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Using Choice Experiments to value biodiversity in a Megadiverse Protected Area: The case of Manu National Park, Peru

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ABSTRACT: Biodiversity loss in megadiverse countries such as Peru threatens the resilience of ecosystems and cultural heritage, although evidence of its economic value is limited. This paper estimates the economic value of conserving biodiversity in Manu National Park, a UNESCO world heritage site. Using choice experiments, willingness to pay (WTP) for protecting threatened flora and fauna and reducing deforestation was estimated. The results show higher WTP for threatened flora associated with cultural familiarity. The non-use value amounts to USD 19.7 million, supporting conservation policies.

Experimentos de Elección en la valoración de la biodiversidad en un Área Protegida Megadiversa: El caso del Parque Nacional del Manu, Perú

RESUMEN: La pérdida de biodiversidad en países megadiversos como Perú amenaza la resiliencia de los ecosistemas y el patrimonio cultural, aunque la evidencia sobre su valoración económica es limitada. Este estudio estima el valor económico de conservar la biodiversidad en el Parque Nacional del Manu, patrimonio de la UNESCO. Mediante experimentos de elección, se estimó la disposición a pagar (DAP) por proteger flora y fauna amenazadas y reducir deforestación. Los resultados evidencian mayor DAP por flora amenazada asociada a familiaridad cultural. El valor de no uso asciende a USD 19,7 millones, respaldando políticas de conservación.

KEYWORDS / PALABRAS CLAVE: Biodiversity conservation, choice experiment, willingness to pay, Manu National Park, latent class model / Conservación de la biodiversidad, experimentos de elección, disposición a pagar, Parque Nacional del Manu, modelo de clases latentes.

JEL classification / Clasificación JEL: Q20, Q50, Q57

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1. Introduction

Biodiversity conservation is broadly acknowledged as a global public good, owing to its non-rival and non-excludable characteristics (Bishop & Welsh, 1992; Dasgupta, 2021). According to the Convention on Biological Diversity adopted on 1992 (United Nations Environment Programme, 2011), biodiversity encompasses the variability among living organisms from all sources –terrestrial, marine, and other aquatic ecosystem– as well as the ecological complexes to which they belong. It includes diversity within species, between species, and across ecosystems.

The public good nature of biodiversity conservation presents substantial challenges to the development of market mechanisms capable of capturing its full ecological and social value (Arrow *et al*., 1996; Hanley & Perrings, 2019). As a result, economic valuation has become a central tool to inform conservation policy, particularly in the face of accelerating biodiversity decline (Arrow *et al*., 1993; Shoyama *et al*., 2013; Bhat *et al*., 2020). The urgency of this task is underscored by the essential role biodiversity plays in sustaining ecosystem services such as food provision, water regulation, and climate stability (Bateman & Mace, 2020).

The Amazon basin, for example, supports an extraordinary number of endemic species while performing global functions, including carbon storage and hydrological regulation (Adams *et al*., 2008). Within this context, Manu National Park (hereafter Manu) stands out as a global conservation priority. Designated a UNESCO World Heritage Site in 1987, Manu spans a mosaic of lowland rainforests and montane cloud forests, hosting some of the highest levels of biodiversity ever recorded (SERNANP, 2014). Its protection is not only ecologically critical but also socially and culturally significant for local communities who rely on its natural resources.

Beyond its biological richness, Manu also provides critical cultural ecosystem services (Millennium Ecosystem Assessment, 2005). It serves as a refuge for several Indigenous groups, including peoples in voluntary isolation, and contributes to the preservation of cultural identity, traditional ecological knowledge, and social cohesion (Maffi, 2005; SERNANP, 2014; Berkes, 2017). These dimensions highlight that public support for biodiversity conservation may be driven not only by ecological concerns but also by cultural attachment and heritage meanings associated with the landscape (Chan *et al*., 2012; Fish *et al*., 2016). As such, our valuation framework implicitly captures non-biophysical motivations for conservation, even if not all cultural services were explicitly framed in the attribute design (Martín-López *et al*., 2012).

In response to the biodiversity crisis, the use of economic valuation tools has gained traction among conservation planners and policymakers (Jacobsen *et al*., 2008; Bartkowski *et al*., 2015; Giguere *et al*., 2020). By translating the ecological and non-market values of biodiversity conservation into monetary terms, these tools enable cost–benefit comparisons across policy alternatives and increase the visibility of conservation benefits in decision-making (Hanley & Barbier, 2009; Dasgupta, 2021).

In particular, valuation methods that capture both use and non-use values enhance the societal legitimacy of conservation efforts by recognizing that ecosystems hold value beyond direct exploitation (Millennium Ecosystem Assessment, 2005; TEEB, 2010). Use values reflect tangible interactions with nature –such as recreation, resource extraction, and tourism– while non-use values encompass existence, bequest, and intrinsic motivations for conservation (Norton, 1987; Hanemann, 1994). Including both dimensions acknowledges the preferences of a broader and more diverse public, including those who value nature for moral, cultural, or intergenerational reasons (Kahneman & Knetsch, 1992; Ojea & Loureiro, 2009; Dasgupta, 2021). This broader inclusion supports more representative decision-making processes, and strengthens the democratic foundation of conservation policy (Ring *et al*., 2010; TEEB, 2010; Bateman & Mace, 2020; OECD, 2020).

Among these approaches, stated preference (SP) methods, such as choice experiments (CE), are widely employed to elicit individuals' willingness to pay (WTP) for changes in biodiversity attributes. CE designs allow researchers to evaluate trade-offs among specific ecological features, such as the protection of threatened species or the reduction of deforestation, providing valuable insights into public conservation priorities (Hanley *et al*., 2003; Jacobsen *et al*., 2008; Martin-Ortega *et al*., 2015; Hjerpe & Hussain, 2016).

Despite their widespread use, CEs have rarely been applied in megadiverse countries like Peru, and even less so in the Amazon. This gap limits our understanding of how the public values biodiversity conservation in some of the most ecologically critical regions on Earth. Moreover, most CE studies rely on simplified biodiversity proxies, such as species richness or habitat area, which may not fully reflect ecological resilience or cultural relevance (Bartkowski *et al*., 2015; Castillo-Eguskitza *et al*., 2019).

At the same time, recent methodological advances, such as latent class models (LCM), have improved our ability to account for preference heterogeneity–a key concern when designing socially responsive conservation strategies. These models allow researchers to identify segments of the population with distinct sociodemographic profiles or conservation preferences, thereby informing more targeted and effective policy interventions (Ben-Akiva *et al*., 1997; Birol *et al*., 2009).

Unlike the traditional conditional logit model (CLM), which assumes homogeneous preferences and independence of irrelevant alternatives (IIA), LCM and mixed logit models (MLM) offer greater flexibility in modeling individual-level variation. The LCM captures discrete heterogeneity by probabilistically assigning respondents to preference classes, while the MLM allows for continuous variation in preferences through random parameters (Train, 2009; Hensher *et al*., 2015). These advanced models not only improve statistical fit but also yield more realistic estimates of WTP, particularly in contexts characterized by complex trade-offs-such as biodiversity conservation in Manu.

This study contributes to the growing body of research on SP for biodiversity conservation by applying a CE and LCM in Manu-one of the world's most biologically rich and culturally significant protected areas. While the econometric tools employed are well established in the literature, our contribution lies in their application within an underrepresented yet globally strategic context: a megadiverse region in a low- to middle-income country where empirical evidence remains limited.

By estimating WTP across distinct population segments, our study provides context-sensitive and policy-relevant evidence to support biodiversity conservation. This contribution aligns with international biodiversity goals under the Convention on Biological Diversity and the Sustainable Development Goals, which emphasize inclusive, empirically grounded, and socially legitimate environmental decision-making.

The remainder of this paper is organized as follows. Section 2 outlines the materials and methods used in this study, including the design of CE and the econometric modeling approach. Section 3 presents the results, highlighting key insights into public preferences and WTP for biodiversity attributes in Manu. Section 4 discusses the implications of these findings in relation to prior research and conservation policy, while Section 5 concludes with recommendations for future research and policy development.

2. Methodology

2.1. Study area

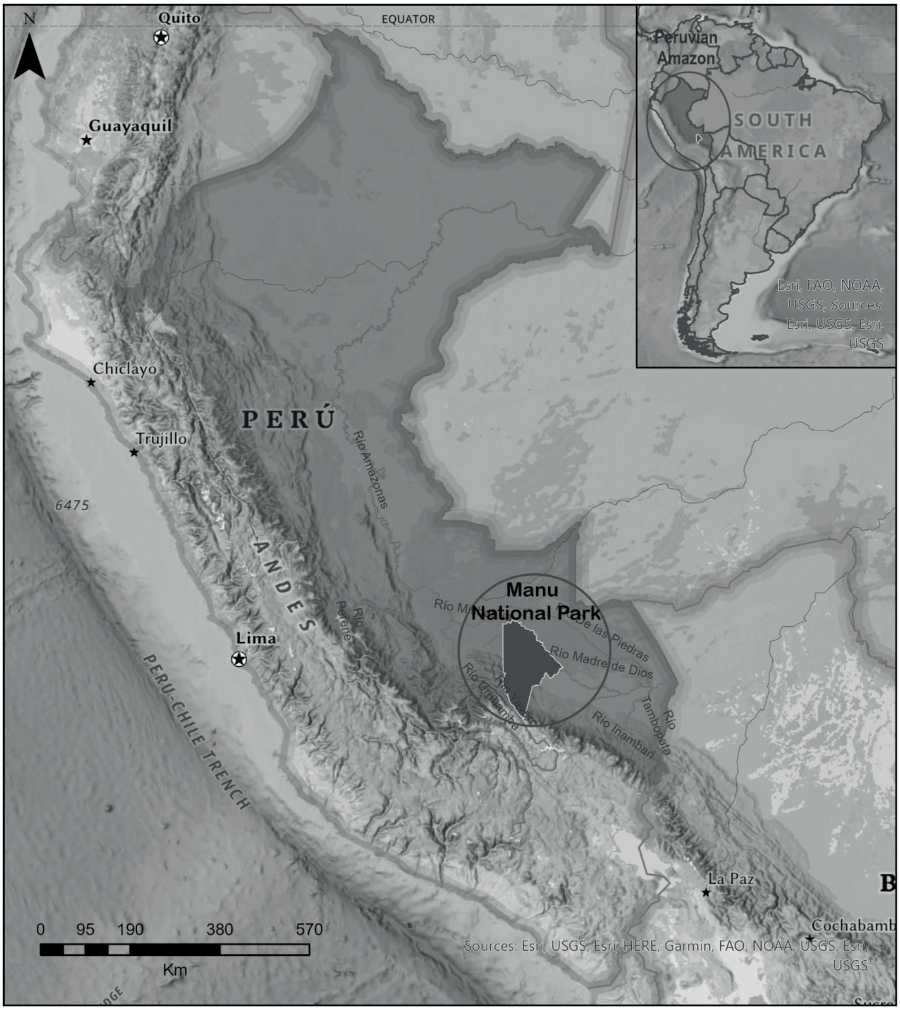
Located in southeastern Peru, Manu covers 1.8 million hectares across the regions of Cusco and Madre de Dios (see Figure 1). This vast protected area is renowned for its unparalleled biodiversity, harboring a significant portion of the flora and fauna of the Peruvian Amazon.

The park harbors more than 160 mammal species, 1000 bird species, 140 amphibians, and 210 fish species. Insects are particularly abundant, with estimates exceeding 30 million individuals, including over 1300 butterfly and 650 beetle species (SERNANP, 2014; SERNANP, 2019). This extraordinary concentration of species has earned Manu recognition as a UNESCO World Heritage Site and a global conservation priority.

From a botanical perspective, Manu contains at least 162 flora families, 1191 genera, and 4385 identified species (SERNANP, 2019). Remarkably, a single hectare within the park can host up to 250 tree species. Furthermore, Manu provides a sanctuary for 10 % of the world's bird species, positioning it as Peru's third-largest protected area, after Alto Purús National Park and Pacaya Samiria National Reserve. Its tropical forests are among the most pristine in the Amazon Basin, experiencing minimal direct human impact. The park is also home to Indigenous peoples representing a rich diversity of Amazonian ethnic groups (SERNANP, 2014).

FIGURE 1

Manu location



Source: SERNANP (2019).

Despite its status as a strictly protected area, Manu faces indirect anthropic pressures arising from economic activities in its buffer zones and surrounding regions. Madre de Dios and Cusco regions support a combination of extractive, agricultural, and tourism-based economies. According to official statistics, more than 30 % of deforestation in Madre de Dios has been attributed to informal or illegal gold mining, while shifting agriculture and cattle grazing account for an additional 25 % (SERNANP, 2019; CEPLAN, 2022). The forestry sector also contributes to land conversion, particularly in the buffer zones, where selective logging of high-value timber species such as mahogany persists despite regulatory efforts. Between 2001 and 2020, Madre de Dios lost over 360000 ha of forest cover, representing approximately 9 % of its original forested area (Global Forest Watch, 2023).

2.2. Modeling approach

Choice Experiment is an attribute-based valuation method extensively utilized in nonmarket valuation since the 1990s (Hanley *et al*., 1998; Boxall & Macnab, 2000; Rolfe *et al*., 2000; Bennett & Birol, 2010; Bartkowski *et al*., 2015; Börger *et al*., 2021). Our study employs a model grounded in the assumptions of McFadden's random utility model (RUM) (McFadden, 1974) and Lancaster's consumer theory (Lancaster, 1966), which conceptualizes consumer preferences based on the utility derived from attributes of goods rather than the goods themselves. The random utility function is represented as follows [1]:

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} \qquad [1]$$

Where U_{ijt} denotes the utility that individual i obtains from choosing alternative j in choice occasion t; V_{ijt} represents the deterministic component of utility, and ε_{ijt} is the stochastic term. The individual selects the alternative perceived to maximize their welfare.

Depending on the assumptions about the error term distribution, various probabilistic models can be applied. One of the most used is the CLM, assuming an extreme Value Type I distribution for the error terms (McFadden, 1974). The estimation of the coefficients (β) in this model is performed using the maximum likelihood method, with the likelihood function expressed as [2]:

$$L(\beta) = \prod_{i=1}^{N} \prod_{t=1}^{T} \frac{e^{\beta' x_{ijt}}}{\sum_l e^{\beta' x_{ilt}}} \qquad [2]$$

Where β is a vector of coefficients associated with the attributes and characteristics of the alternatives, x_{ijt} denotes the explanatory variables, i represents individuals, j and l refer to alternative choices, and t represents decision occasions. The term within the product indicates the probability of individual i selecting alternative j in choice occasion t.

This analysis employs three discrete choice models to estimate the mean WTP for biodiversity conservation: the CLM (Horne, 2006; Bhat *et al*., 2020; Liu *et al*., 2024), the MLM (Delibes-Mateos *et al*., 2014; Greiner, 2016; Ureta *et al*., 2022), and the LCM (Garrod *et al*., 2012; Sangkapitux *et al*., 2017; Schaak & Musshoff, 2020).

The CLM represents a standard approach in SP studies. It assumes homogeneous preferences across respondents and relies on an Independently and Identically Distributed (IID) Gumbel error structure (Horne, 2006). In contrast, the MLM relaxes these assumptions by incorporating random parameters to account for unobserved preference heterogeneity (McFadden & Train, 2000; Hensher *et al*., 2015).

Assuming a normal distribution, the random parameters are represented as $f(\beta \mid b, W)$, where β contains all random coefficients, b is the mean vector, and W denotes the covariance matrix. Since the unconditional choice probability lacks a closed-form solution, simulation methods approximate the integral to estimate the probability, P_{ijt}, of individual i choosing alternative j in choice occasion t, which is defined as follows [3]:

$$P_{ijt} = \int \frac{e^{\beta'_i x_{ijt}}}{\sum_{j=l}^{J} e^{\beta'_i x_{ilt}}} f(\beta|b|W)d\beta \qquad [3]$$

Conversely, LCM assumes a discrete distribution of preferences, where individuals are probabilistically assigned to distinct segments or classes, each characterized by homogenous preferences within the class but heterogeneous preferences across segments (Ben-Akiva *et al*., 1997). LCM supports evaluating how socioeconomic factors and attitudes influence class membership probabilities (Hynes *et al*., 2011). This segmentation is particularly valuable for policymakers, as it enables the identification and analysis of groups with specific preference structures, providing insights into targeted policy design and more effective resource allocation (Boxall & Adamowicz, 2002). The probability of choice varies among classes in this case; that is, the probability of individual i in class q choosing alternative j in choice occasion t is given by (P_{ijt}^{q}) , which is determined as follows [4]:

$$P_{ijt}^{q} = P_{(q)} \cdot \frac{e^{\beta'_q x_{ijt}}}{\sum_{l=1}^{J} e^{\beta'_q x_{ilt}}} \qquad [4]$$

q classes exist, in which the probability of choosing each alternative differs from other classes since the coefficients differ (β_q).

The models provide estimates of the marginal WTP for changes in attribute levels by computing the ratio of the attribute's coefficient to the price coefficient, expressed as $\frac{-\beta_x}{\beta_y}$ (Louviere *et al*., 2000). This ratio represents the marginal rate of substitution (MRS) between the non-market attribute and income, and reflects the amount of money respondents are willing to forgo to secure a marginal improvement in the attribute. In this framework, the price attribute captures the disutility associated with monetary cost, and its negative coefficient ensures that increases in price reduce overall utility, as expected by economic theory. The use of MRS as a measure of marginal WTP allows for the monetization of environmental changes in a way that is consistent with the microeconomic foundations of utility maximization and trade-off behavior (Train, 2009; Hensher *et al*., 2015).

2.3. Choice experiment design

To assess potential changes in the biodiversity of the Manu, we collaborated with ecologists who have extensively studied biodiversity and environmental conditions in the Manu and other megadiverse protected areas worldwide. Given the study's emphasis on biodiversity conservation, we selected diversity indicators that encapsulate conservation factors, including specific habitat and species values.

To refine the CE design, we pretested a list of potential attributes through two focus groups: one composed of members of the general public (n = 6) and another consisting of a multidisciplinary team of ecologists, biologists, and environmental economists (n = 7). This dual approach allowed us to assess both the cognitive accessibility of the attributes for non-expert respondents and their ecological and policy relevance according to domain experts. Similar mixed-group validation strategies have been employed in previous SP studies to balance scientific accuracy with public salience (Christie *et al*., 2006).

This process resulted in four key attributes, each with three to six levels. These attributes (see Table 1) represent meaningful biodiversity proxies identified by focus group participants. As such, our valuation framework implicitly captures non-biophysical motivations for conservation, even if not all cultural services were explicitly framed in the attribute design (Martín-López *et al*., 2012).

The first two attributes measure the number of threatened flora and fauna species. For instance, cedar and mahogany represent endangered flora species, while spectacled bears and jaguars are examples of threatened fauna. Each of these attributes includes three levels, where the loss of 24 species serves as the *status quo* (SQ), reflecting a more critical biodiversity scenario compared to losses of 16 or 8 species.

The third attribute addresses habitat loss caused by deforestation, quantified by the annual number of hectares deforested. Increased deforestation correlates with greater habitat and biodiversity loss. We presented three levels for this attribute: annual losses of 286 ha, 700 ha, and 1400 ha (SQ). We selected these biodiversity proxies because they are ecologically meaningful and culturally salient, offering intuitive reference points for public engagement and actionable insights for conservation planning, rather than abstract complex indicators such as networks of species interactions (Jacobsen *et al*., 2008; Vedogbeton & Johnston, 2020; Dávila *et al*., 2023).

TABLE 1

Attributes and levels of biodiversity of the Manu for the optimal CE design

Attribute	Definition	Proposed levels	Name
Threatened flora biodiversity	Number of threatened flora species in the Manu	Low (8)	flora_8
		Medium (16)	flora_16
		High (24)	*status quo* (SQ)
Threatened fauna biodiversity	Number of threatened fauna species in the Manu	Low (8)	fauna_8
		Medium (16)	fauna_16
		High (24)	SQ
Habitat	Annual average deforestation (ha) in the Manu	Low (286)	def_286
		Medium (700)	def_700
		High (1400)	SQ
Price	Monthly economic contribution in Peruvian soles (PEN) to avoid the loss of the remaining Manu biodiversity attributes	PEN 32, 24, 16, 12, 8, 0 (SQ)	Price

Source: Own elaboration.

The SQ levels were deliberately defined to reflect a critical biodiversity loss scenario, informed by expert judgment and plausible projections under a business-as-usual trajectory.

The final attribute evaluates respondents' WTP to mitigate biodiversity loss across the three attributes. Intuitively, individuals aiming to minimize biodiversity damage should be prepared to contribute higher amounts. Payment options ranged from PEN 0 to PEN 32 (1 USD = 3.70 PEN), with six possible levels (0, 8, 12, 16, 24, 32).

To enhance respondent comprehension and reduce cognitive burden, each attribute was accompanied by color-coded icons and illustrative pictograms that visually represented biodiversity levels. As shown in Figure 2, flora and fauna were illustrated with intuitive symbols –such as leaves, jaguars, frogs, and tapirs– while deforestation levels were represented with images of forest landscapes displaying varying degrees of degradation. Contribution levels included coin icons to improve budget salience. This visual enhancement followed best practices in SP research (Christie *et al*., 2006; Mariel *et al*., 2021) and was refined based on focus group and pilot feedback.

The experimental design was developed using Ngene software and followed a D-optimal design strategy to maximize statistical efficiency (Johnson *et al*., 2013). Each choice set included a constant SQ alternative (option C), with fixed attribute levels representing a critical biodiversity loss scenario. Each respondent was presented with four choice sets, each comprising three alternatives: two hypothetical conservation programs and one SQ option.

FIGURE 2

Choice card example

	OPTION A	OPTION B	OPTION C (STATUS QUO)
Number of threatened flora species	16	8	24
Number of threatened fauna species	16	8	24
Annual deforestation (ha)	700	286	1400
Contribution (PEN)	8	12	0
Choice			

Source: Own elaboration.

2.4. Survey design and sample

Unlike the contingent valuation (CV) method, which directly asks individuals for their WTP or willingness to accept (WTA) compensation, CE presents respondents with a series of hypothetical choice sets in which they must select their preferred alternative among options that vary across defined attributes and levels (Hanley *et al*., 1998; Bennett & Birol, 2010; Giguere *et al*., 2020).

The survey was conducted between October 2018 and March 2019, using face-to-face interviews in accordance with NOAA Panel best practices for SP studies (Arrow *et al*., 1993). Prior to full deployment, we conducted a focus group to refine survey structure, assess clarity of wording, and identify necessary improvements. A subsequent pilot survey with twenty participants further helped reduce potential comprehension biases. The final instrument was divided into three structured sections: introduction and context, choice tasks, and sociodemographic information. On average, the survey took 18 minutes to complete.

The first section of the survey provided an overview of the study's objectives and obtained informed consent from participants. To enhance clarity and engagement, all attributes were illustrated using printed visual materials, including posters and brochures (Christie *et al*., 2006). Respondents were informed that the Universidad Nacional Agraria La Molina (UNALM) and the Servicio Nacional de Áreas Naturales Protegidas por el Estado (SERNANP) were evaluating the implementation of conservation initiatives to reduce biodiversity loss.

The payment vehicle was presented as a mandatory monthly contribution for one year to a biodiversity conservation fund jointly administered by the Peruvian government and SERNANP. Our design followed NOAA Panel recommendations (Arrow *et al*., 1993) to enhance policy realism and consequentiality. The payment was explicitly framed as a program fee rather than a tax or voluntary donation, emphasizing that it would directly funding specific conservation actions in Manu, such as forest monitoring, protection of threatened species, and implementation of management strategies.

To strengthen credibility and reduce hypothetical bias, we incorporated several design elements. Institutional backing from SERNANP and UNALM reinforced the realism of the program (Carson & Groves, 2007), and visual aids illustrated biodiversity outcomes and funding use (Christie *et al*., 2006).

The second section of the survey aimed to elicit respondents' WTP for each choice set, as shown in Figure 2. To minimize hypothetical bias, the survey administration team included a cheap-talk script at the beginning of both the hypothetical market description and the CE, explicitly instructing participants: *"It is VERY IMPORTANT that you carefully consider your household budget and the contributions you are realistically willing to make"* (Do & Bennett, 2009; Mariel *et al*., 2021).

The third and final section collected sociodemographic information, including place of birth, age, marital status, sex, educational attainment, occupation, and income level.

For determining the sample size (*n*), we employed Cochran's formula (Cochran, 1963) [5], which is appropriate for large populations.

$$n = \frac{NZ^2pq}{(N-1)e^2 + Z^2pq} \quad [5]$$

Where: N is the population size, Z is the critical value corresponding to the desired confidence level, p is the expected proportion of the population with the characteristic of interest (in this case, 50 %), q is the complement of the expected proportion, and e the acceptable margin of error (in this case, 5 %).

We implemented a stratified random sampling strategy following Rose & Bliemer (2013), segmenting the population into G mutually exclusive groups based on geographic region. Specifically, we selected seven cities –Lima (51 %), Piura (13 %), Arequipa (11 %), Junín (9 %), Cusco (7 %), San Martín (5 %), and Ucayali (3 %)– which together account for over 55 % of the Peruvian population. The budgetary constraints limited coverage to these departments. The target population consisted of approximately 4.4 million households, each with an average of four members. Although not nationally representative, the selected regions capture considerable socioeconomic and geographic heterogeneity relevant to biodiversity conservation in Peru.

3. Results

We carried out in-person surveys across seven of Peru's largest cities, including Lima. Out of the 1500 individuals approached, 1164 completed the questionnaire, resulting in a 77.6 % response rate–well above what is reported in similar SP studies (Christensen *et al.*, 2011; Mueller *et al.*, 2017; Grilli & Notaro, 2019). The final sample exceeds the minimum requirement of 384 respondents calculated using Cochran's formula [5], thereby enhancing the statistical reliability and subgroup representativeness of the dataset. Notably, most respondents resided in Lima, which accounts for approximately 30 % of the national population and thus constitutes a critical region for understanding urban preferences regarding biodiversity conservation.

3.1. Socioeconomic characteristics

The sample exhibits a balanced sex distribution (48 % male, 52 % female) and an average respondent age of 45 years. The majority of participants were either married or cohabiting (66 %), followed by those who were single (23 %). Regarding household income, 18 % earned below PEN 1801, 47 % between PEN 1801 and PEN 4000, and 34 % above PEN 4000; only 1 % chose not to disclose their income. About 53 % of the people we surveyed had either started or finished higher education, which suggests that the sample included a fairly educated group. The average household size was four members, and 67 % of households included at least one child under 18.

According to national labor statistics, Peru's economically active population reached approximately 17.8 million individuals in 2023, accounting for 53.8 % of the total population (INEI, 2023a). The labor force was composed of 56 % men and 44 % women (INEI, 2023b). In terms of educational background, about 75 % of the workforce had completed at least secondary education (INEI, 2023a). Regarding income, only 21 % of workers reported monthly earnings exceeding PEN 1800 (INEI, 2023a).

Our sample shows higher education and household income levels compared to the national average. This divergence is not uncommon in SP studies in developing countries, particularly when face-to-face interviews are conducted in urban centers due to logistical and budgetary constraints (Christie *et al.*, 2006; Czajkowski & Hanley, 2009). While this limits the statistical representativeness of the sample, it does not undermine the study's core objective: to estimate WTP for biodiversity conservation among a more informed and economically empowered urban segment–groups that are often more capable of processing complex trade-offs and have greater influence on public policy (Bateman *et al.*, 2011; Kaczan *et al.*, 2017).

Nonetheless, we acknowledge that this sampling profile may introduce an upward bias in WTP estimates. In our data, higher-income respondents showed stronger support for conservation attributes, particularly flora and habitat. This is consistent with findings from other CE studies that identify a positive association between socioeconomic status and stated preferences WTP (Birol *et al*., 2009; Alcon *et al*., 2019).

3.2. Model results

Table 2 presents the econometric results for the CLM, MLM, and LCM models. Across all specifications, the coefficients for the threatened flora attributes (flora_16 and flora_8) are positive and statistically significant ($p < 0.01$ in CLM, MLM, and LCM class 1), indicating strong public support for flora conservation, particularly among respondents in class 1 (LC1) of the LCM.

The fauna attributes (fauna_16 and fauna_8) exhibit mixed patterns across models. Fauna_16 shows positive and statistically significant coefficients in CLM, MLM, and LC1 ($p < 0.01$), indicating moderate support for fauna conservation. Fauna_8 also has positive and statistically significant coefficients in CLM ($p < 0.05$) and MLM ($p < 0.01$), but is not statistically significant in either class of the LCM. These results suggest that preferences for fauna conservation are more heterogeneous and less pronounced than for flora attributes.

Regarding habitat attributes, the medium-deforestation level (habitat_700) is associated with a negative and statistically significant coefficient in CLM, MLM, and class 2 (LC2) ($p < 0.01$) in LCM, indicating that respondents perceive disutility from increased forest loss. Conversely, the low deforestation level (habitat_286) is positively valued and statistically significant in CLM ($p < 0.10$), MLM ($p < 0.05$), and LC1 ($p < 0.01$), consistent with expectations of WTP for improved forest conservation. These findings confirm the ecological relevance and societal importance attributed to forest protection in the context of biodiversity conservation.

The MLM further reveals substantial unobserved variation in preferences, as indicated by large and statistically significant standard deviations for several attributes– particularly flora_8, habitat_700, and the SQ alternative. This heterogeneity highlights that preferences for both conservation improvements and maintaining current conditions vary considerably across individuals, reaffirming the importance of incorporating random taste variation in biodiversity valuation models.

The SQ coefficient is consistently negative and statistically significant in CLM, MLM, and LC1, indicating that most respondents dislike the SQ scenario of ongoing biodiversity degradation. In LC2, however, the SQ coefficient is positive and statistically significant, suggesting disengagement or protest among that group.

To determine the optimal number of latent classes, models with two and three classes were estimated. The three-class specification failed to converge despite multiple optimization attempts. Consequently, the two-class model was retained due to its superior statistical fit, convergence stability, and theoretical interpretability. The LCM demonstrates a markedly improved model fit relative to both the CLM and

MLM, with reductions exceeding 1200 points in AIC and more than 400 points in BIC compared to the CLM and MLM, respectively.

TABLE 2

Econometric results for CLM, MLM, and LCM

Variables	CLM	MLM		LCM	
	Coefficient	Coefficient	SD	Coefficient Class1	Coefficient Class2
sq	-0.853***	-2.056***	2.675***	-2.912***	0.521***
	(0.0771)	(0.165)	(0.162)	(0.266)	(0.202)
flora_16	0.502***	0.802***	0.0348	0.545***	0.503***
	(0.0524)	(0.077)	(0.141)	(0.069)	(0.154)
flora_8	0.232***	0.287***	1.172***	0.375***	-0.028
	(0.0553)	(0.0843)	(0.133)	(0.0733)	(0.157)
fauna_16	0.148***	0.288***	-0.00717	0.176***	0.152
	(0.0535)	(0.0746)	(0.146)	(0.068)	(0.143)
fauna_8	0.122**	0.220***	0.0391	0.0919	0.154
	(0.0537)	(0.0689)	(0.173)	(0.0685)	(0.159)
habitat_700	-0.287***	-0.770***	1.968***	0.0653	-1.010***
	(0.054)	(0.11)	(0.144)	(0.0748)	(0.166)
habitat_286	0.0981*	0.164**	-0.0224	0.269***	-0.440***
	(0.0526)	(0.0677)	(0.133)	(0.0717)	(0.138)
cost	-0.0491***	-0.0743**	-0.00332	-0.0529***	-0.0365***
	(0.00432)	(0.00628)	(0.0074)	(0.00518)	(0.012)
Class 1					
Income				-0.144***	
				(0.0421)	
Sex				0.131	
				(0.175)	
marital status				0.0607	
				(0.158)	
Age				0.00427	
				(0.00772)	
education				-0.0671	
				(0.0487)	
household size				0.0248	
				(0.0739)	

TABLE 2 (CONT.)

Econometric results for CLM, MLM, and LCM

Variables	CLM	MLM		LCM	
	Coefficient	Coefficient	SD	Coefficient Class1	Coefficient Class2
children in household				0.0361 (0.106)	
cons				1.219* (0.632)	
Class probability	100 %	100 %		66.80 %	33.20 %
AIC	7379.749	6549.095		6082.307	
BIC	7437.980	6665.558		6254.696	

In parenthesis Robust Standard Errors. p-value < 0.10 (*), p-value < 0.05 (**), p-value < 0.01 (***).

Source: Own elaboration.

In our LCM, class 1 (66.8 % of the sample) displays coherent preferences for biodiversity conservation. The coefficients for flora_16, flora_8, and habitat_286 are statistically significant ($p < 0.01$) and have the expected positive signs, reflecting a clear WTP for flora protection and reduced deforestation. Fauna_16 is also statistically significant ($p < 0.01$) and positive, supporting the interpretation of conservation-oriented preferences.

In contrast, LC2 (33.2 % of the sample) exhibits a more mixed pattern. While flora_16 remains statistically significant and positively valued ($p < 0.01$), the coefficients for habitat_700 and habitat_286 are both statistically significant but negative, contrary to expectations of conservation benefits. Additionally, flora_8 and fauna_8 are not statistically significant in this class, further suggesting lower salience or attribute non-attendance (ANA) among these respondents.

The lower panel of Table 2 reports the class membership function for the LCM, which identifies sociodemographic predictors of latent class assignment. Among the included variables, only income is statistically significant ($p < 0.01$) and negatively associated with LC1. This indicates that individuals with lower income are more likely to belong to LC1, whereas higher-income respondents tend to belong in LC2. Other variables are not statistically significant, suggesting that latent preference heterogeneity across classes is primarily driven by unobserved behavioral factors than by measured demographics.

Table 3 presents the sociodemographic characteristics of respondents by their most probable latent class assignment. LC1, comprising 66.8 % of the sample, includes a higher proportion of males (50 %), older respondents (average age 46), and a significantly larger class of individuals who are married or cohabiting (70 %) compared to LC2. Notably, 68 % of LC1 participants report having at least initiated or completed higher education, versus only 22 % in LC2. LC1 also includes a greater proportion of low-income respondents (21 % earn less than PEN 1800/month).

TABLE 3

Sociodemographic characteristics of respondents by latent class

Variables	Class 1 (n = 778, 66.8 %)	Class 2 (n = 386, 33.2 %)
Sex (% male)	50.00	30.00
Average age (years)	46.03	40.03
Married/Cohabiting (%)	69.86	57.58
Higher education (%)	67.91	22.40
Income < PEN 1800 /month (%)	21.47	10.98
Average household size	4.10	3.87
% with children in home	68.79	67.48

Source: Own elaboration.

Table 4 presents the marginal WTP estimates for each biodiversity attribute across the CLM, MLM, and LCM models. The flora attributes consistently exhibit the highest and most robust WTP values. Both flora_16 and flora_8 are statistically significant ($p < 0.01$) in all models except LC2. In LC1, respondents show particularly strong and coherent preferences, with WTP values reaching PEN 10.29 for flora_16 and PEN 7.09 for flora_8, higher than in CLM (PEN 10.23 and 4.72, respectively) or MLM (PEN 10.78 and 3.86). In contrast, LC2 respondents exhibit a negative and statistically insignificant WTP for flora_8 (PEN –0.77), and a positive but statistically insignificant WTP for flora_16 (PEN 13.77), suggesting lower salience or higher variance in preferences in this subgroup.

The fauna attributes yield mixed and generally lower WTP values compared to flora. In CLM and MLM, the WTP estimates for fauna_16 are positive and statistically significant (PEN 3.02 and 3.87, respectively), indicating moderate support for increasing conservation of threatened fauna. Fauna_8 also shows positive and significant WTP values in both models (PEN 2.48 and 2.96). In LC1, fauna_16 maintains a positive and statistically significant WTP (PEN 3.32), while fauna_8 is positive but statistically insignificant (PEN 1.73). In LC2, both fauna attributes are statistically insignificant, with WTP estimates of PEN 4.16 for fauna_16 and PEN 4.22 for fauna_8. These results highlight heterogeneity in fauna conservation preferences, with somewhat slightly stronger valuation across classes.

The habitat attributes display the widest range of WTP estimates. The low deforestation level (habitat_286) receives positive and statistically significant WTP values in CLM (PEN 2.00), MLM (PEN 2.21), and LC1 (PEN 5.09), consistent with public support for forest conservation. LC1 also yields a small but positive and statistically insignificant WTP for habitat_700 (PEN 1.23), suggesting mild disutility from moderate deforestation. By contrast, LC2 presents statistically significant and negative WTP values for both habitat levels: PEN –12.05 for habitat_286 and PEN –27.64 for habitat_700.

TABLE 4

WTP for CLM, MLM, and LCM

	CLM	MLM	LCM	
			LC1 (66.8%)	LC2 (33.2%)
flora_16	10.23***	10.78***	10.29***	13.77
flora_8	4.72***	3.86***	7.09***	-0.77
fauna_16	3.02***	3.87***	3.32***	4.16
fauna_8	2.48**	2.96***	1.73	4.22
habitat_700	-5.84	-10.35***	1.23	-27.64***
habitat_286	2.00*	2.21**	5.09***	-12.05*

p-value < 0.10 (*), p-value < 0.05 (**), p-value < 0.01 (***).

Source: Own elaboration.

3.3. Manu non-use total value

Following Chen & Chen (2019) and Toledo-Gallegos *et al*. (2022), we developed policy scenarios and estimated the aggregate non-use value of biodiversity conservation in Manu by averaging the WTP estimates for the most preferred and statistically significant attribute levels. Specifically, we constructed a conservation scenario that includes the protection of 8 threatened plant species, 8 threatened animal species, and a reduction of annual deforestation to 286 hectares. These attribute levels were chosen not only for their ecological and policy relevance, but also because they yielded significant WTP estimates across both the CLM and MLM models (see Table 5).

Under this scenario, the estimated mean annual WTP per household is PEN 64.22 (USD 17.36), calculated as the average of the CLM (PEN 61.00) and MLM (PEN 67.44) models. This corresponds to a monthly WTP of approximately PEN 5.35 (USD 1.45). Based on a study population of 4,416,254 households across seven major regions of Peru, we estimate the total non-use economic value of biodiversity conservation in Manu to be PEN 72.8 million (USD 19.7 million) annually. This figure reflects the substantial economic value that surveyed households assign to biodiversity protection in Manu and provides compelling support for public investment in conservation initiatives.

TABLE 5.

Estimated Aggregate Non-Use Value of Biodiversity Conservation in Manu

Biodiversity representation	Level of attribute (WTP) – CLM	Level of attribute (WTP) – MLM
Flora species	16 threatened flora species (PEN 10.23)	16 threatened flora species (PEN 10.78)
Fauna species	16 threatened fauna species (PEN 3.02)	16 threatened fauna species (PEN 3.87)
Habitat	286 ha annual deforestation (PEN 2.00)	286 ha annual deforestation (PEN 2.21)
WTP (household/month)	PEN 5.08 (USD 1.37)	PEN 5.62 (USD 1.52)
WTP (household/year)	PEN 61.0 (USD 16.49)	PEN 67.44 (USD 18.23)
Mean WTP (household/year)	PEN 64.22 (USD 17.36)	
Total Mean WTP per year	PEN 72,808,511 (USD 19,677,976)	

Average exchange rate: USD 1 = PEN 3.70.

Source: Own elaboration.

4. Discussion

This study provides a detailed assessment of public preferences for biodiversity conservation in Manu using advanced econometric models that capture heterogeneity in how individuals value ecological attributes. Consistent with earlier studies (Christie *et al*., 2006; He *et al*., 2017), species richness and habitat integrity emerged as key determinants of WTP, underscoring public support for ecologically diverse and visibly threatened ecosystems.

A central contribution of this research lies in the explicit disaggregation between threatened flora and fauna, a distinction seldom addressed in previous studies (Castillo-Eguskitza *et al*., 2019; Talebi Otaghvar *et al*., 2022). Our findings indicate a clear prioritization of flora over fauna–an outcome that contrasts with results from Japan (Shoyama *et al*., 2013) and Sweden (Carlsson *et al*., 2003), where preferences are distributed across multiple environmental attributes. This likely reflects culturally embedded values, where flora holds significant relevance for livelihoods and cultural identity (Bussmann & Sharon, 2006).

Marginal WTP estimates for flora exceeded USD 3 per attribute, substantially higher than those reported in Iran (Talebi Otaghvar *et al*., 2022), where values fell below USD 1, and surpassing comparable studies in Central Europe (Müller *et al*., 2020; Carlsson *et al*., 2003). This reinforces both the ecological uniqueness of megadiverse settings like Peru and the importance of native flora. As noted by Castillo-Eguskitza *et al*. (2019), culturally salient biodiversity proxies are more likely to elicit meaningful responses from the public.

While overall WTP for fauna attributes was lower than for flora in CLM and MLM models, the LCM revealed significant heterogeneity. In particular, LC2 yielded a relatively high but statistically insignificant WTP for fauna_16, suggesting stronger preferences for charismatic species among certain respondent groups (Wallmo & Lew, 2011; Morse-Jones *et al*., 2012). These preferences may be influenced by iconic fauna such as the spectacled bear or jaguar, which carry symbolic and emotional appeal within Peru's environmental discourse.

Habitat attributes revealed the widest variation in valuation. LC1 –predominantly composed of respondents with higher levels of formal education– demonstrated positive and significant WTP for reduced deforestation, in line with ecological expectations. In contrast, LC2 showed statistically significant negative WTP values for both levels of deforestation. These reversed signs could indicate protest behavior, cognitive burden, or a lack of engagement with technical ecological indicators (Tonn *et al*., 2006; Spence *et al*., 2012). As Christie *et al*. (2007) and Czajkowski & Hanley (2009) point out, abstract attributes such as "hectares lost" may fail to evoke emotional resonance and thus weaken the connection with conservation goals.

While our study initially considered using functionally meaningful ecological proxies, such as network of species interaction, the final CE relied on more conventional biodiversity indicators (e.g., number of threatened species and deforestation levels). The decision to omit functional complexity was driven by concerns over cognitive burden and attribute interpretability. As Castillo-Eguskitza *et al*. (2019) argue, technically robust but abstract indicators may fail to elicit stable preferences. Future research could revisit this challenge by designing hybrid proxies (Bartkowski *et al*., 2015; Jordano, 2016) that combine ecological relevance with cultural familiarity –for example, highlighting species with medicinal or ritual value.

The LCM and MLM models revealed clear patterns of preference heterogeneity, in line with studies by Hanley *et al*. (2003), Birol *et al*. (2009), and Alcon *et al*. (2019). LC1, comprising 66.8 % of the sample, displayed statistically significant and coherent preferences for flora and habitat conservation, while LC2 was characterized by weaker or counterintuitive patterns, likely driven by reduced salience or cognitive disengagement. These patterns were also reflected in sociodemographic characteristics, with LC1 consisting of more educated and economically advantaged individuals, and LC2 including younger respondents with lower formal education.

This aligns with Engel *et al*. (2008) and Kaczan *et al*. (2017), who emphasize tailoring conservation incentives to demographic and motivational heterogeneity.

While the LCM improved statistical fit and revealed distinct preference patterns, its explanatory power is partly constrained by the limited sociodemographic variability of the sample –particularly the high proportion of urban and higher-educated respondents (Boxall & Adamowicz, 2002; Scarpa & Thiene, 2005). This situation may reduce the segmentation potential of the model, as fewer observable dimensions are available for meaningful class differentiation (Hensher & Greene, 2003). Nonetheless, the model identified latent classes with clear and contrasting preference structures, suggesting that unobserved factors –such as motivation and cognitive style– play a role in shaping biodiversity preferences (Spence *et al*., 2012).

Our estimated average WTP was USD 17.36 per household per year, equivalent to approximately 0.48% of the average monthly wage in Peru (USD 300). This proportion is lower than the estimate reported for Spain (2.39 %; Alcon *et al*., 2019), but higher than those found in Iran (0.43 %; Talebi Otaghvar *et al*., 2022) and Norway (0.17 %; Hynes *et al*., 2021). These comparisons underscore the relative strength of biodiversity's non-use value in a developing country context, even among populations with modest income levels.

Despite these insights, several methodological limitations warrant consideration. Our survey did not include self-reported ANA questions, limiting our ability to detect potential sources of bias in welfare estimates (Hole, 2011; Lew & Whitehead, 2020). Although we followed NOAA guidelines and used visual aids to enhance comprehension, some anomalous or statistically weak coefficients likely reflect simplification strategies or cognitive overload (Hensher *et al*., 2015). Furthermore, despite the fact the attribute design was informed by expert consultation and pretesting, we did not formally assess scope sensitivity or plausibility –two key benchmarks of internal validity in SP studies (Arrow *et al*., 1993; Boyle *et al*., 2000; Jacobsen *et al*., 2011; Burrows *et al*., 2017).

The sample's urban and relatively affluent composition constrains the generalizability of our findings. The results primarily reflect the preferences of a more informed and economically empowered segment of the population. This limitation is consistent with other SP studies conducted in urban areas of developing countries (Khai & Yabe, 2014; Owuor *et al*., 2019; Khan *et al*., 2019). Therefore, our findings should not be extrapolated to the national population but rather interpreted as reflecting the preferences of more urban, educated, and environmentally engaged segments of society.

5. Conclusions

This study provides empirical evidence on how the Peruvian public values biodiversity conservation in a megadiverse protected area using CE models. Our findings show that the conservation of threatened flora species elicits significantly higher WTP than fauna or habitat attributes –a pattern not commonly observed in similar studies from Europe or Asia. This preference likely stems from the cultural salience of native plants and their embeddedness in local livelihoods and traditions, particularly within the Peruvian context.

The latent class analysis revealed distinct preference segments. Specifically, individuals with higher education exhibited stronger preferences for flora protection and reduced deforestation, suggesting potential for differentiated financing mechanisms, such as voluntary contributions or payments for ecosystem services (PES) tailored to specific socioeconomic profiles.

Nonetheless, several limitations must be acknowledged. First, the sample is predominantly composed of urban, higher-income, and more educated individuals, which may result in upwardly biased WTP estimates and limit the external validity of the results. Although the sample, while geographically diverse, includes only seven of Peru's most populous departments, it does not capture the full diversity of social, cultural, and geographic contexts across the country. Second, the absence of self-reported ANA limits our ability to detect cognitive simplification strategies or respondent fatigue. Third, scope sensitivity and plausibility tests, which are key components of internal validity, were also omitted.

Despite these limitations, the study adhered to best practices in experimental design, including the use of visual aids, cheap-talk scripts, and participatory pretesting of attributes. Moreover, the application of advanced econometric models allowed us to capture heterogeneous preferences and provide realistic WTP estimates. The aggregate annual WTP of approximately PEN 72.8 million (USD 19.7 million) underscores the substantial non-use value that urban Peruvians assign to biodiversity conservation in Manu. This highlights the cultural and ecological importance of biodiversity in megadiverse settings and the public's willingness to support its protection even in a developing country context.

Future research should aim to improve representativeness by including rural areas and underrepresented socioeconomic groups. Doing so would enhance external validity, reduce potential biases in WTP estimates, and allow for more nuanced modeling of variation in preferences. Further efforts could include the use of self-reported ANA questions to identify cognitive simplification, and the integration of scope sensitivity and plausibility checks to strengthen internal validity. Finally, collaboratively designing valuation attributes with Indigenous communities and incorporating cultural heritage values would improve the salience, legitimacy, and policy relevance of biodiversity valuation frameworks in megadiverse countries.

Authorship contribution

José Dávila-García: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Carlos Enrique Orihuela:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Felipe Vásquez-Lavín:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Hugo Luna:** Investigation, Data curation, Writing – review & editing. **Carlos Minaya Gutiérrez:** Investigation, Data curation, Writing – review & editing.

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Declaration of conflict of interest

None.

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