosen households across two wards—Matapato North and Matapato South to ensure its validity and clarity [25]. Following the pilot testing phase, the starting bid values were established based on the median willingness-to-pay derived from open-ended responses. The initial bid values (t^1) were set at 4,500, 8,000, 10,000, and 12,000 Kenyan shillings (KES) per household per year, based on the methodologies outlined by [26]-[28]. The follow-up bids (t^2) were adjusted dynamically based on the household's response to the first bid (t^1). If a household accepted the initial bid, the follow-up bid was increased to determine their maximum willingness to pay [26] [29]. These four predetermined bid values were then distributed uniformly and randomly among all surveyed households. The households were assured that the cash annual contribution would be collected efficiently through a mandatory surcharge on existing household utility bills. These collected funds would then be administered by a dedicated and publicly audited trust to ensure they are used solely for the intended conservation purpose.

2.4. Econometric Model Specification

2.4.1. Estimation of Mean Willingness to Pay

This study used the Contingent Valuation Method (CVM), which is the most commonly used approach for estimating values that cannot be derived through traditional market mechanisms. A primary reason for its application is its unique capacity to capture both use and non-use values. This methodology has been effectively employed in several recent studies across East Africa, including research by [30] [31] in Ethiopia, [32] in Kenya, and [33] in Uganda, to assess willingness-to-pay for a variety of environmental goods. When analyzing two dichotomous response variables (WTP1 and WTP2), standard probit or logit models prove inadequate for simultaneous equation estimation. In such cases, the seemingly unrelated bivariate probit model emerges as the preferred econometric approach, as it can concurrently estimate both the initial and follow-up bid equations. Assuming the error terms are normally distributed with a mean of zero and variance of δ_1 and δ_2, the WTP_1 and WTP_2 have a bivariate normal distribution with means μ_1 and μ_2 and variances δ_1 and δ_2, and with correlation coefficient ρ, which is the covariance between errors of the two bids. The probability that $WTP_1 < t_1$ and $WTP_2 < t_2$ *i.e.*

Pro (No-No) is

$$\mathbf{pro}\left(\mathbf{u}_1 + \mathbf{e}_1 < \mathbf{t}_1, \mathbf{u}_2 + \mathbf{e}_2 < \mathbf{t}_2\right) = \boldsymbol{\Phi}\mathbf{e}_1\mathbf{e}_2\left(\frac{\mathbf{t}_1 - \mathbf{u}_1}{\boldsymbol{\delta}_1}, \frac{\mathbf{t}_2 - \mathbf{u}_2}{\boldsymbol{\delta}_2}, \boldsymbol{\rho}\right) \tag{2}$$

Pro (No- Yes) is

$$\mathbf{pro}\left(\mathbf{u}_1 + \mathbf{e}_1 < \mathbf{t}_1, \mathbf{u}_2 + \mathbf{e}_2 \geq \mathbf{t}_2\right) = \boldsymbol{\Phi}\mathbf{e}_1\mathbf{e}_2\left(\frac{\mathbf{t}_1 - \mathbf{u}_1}{\boldsymbol{\delta}_1}, \frac{\mathbf{t}_2 - \mathbf{u}_2}{\boldsymbol{\delta}_2}, \boldsymbol{\rho}\right) \tag{3}$$

Pro (Yes –No) is

$$\mathbf{pro}\left(\mathbf{u}_1 + \mathbf{e}_1 > \mathbf{t}_1, \mathbf{u}_2 + \mathbf{e}_2 < \mathbf{t}_2\right) = \boldsymbol{\Phi}\mathbf{e}_1\mathbf{e}_2\left(\frac{\mathbf{t}_1 - \mathbf{u}_1}{\boldsymbol{\delta}_1}, \frac{\mathbf{t}_2 - \mathbf{u}_2}{\boldsymbol{\delta}_2}, \boldsymbol{\rho}\right) \tag{4}$$

Pro (Yes- Yes) is

$$\mathbf{pro}\left(\mathbf{u}_1 + \mathbf{e}_1 \geq \mathbf{t}_1, \mathbf{u}_2 + \mathbf{e}_2 \geq \mathbf{t}_2\right) = \boldsymbol{\Phi}\mathbf{e}_1\mathbf{e}_2\left(\frac{\mathbf{t}_1 - \mathbf{u}_1}{\boldsymbol{\delta}_1}, \frac{\mathbf{t}_2 - \mathbf{u}_2}{\boldsymbol{\delta}_2}, \boldsymbol{\rho}\right) \tag{5}$$

where:

$\boldsymbol{\Phi}_{\mathbf{e1e2}}$ is the standard bivariate normal cumulative distribution function with zero mean and unit variance and correlation coefficient ρ.

$y_{1i} = 1$ if the response to the first question is yes and 0 otherwise,

$y_{2i} = 1$ if the response to the second question is yes, and 0 otherwise

$d_{1i} = 2y_{1i} - 1$ and $d_{2i} = 2y_{2i} - 1$, i^{th} contribution to the bivariate probit likelihood function becomes

$$\mathbf{L}_i\left(\mathbf{u}_1/\mathbf{t}\right) = \boldsymbol{\Phi}\mathbf{e}_1\mathbf{e}_2\left[\mathbf{d}_{1i}\left(\frac{t_1 - u_1}{\delta_1}, \mathbf{d}_{2i}\frac{t_2 - u_2}{\delta_2}, \mathbf{d}_{1i}\mathbf{d}_{2i}\boldsymbol{\rho}\right)\right. \tag{6}$$

Following [34], a SUBP model can be specified as follows:

$$\boldsymbol{y}_1{}^* = \boldsymbol{\alpha}_1 + \boldsymbol{\beta}_1\boldsymbol{t}_1 + \boldsymbol{e}_1 \tag{7}$$

$$\boldsymbol{y}_2{}^* = \boldsymbol{\alpha}_2 + \boldsymbol{\beta}_2\boldsymbol{t}_2 + \boldsymbol{e}_2 \tag{8}$$

$$\mathbf{E}\left(\boldsymbol{e}_1 \middle| \mathbf{t}_1, \mathbf{t}_2\right) = \mathbf{E}\left(\mathbf{e}_2 \middle| \mathbf{t}_1, \mathbf{t}_2\right) = 0 \tag{9}$$

$$\mathbf{Var}\left(\boldsymbol{e}_1 \middle| \mathbf{t}_1, \mathbf{t}_2\right) = \mathbf{Var}\left(\mathbf{e}_2 \middle| \mathbf{t}_1, \mathbf{t}_2\right) = 1 \tag{10}$$

$$\mathbf{Cov}\left(\boldsymbol{e}_1, \boldsymbol{e}_2 \middle| \mathbf{t}_1, \mathbf{t}_2\right) = \boldsymbol{\rho} \tag{11}$$

where:

$\boldsymbol{y}_1{}^*$ ***is*** ith respondents' unobservable true WTP at the time of the first bid

$WTP_1 = 1$, if $y^1 > Bid_1$, 0 otherwise and $WTP_2 = 1$, $if\ y^2 > Bid_2$, 0 otherwise

$\boldsymbol{y}_2{}^*$ is the i^{th} respondent's implicit underlying point estimate at the time of the second Bid

$\mathbf{t}_1$ and $\mathbf{t}_2$ are the 1st and 2nd bids offered to the respondents, respectively.

$\mathbf{b}_1$ and $\mathbf{b}_2$ are coefficients of the 1st and 2nd bid offered.

$\mathbf{e}_1$ and $\mathbf{e}_2$ are error terms of the 1st and 2nd questions.

Finally, the mean willingness to pay from the SUBP model can be calculated using the double-bounded parameter estimation formula specified by [26].

$$\mathbf{MWTP} = -\alpha/\beta \tag{12}$$

where: $\boldsymbol{\alpha}$ **:** is a coefficient for the constant term, and

β : - is a coefficient of the bid offered to the respondent.

The SUBP model is specified with only the bid and a constant term in the equation to achieve two primary objectives: (1) to derive a robust, mean willingness-to-pay (WTP) estimate, calculated as $-\alpha/\beta$, that is generalizable for policy analysis, and (2) to ensure an unbiased estimate of the correlation parameter, which captures the effect of unobserved individual-specific factors that jointly influence both contingent valuation decisions. This parsimonious specification prioritizes the scope and interpretability of the welfare measure over statistical efficiency, accepting that, while the inclusion of socio-economic covariates could improve estimator precision, it would condition WTP estimates on specific sample characteristics, limiting their broader applicability.

2.4.2. Determinants of Willingness to Pay

When the dependent variable in a regression model is binary, the analysis could be conducted using linear probability, logit, or probit models. However, the results of the linear probability model may generate predicted values less than zero or greater than one, which violates the basic principles of probability. However, logit or probit models generate predicted values between 0 and 1, and they fit well with the non-linear relationship between the probabilities and the explanatory variables [35]. Besides, the probit model works better for bivariate models than the logit model. Furthermore, the double-bounded dichotomous choice question in the current study will have two binary dependent variables. Two latent variables emerged from the two binary dependent variables in this instance. Therefore, in this study, the Seemingly Unrelated Bivariate probit model was used to determine the factors that affect a household's WTP for the control of *Ipomoea* plant species [36]. The Seemingly Unrelated Bivariate probit model is specified as follows: -

$$Y1^* = \beta_1 x_i + \varepsilon_i \tag{13}$$

$$Y_2^* = \beta_2 x_i + \varepsilon_i \tag{14}$$

$$\boldsymbol{Y} = 1 \ \text{if} \ Y_i^* > I_i^* \tag{15}$$

$$\boldsymbol{Y} = 0 \ \text{if} \ Y_i^* < I_i^* \tag{16}$$

Where: β = vector of unknown parameters of the model,

Xi = vector of explanatory variables,

Y_i^* = unobservable households' actual WTP for control of *Ipomoea* plant species,

Yi = discrete response of the respondents for the WTP,

I_i^* = the offered initial bid assigned arbitrarily to the ith respondent,

εi = unobservable random component distributed N (0, σ).

3. Results and Discussion

From the total sample of 267 respondents, 81.15% valid responses were retained for analysis, while 2.62% were excluded due to protest responses of unwillingness to contribute to *Ipomoea* plant species control measures. In accordance with the National Oceanic and Atmospheric Administration (NOAA) panel guidelines for contingent valuation studies, protest responses should be excluded from analysis to ensure unbiased estimation of willingness-to-pay (WTP) values [37]. Many scholars also apply this approach in their willingness-to-pay studies for different environmental goods [38] [39]. According to NOAA, the criteria or the decision rule for classifying protest responses was based on households' self-stated reasons for a zero WTP. Households who cited reasons such as (1) could not afford to pay (90.74%) were classified as true zeros, and households who cited (1) the government should do it (5.56%) and (2) a belief that another party should be responsible for payment (3.70%) were classified as protest respondents and excluded from further analysis. The study utilized cash as payment vehicles. 18.85% of households provided non-willing responses with genuine reasons regarding cash contributions. Therefore, the study comprised a total of 260 respondents, with the majority, 74.62%, residing in the Purko ward. The Dalalekutuk ward accounted for 20.00% of respondents, while the Ildamat ward represented 5.38%.

3.1. Descriptive Statistics on the Households' Characteristics

The descriptive statistics summarize the demographic, socioeconomic, and institutional characteristics of the surveyed households based on their willingness to pay for the control of the *Ipomoea* plant species. The mean age of household heads who were willing to pay was 50.51 years, while for those not willing to contribute, the mean age was 41.92 years. The mean monthly income for the willing group was 19,857 Kenyan Shillings, compared to 11,724 Kenyan Shillings for the non-willing group. In terms of education levels, the average number of years of schooling for those who were willing to pay was 5.21 years, while for those not willing it was 3.37 years. The mean household size, measured in adult equivalent ratio (AE), was 5.28 for those willing to pay and 6.05 for those not willing. The average livestock ownership, measured in Tropical Livestock Units (TLU), was 9.56 for the willing household heads and 6.14 for the non-willing. The dependency ratio, calculated based on household members under 15 and over 65 years of age, was 1.21 for the willing households and 1.52 for the non-willing households. Regarding land ownership, the average land size for households willing to pay was 36.97 acres, while for the non-willing households, it was 21 acres. Finally, the past awareness score related to the *Ipomoea* plant species was 19.22 for willing households and 22.80 for those who were not willing (**Table 1**). As the t-test result depicts, there was a significant proportion difference in willingness to pay between dependency ratio, past awareness about *Ipomoea*, family size, livestock ownership, and education level of the household at a 5% probability level, and there was a significant difference between age of the household and willingness to pay at a 1% probability level (Table 1).

Table 1. The relationship between continuous independent variables and WTP.

Variable	WTP		NWTP		t-value	P-value
	Mean	SD	Mean	SD		
Age (Hage)	50.51	11.54	41.91	13.05	4.24***	0.0000
Income (HIncome)	19,857	13,224	11,724	4519	−4.24***	0.0000
Education years (Edu_years)	5.21	5.46	3.37	4.54	−2.25*	0.0256
Family size (AER)	5.28	2.20	6.05	2.66	2.10*	0.0363
Livestock ownership (TLU)	9.56	11.55	6.14	6.63	−1.99*	0.0474
Dependency ratio (DR)	1.21	0.83	1.52	0.91	2.33*	0.02
Size of own land (land_size)	36.97	55.59	21	27.60	−1.95	0.051
Past awareness (past_awarness)	19.22	9.87	22.80	11.00	2.23*	0.0132

*** shows significant variables at the 1% probability level, ** shows significant variables at the 5% probability level, and * shows significance at the 10% probability level.

The descriptive statistics for categorical variables show the distribution of willingness to pay among different household characteristics. In terms of gender, among male household heads, 119 (86.86%) were willing to contribute while 18 (13.14%) were not willing. Among female household heads, 92 (74.80%) were willing to pay, and 31 (25%) were not willing. Regarding land tenure security, willingness to contribute increased with land tenure security, ranging from very insecure (72.73%) to very secure (100%) as outlined in Table 2. Concerning extension service access, of those who reported having access, 30 (90.91%) were willing and 3 (9.09%) were not willing to contribute. Among those who did not have access, 181 (79.73%) were willing and 46 (20.27%) were not willing. In terms of major livelihood activity, households' willingness to pay varied from casual laborers (71.43%) to livestock rearing (92.00%) as outlined in Table 2. Regarding credit access, among households who reported having access to credit, 28 (96.55%) were willing and 1 (3.45%) was not. Among those without access, 183 (79.22%) were willing and 48 (20.78%) were not (Table 2). As the chi-square (χ^2) result depicts, there was a significant proportion difference between willingness to pay and major livelihood activities and land security at the 1% probability level, and there was a significant proportion difference between gender and willingness to pay at the 5% probability level (Table 2).

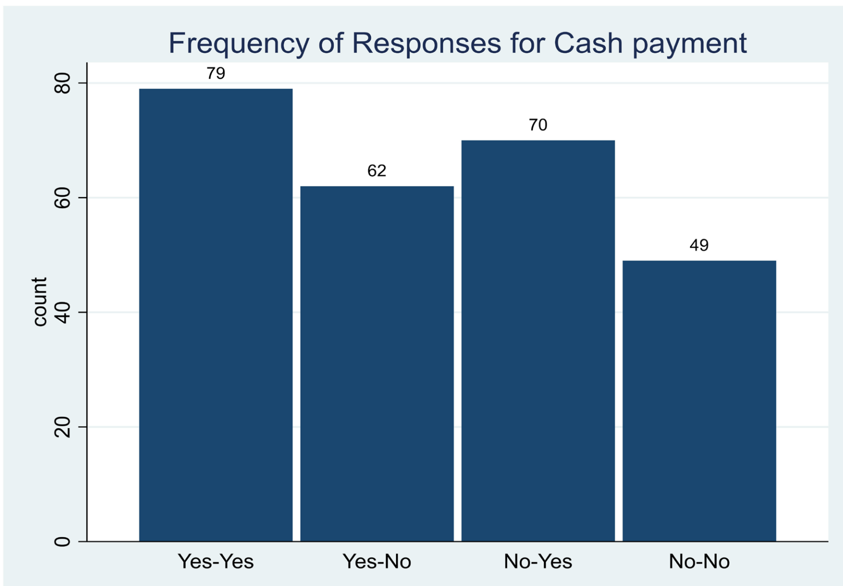
Table 2. Association between demographic and institutional variables (categorical) with WTP.

Variable	Category	WTP		NWTP		Total	χ^2	P-value
		N	%	N	%			
Gender (Rgen)	Male	119	86.86	18	13.14	137	6.17*	0.013
	Female	92	74.80	31	25.0	123		
Land security (land_secure)	Very insecure	72	72.73	27	27.27	99	16.23**	0.003
	Somewhat Insecure	46	79.31	12	20.69	58		
	Neutral	18	85.71	3	14.29	21		
	Somewhat secure	27	79.41	7	20.59	34		
	Very secure	48	100.00	0	0.00	48		
Extension service (Ext_access)	Yes	30	90.91	3	9.09	33	2.35	0.125
	No	181	79.73	46	20.27	227		
Major livelihood activities (Occ)	Casual labourer	15	71.43	6	28.57	21	27.71***	0.000
	Livestock Business	56	65.12	30	34.88	86		
	Salary earner	2	66.67	1	33.33	3		
	Livestock production	138	92.0	12	8.0	150		
Credit service (Cred_access)	Yes	28	96.55	1	3.45	29	5.06*	0.024
	No	183	79.22	48	20.78	231		

*** shows significant variables at the 1% probability level, ** shows significant variables at the 5% probability level, and * shows significance at the 10% probability level.

3.2. Contingent Valuation Results

3.2.1. Response Patterns for the Double Bounded Dichotomous Choice Method (DBDC)



Note: "Yes-Yes" responses indicate acceptance of both offered bids, while "No-No" responses denote rejection of all proposed amounts. Intermediate response patterns occur when participants accept either the initial bid while rejecting the subsequent (higher) offer, or vice versa.

Figure 2. Response patterns in terms of cash payment.

A double-bounded dichotomous choice contingent valuation survey result indicated that 30.38% of households accepted both bids, 23.85% accepted the initial bid but rejected the subsequent bid, 26.92% rejected the first bid but accepted the second, and 18.85% rejected both bids (**Figure 2**).

3.2.2. Application of Econometric Models and Their Estimates

Table 3. Seemingly Unrelated Bivariate Probit parameter estimates for Bids payment.

	Variable	Coefficient	Std. err	P > |Z|	$\frac{-\alpha}{\beta}$	MWTP	$\frac{\mathbf{MWTP}1+\mathbf{WTP}2}{2}$
WTP1	Bid1	−0.0001455	0.0000301	0.000***	−(1.384996)/−0.0001455	9518.87	9541.44
	constant	1.384996	0.2819575	0.000***			
WTP2	Bid2	−0.0003158	0.0000315	0.000***	−(3.020315)/−0.0003158	9564.01	
	constant	3.020315	0.2966435	0.000***			
Athrho		0.7355694	0.2170882	0.001***			
Rho/P***		0.6264608	0.1318913				

Number of observations = 260

Log likelihood = −305.47

Wald chi2 (2) = 106.56

Prob > chi2 = 0.0000

Likelihood-ratio test of rho = 0 chi2 (1) = 17.032 Prob > chi2 = 0.0000

Mean WTP = 9541 KES per year CI at 95% (18,290.13 KES to 5262.405 KES)

The empirical estimation of willingness-to-pay (WTP) from the contingent valuation survey aimed to determine the mean WTP distribution, supported by strong statistical evidence. The highly significant Wald chi-square statistic (Wald χ^2 (2) = 105.56, p < 0.01) (**Table 3**) confirmed the joint significance of the model's coefficients, while the Likelihood Ratio test (χ^2 (1) = 17.03, p < 0.01) validated the interdependence between initial and follow-up responses in the double-bounded dichotomous choice approach. A positive and significant correlation coefficient ($\rho = 0.626$) indicated related but imperfectly correlated WTP responses, justifying the use of the seemingly unrelated bivariate probit model to account for this dependence while allowing for residual variation. This methodological approach aligns with previous studies by [31] [40] [41] [42] in addressing correlated errors in contingent valuation studies. Based on the parameter estimates and applying [26] formula, the mean annual WTP for proposed *Ipomoea* control measures was estimated at KES 9,541.44 per household (**Table 3**). A sensitivity test was conducted to assess the impact of exclusion of protest zeros on mean WTP. When protest zeros were included in the dataset, the mean WTP was estimated at 9,387.29 KES per household. After excluding protest responses**,** the mean WTP increased to 9,541.44 KES per household. This demonstrates that the treatment of protest responses has a substantial effect on welfare estimates, and thus the primary analysis proceeds with the cleaned dataset excluding protest bids.

3.3. Reasons for Accepting and Rejecting the Offered Bids

Out of the 211 households willing to contribute cash, the majority (94.8%) stated that they needed more pasture for their livestock, highlighting the serious impact *Ipomoea* has had on forage availability. Additionally, 55.5% believed the proposed control measure was worth the money. This is consistent with the findings of [41], who found that households were willing to pay for soil conservation of communal lands due to the reason that it was worth the money, and 8.5% expressed a strong interest in managing communal grazing land (**Table 4**).

Table 4. Reasons for accepting the offered Bids.

Reason for Willingness to Pay	Number of Households (n) who answered Yes	(%)	Number of households (n) who answered No	(%)	Total
I need more pasture for my livestock.	200	94.8	11	5.2	211 (100)
I think it is worth that money.	117	55.45	94	44.55	211 (100)
I am highly interested in the management of grazing land.	80	37.91	131	62.09	211 (100)

In addition to the households who expressed willingness to pay, the study also examined the reasons given by those who rejected the offered bids for the hypothetical intervention to control *Ipomoea*. 90.74% of households reported they could not afford to pay. This is consistent with the findings of [40] [41] [43], who identified low financial capacity as a reason and a genuine response. In this study, it was also accepted as a genuine economic limitation. However, five other households rejected the offer on grounds such as that the government should fund the intervention 3 (5.56%) or that it was not their responsibility 2 (3.70%) (**Table 5**). These five cases were also categorized as protest zeros, as they reflect a rejection of the payment scenario rather than a lack of means.

Table 5. Reasons for rejecting the offered bids.

Reasons for Not Willing to Pay	Frequency	Percentage
I cannot afford to pay	49	90.74
The government should do it.	3	5.56
It is not my responsibility.	2	3.70
Total	54	100

3.4. Determinants of Households' Willingness to Pay

Before conducting econometric analysis, multicollinearity was checked. Variance

Inflation Factors (VIF) and pairwise correlation (pw corr) tests were used for continuous variables and dummy variables, respectively. Based on [35], multicollinearity is present if VIF is greater than 10. The analysis showed that there was no significant multicollinearity among the dummy variables (Gender, Extension access, Major livelihood activities, and land security). Therefore, all 12 of the predictors that were hypothesized were used in the estimation of the Seemingly Unrelated Bivariate Probit (SUBP) model (**Table 6**).

Table 6. Variance inflation factor test results for multicollinearity.

Variables	VIF	1/VIF
Bid1	1.75	0.57
Bid2	1.71	0.59
Age	1.60	0.63
Education level	1.54	0.65
Past awareness	1.29	0.77
TLU (Livestock ownership)	1.25	0.80
Income	1.24	0.81
Family size	1.24	0.81
Land size	1.12	0.89
Dependency ratio	1.04	0.96
Mean VIF	1.38	

The bivariate probit model used in this study was statistically significant overall, confirming the model's suitability in examining factors influencing households' willingness to pay for the control of the invasive Ipomoea plant species. In the cash-based willingness to pay model, the Wald chi-square tests for joint significance yielded highly significant results (p-value = 0.0000), indicating that the explanatory variables, taken together, contribute meaningfully to explaining the probability of willingness to pay. Moreover, the rho (ρ) values were significantly different from zero, as evidenced by the Wald test of rho = 0. Specifically, the rho value was 0.406 (p = 0.0351) (**Table 7**), suggesting that the two equations in the model (e.g., WTP1 and WTP2) are not independent. This validates the use of the bivariate probit model over separate univariate probit models, as it accounts for potential correlation between the unobserved factors influencing the two willingness-to-pay outcomes. In other words, households' responses to different bid versions are likely interrelated, and modeling them jointly improves estimation efficiency and accuracy. The log pseudo-likelihood values of −267.6 (cash WTP) also indicate good model fit, especially in the context of the Contingent Valuation Method (CVM). Furthermore, the predicted joint probabilities (Pr (WTP1 = 1, WTP2 = 1)) were 0.40 (**Table 7**), suggesting that a substantial portion of respondents were willing to support Ipomoea control under at least one contribution format.

Table 7. Determinants of rural households' WTP for Ipomoea control measures.

Variables	WTP1		WTP2		Joint Marginal effects
	Coefficient	Std. error	Coefficient	Std. error	
Bid1	−0.0002***	0.0000			−0.0000376
Bid2			−0.0003***	0.0000	−0.0000701
Age	0.0032	0.0085	0.0005	0.0087	0.00083
Gender*	−0.0781	0.1988	−0.0475	0.1964	−0.0274
Education level	−0.0030	0.0209	−0.0007	0.0201	−0.0008
Income	0.0000	7.72e−06	0.0000	7.67e−06	8.06e−06
Livelihood activities	0.1231*	0.0652	0.1415**	0.0666	0.0569
Extension access*	0.6988**	0.2789	0.1829	0.2541	0.1839
Size of land	0.0032*	0.0018	0.0028	0.0018	0.0013
Tenure security	0.1165*	0.0591	0.1211*	0.0558	0.0512
Past awareness	−0.0048	0.0095	−0.0000	0.0102	0.0012
Livestock ownership	0.0262**	0.0106	0.0189*	0.0101	0.0098
Family size	−0.1377***	0.0436	−0.0467*	0.0410	−0.0407
Dependency ratio	−0.1105	0.1084	−0.1368	0.0998	−0.0531
cons	0.95449	0.6071	2.2009	0.6968	
Number of Observation = 260					
Log pseudo likelihood = -267.61494					
Wald χ^2 (26) = 152.40					
Prob > chi2 = 0.0000					
Rho = 0.406					
Wald test of rho = 0: chi2 (1) = 4.44083 Prob > chi2 = 0.0351					
y = Pr (WTP1 = 1, WTP2 = 1) (predict, p11) 0.402					

*** shows significant variables at the 1% probability level, ** shows significant variables at the 5% probability level, and * shows significance at the 10% probability level.

As expected, Initial and Follow-up bid had a negative and statistically significant effect on household willingness to pay for controlling the invasive Ipomoea plant species. In the SUBP model, both Bid1 and Bid2 coefficients were negative and highly significant at the 1% level, indicating that as the proposed monetary contribution increased, households were less likely to accept the bid. Specifically, the joint marginal effects show that a one-unit increase in the bid amount decreased the probability of willingness to pay by approximately 0.0038% to 0.0070%, holding all other variables constant (Table 7). This outcome aligns with the law of demand, which suggests that as the cost of a good or service increases, the likelihood of purchase or support tends to decrease. In this context, increasing the financial contribution required from households reduced their probability of supporting the *Ipomoea* control initiative. Moreover, this result aligns with previous contingent valuation studies, such as [31] [43], who also reported a significant negative relationship between bid amount and willingness to pay for environmental services.

As hypothesized, access to extension services had a positive and statistically significant effect on households' willingness to pay for the control of the invasive *Ipomoea* plant species. Households with access to extension services were 18.4 percentage points more likely to be willing to pay for the control program at the 5% level in the WTP1 equation compared to those without extension access (**Table 7**). This implies that households who have received agricultural extension services are better informed and more aware of the negative impacts of *Ipomoea* on their land, livestock, and livelihoods. The results align with previous research by [42] [44] [45], which demonstrated that access to extension or advisory services significantly increases community participation in conservation efforts and the management of invasive species.

A household's primary source of income significantly impacts their willingness to pay for controlling the *Ipomoea* plant species. As expected, a household's major livelihood activity had a positive and significant influence on their willingness to pay for *Ipomoea* control. In the area studied, major livelihood activities are mainly livestock keeping. The marginal effects suggest that a change in the major source of livelihood leads to an approximate 5.7 percentage point increase in the likelihood of a household being willing to pay for *Ipomoea* control, assuming all other factors remain constant (**Table 7**). This study result is consistent with the hypothesis and a previous study by [46], which reported that pastoralists whose only source of livelihood is livestock production are more willing to pay than those who have other alternatives as their primary source of livelihood, such as farming.

The results show that Livestock Ownership (TLU) had a positive and significant influence on the willingness to pay for *ipomoea* plant species control measures. Households with more livestock units (TLU) were significantly more willing to pay for *ipomoea* plant species than households with fewer livestock units (TLU). This is expected, as *Ipomoea* has toxic effects on livestock, and livestock keepers may be more affected by the economic losses caused by the invasive plant. Therefore, an increase in Tropical Livestock Unit by one more increases the households' WTP by almost 1%, and it happened to be significant at the 5% and 10% probability levels for the first and second responses, respectively, *citrus paribus* (**Table 7**). The results are consistent with the findings of [41] [47] [48], who argued that having a higher TLU indicates not directly households' intention to rehabilitate the area but rather also indicates their intention to get more fodder both directly from their share and by purchasing from others who do not own at all or own a small herd size, or it is due to economies of scale [49] [50].

Conversely, household size (Adult Equivalents) had a negative and statistically significant effect on willingness to pay. A one-unit increase in adult-equivalent size reduced the probability of agreeing to pay by about 4.1 percentage points (**Table 7**). This may be due to larger families facing tighter household budgets or prioritizing other pressing needs over environmental management. The study result is consistent with the findings of [43] [51], who argued that an increase in family size means more expenditures on other things and decreases the per capita income of the members and hence will decrease participation in environmental or natural resource management. Their reason extends to the fact that an increase in family size decreases the per capita income of the members and, hence, will decrease the payment for environmental goods.

4. Conclusion and Recommendations

Grazing lands are facing significant deterioration due to a combination of socio-economic pressures and ecological disturbances. As a primary source of feed for livestock, the degradation of grazing lands poses a serious threat to pastoral livelihoods. Given these concerns, interventions to rehabilitate the grazing lands are important, and so are studies related to local households' willingness to manage the grazing lands. Considering this situation, this study focused on households' willingness to pay for *Ipomoea* plant species control in Kajiado Central sub-county and found that a large proportion of livestock-keeping households in Kajiado-Central sub-county are aware of the threat posed by the *Ipomoea* plant species and are willing to support its control. As the descriptive statistics show, 81.15% were willing to pay cash in KES toward *ipomoea* plant species control measures. This reflects strong community support for a communal intervention targeting the restoration of grazing lands. The contingent valuation method gave the mean willingness to pay values of household contribution using the seemingly unrelated bivariate probit model. These values highlight the commitments of households willing to rehabilitate the invaded grazing lands. Several factors significantly influenced households' willingness to pay (WTP) in *Ipomoea* control measures, including initial and follow-up bid amounts, livestock ownership, access to extension services, the household's primary livelihood activities, and family size. It is therefore recommended that policymakers should consider these variables when designing community projects, and the county government should provide training and demonstrations on effective control techniques. Also, the county should integrate the control of *Ipomoea* plant species into its County Integrated Development Plan (CIDP) as part of broader environmental conservation and livestock productivity strategies. In addition, the county government should collaborate with non-governmental organizations (NGOs), community-based organizations, and research institutions to support the implementation of community-based control programs. It is also recommended that further research should be conducted to examine the effects of *Ipomoea* infestation on livestock productivity at the household level.

Acknowledgements

This research was conducted as part of an MSc thesis program at Egerton University. The authors extend their sincere gratitude to the livestock farmers in Kajiado Central Sub-County for their generous participation and insightful contributions during the field survey. We are particularly grateful for the financial support provided by the Inter-University Council for East Africa (IUCEA) through the Center of Excellence in Sustainable Agriculture and Agribusiness Management (CESAAM), which was instrumental in facilitating this study. Finally, we acknowledge with appreciation the dedicated efforts of all research assistants who contributed to the data collection process.

Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this paper.

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