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ABSTRACT

The economic valuation of ecosystem services is a support tool for decision-making processes associated with the integral management of natural resources. In this respect, the aim of the present study is to estimate the Total Economic Value (TEV) for ecosystem goods and services offered by the Tumucumaque Mountains National Park (PNMT). The methodology used was based on the application of the Contingent Valuation Method (CVM), through a binary logistic regression model for calculating individual Willingness to Pay (WTP), and to obtain the TEV, other methods were used, such as the Avoided Cost Method (ACM), Market Price Method (MPM) and Benefit Transfer Method (BTM). Through a simple stratified probabilistic sampling with proportional allocation, an optimal sample of 167 individuals was obtained from eight municipalities that lie within the confines of the park. The result was a Total Economic Value (TEV) of R$16,062,553,242.47, which corresponds to the Use Value (UV) of R$15,927,316,277.69, divided into Direct Use Value (DUV) R$2,260,299.87 and Indirect Use Value (IUV) R$15,925,055,977.82. As Non-Use Values (NUV), the Existence Value (EV) and Bequest Values (BV) were identified, corresponding to a total of R$135,236,964.79. This estimation aids decision-making processes in conservation units by the bodies and institutions responsible for administration in Amapá State, considered the Brazilian state with the highest preserved area index in the country.

Keywords: Environmental economic valuation. Ecosystem goods and services. Total Economic Value. Tumucumaque Mountains National Park.

RESUMO

A valoração econômica de serviços ecossistêmicos se apresenta como uma ferramenta para auxiliar os processos de tomada de decisões associados à gestão integral de recursos naturais. Neste sentido, o objetivo deste estudo consistiu em estimar o Valor Econômico Total (VET) dos bens e serviços ecossistêmicos que oferece o Parque Nacional Montanhas do Tumucumaque (PNMT). A metodologia utilizada baseou-se na aplicação do Método de Valoração Contingente (MVC), mediante um modelo de regressão logístico binário para a obtenção da Disposição a Pagar (DAP) e na obtenção do VET foram utilizados outros métodos como: Método de Custos Evitados (MCE), Métodos de Preços de Mercado (MPM) e Método de Transferência de Benefícios (MTB). A partir de uma amostragem probabilística do tipo estratificado simples com alocação proporcional, obteve-se um tamanho de amostra ótima de 167 indivíduos de oito municípios do parque, para os quais foi aplicado um questionário. Os resultados alcançados permitiram a obtenção de um Valor Econômico Total de (VET) de R$16.062.553.242,47, do qual corresponde ao Valor de Uso (VU) R$15.927.316.277,69, divididos em Valor de Uso Direto (VUD) R$2.260.299,87 e Valor de Uso Indireto (VUI) R$15.925.055.977,82. Como Valor de Não Uso (VNU) foram identificados os Valores de Existência (VE) e Valores de Legado (VL), correspondendo a um total de R$135.236.964,79. A estimativa representa uma contribuição para o processo de tomada de decisões nas unidades de conservação por parte dos órgãos e instituições responsáveis pela administração no Estado do Amapá, considerado o estado brasileiro com maior índice de área preservada do país.

Palavras-chave: Valoração econômica ambiental. Bens e serviços ecossistêmicos. Valor Econômico Total. Parque Nacional Montanhas do Tumucumaque.

INTRODUCTION

Concerns over environmental protection and conservation became the focus of debate when the adverse effects of economic growth on ecosystems was first challenged in the form of environmentalist criticism in the nineteen sixties and seventies (Andrade, 2008). Ever since, the environment has been discussed in scientific, educational, technological and political scenarios as a top priority issue, given its complexity and negative impacts in ecological and socioeconomic terms (Delgado *et al.,* 2021).

In this respect, contemporary science seeks alternatives that study the interaction between the natural environment and society and incorporate the treatment of environmental problems into their analytical framework. For this purpose, it is necessary to adopt new concepts or methodologies that reconcile the incorporation of economic, natural, social, technological and institutional components into the conceptualization of the theory of the economic value of natural space, its measurement and evaluation of changes associated with individuals' social well-being (Santoyo *et al.,* 2013).

To face this challenge, the economic valuation of the environment is a useful tool for decision-making processes, providing relevant information for the creation of environmental regulation instruments, formulating environmental financing mechanisms or knowing the monetary value of the flow of the planet's natural heritage (Gonzales *et al.,* 2015; Tahzeeda *et al.,* 2018; Gabrielli *et al.*, 2020). An important contribution to the regulation and protection of the environment is found in the establishment of conservation units, widely viewed as an efficient strategy for nature conservation. In Brazil, conservation units are regulated by the National System of Conservation Units (SNUC) (Carneiro *et al.,* 2017).

Considering the importance of conservation units in terms of environmental protection, Amapá State is in the Amazon, with 93% of its territory preserved, of which 60% is made up of conservation units, either for full use or sustainable use. In Amapá, there are 19 conservation units, with a total area of approximately 8,798,040.31 hectares, of which 12 are federal, 5 are state and 2 are municipal. The conservation units are divided into 8 full protection units and 11 sustainable use units (Drummond *et al.,* 2008). Among the conservation units for full use is the Tumucumaque Mountains National Park (TMNP), where the present study was conducted.

The aim of this study is to estimate the total economic value of the ecosystem goods and services offered by the TMNP, using methods such as the Contingent Valuation Method, Avoided Cost Method, Market Price Method, and Benefit Transfer Method. The procedure makes it possible to obtain the direct and indirect use values for the ecosystem services and the non-use values, such as the Existence Value and Bequest Value simultaneously. This estimation of the Total Economic Value (TEV) for the TMNP constitutes a contribution as a support mechanism for the development of management plans and strategic projections in the Amapá State involving natural resource management and can be generalized to other protected areas. It promotes a conception of regional development from the perspective of sustainability, respecting the physical limits of natural resources and can assist public policy makers for the formulation of environmental policies.

The study is structured into five sections, including this introduction. The second section provides the basis for and discusses the main concepts of the economic valuation of ecosystem goods and services. The third presents the methodology, which includes the characterization of the area under study, the data collection and sampling process, a presentation of the binary logit model, and the procedure proposed for estimating the TEV. This is followed by an analysis and discussion of the results, the main contributions of the research, and the final considerations.

ECONOMIC VALUATION OF ECOSYSTEM GOODS AND SERVICES

Environmental economic valuation is an instrument of Environmental Economics to value ecosystem goods and services for which there is no market. It emerged as an alternative for the internalization of externalities and optimal intergenerational allocation of natural resources, given the limitations of conventional economics in offering them a measure of economic value. The very nature of the lack of a real market that considers transactions associated with natural resources leads to a problem of inefficient allocation of resources, thus constituting a market failure (Carneiro *et al.,* 2017).

The current economic system does not consider an analysis of measures of individual well-being based on environmental resources. Therefore, natural spaces clearly provide a measure of well-being, and their degradation would directly affect it. Given this limitation of conventional economic models, environmental economic valuation enables the measurement or estimation of individuals' preferences and their respective measures of well-being when faced with possible changes associated with the enjoyment of a given service, or even with an improvement or reduction in environmental quality (Azqueta *et al.*, 2007; Santoyo *et al.,* 2013).

The idea of measuring preferences, given possible changes in the relationship with an environmental asset, means estimating the welfare function. Thus, measurement through environmental valuation considers broader values than those related only to the use of the resource, but also the possibility of future use, or even non-use. This approach leads to understanding the theory of Total Economic Value (TEV) associated with an environmental asset based on two main benefits: Use Value (UV) and Non-Use Value (NUV). UV refers to the use, plan of use or possible future use of a good or service, while NUV or liability is related to the value of existence, altruism and inherited values (Pearce; Moran, 1994; Bateman *et al.,* 2002; Tietenberg; Lewis, 2012; Tahzeeda *et al.,* 2018; Solikin *et al.,* 2019).

The Direct Use Value (DUV) is defined, derived from possible direct uses and benefits such as the production of wood, food, firewood, and water, as well as hunting and fishing. The Indirect Use Value (IUV) is associated with uses not directly compensated in the market, such as CO_2 capture, water regulation, and nutrient retention. Regarding the UV, it is identified as that which society offers in a context of uncertainty regarding the possible future use of the good. The EV refers to individuals' Willingness to Pay (WTP) for the very existence of the good, even without an actual use of it. The Bequest Value (BV) consists of the value offered so that the good itself can be available for future generations, involving values and moral principles, which includes an altruistic conception (Pearce; Moran, 1994; Azqueta *et al.*, 2007; Tietenberg; Lewis, 2012; Field; Field, 2017).

From this conceptualization regarding the theory of TEV, the contribution of environmental economic valuation processes on the path to sustainable development is noted, due to their importance in defining the principles, policies and protective actions for environmental goods and services (Santoyo *et al.,* 2013). On this path, two approaches guide the valuation process: revealed preference methods and declared preference methods. The former is based on the use of observations of the behavior of individuals in conventional markets in an indirect way, implicitly reflecting their individual preference for an environmental asset. The latter is related to directly obtaining of the declared preferences of the user of the good or service, requiring a simulated hypothetical market (Gabrielli *et al.*, 2020).

In this work, the declared preferences method was used, given its relevant advantage over the possibility of estimating values unrelated to Use Value. The decision to choose corresponds specifically to the Contingent Valuation Method (CVM), used according to the guidelines of the National Oceanic and Atmospheric Administration (NOAA). It is based on a direct approach, simulating a hypothetical market based on the application of a questionnaire, in which individuals declare their WTP for an environmental improvement or even their Willingness to Accept (WTA) as compensation for tolerating an environmental cost or loss (Arrow *et al.,* 1993; Motta, 2006; Hanley; Perrings, 2019; Dasgupta, 2021).

The CVM is one of the most frequently used methods to obtain values of public goods and services and it is widely used by government institutions. According to Carneiro *et al.* (2017), it measures in monetary terms the impact on people's well-being owing to a variation in the quality of the environmental goods or services under study. To arrive at an estimation closer to its real value, when obtaining the TEV, in valuation practices, the use of other complementary methods is recommended for certain ecosystem goods or services. Therefore, in this work, the Market Price Method (MPM), Avoided Cost Method (ACM) and the Benefit Transfer Method (BTM) are used.

According to Raphaela and Kómetter (2018), the MPM can be used when there are market prices for ecosystem goods or services as the most direct way to value them. As for the ACM, it is used for situations when a certain environmental good or service is not available on the market but is related to another whose price is known. Regarding the BTM, it consists of transferring the estimated economic benefit from a site where the study has been applied, "site of origin", to the site where the decisions on the management of natural resources will be made, the "site of policy" (Rodríguez, *et al.,* 2016).

Authors such as Rosenberger and Loomis (2003) and Gonzales *et al.* (2015) recognized three ways of transferring benefits: value transfer or unit value transfer (using a single value from a pre-existing primary study), function transfer or benefit transfer of functions (estimating a function from a single primary study) and meta-regression analysis or meta-analysis function transfer (using a function estimated from sets of functions from relevant studies that are combined and applied in the area under study).

METHODOLOGY

STUDIED AREA

The Tumucumaque Mountains National Park was created through Presidential Decree 4.341 of 22 August 2002 to ensure the preservation of natural resources and biological diversity, and for scientific research and the development of education, recreation and ecological tourism. The park is managed by the Chico Mendes Biodiversity Conservation Institute (ICMBIO).

The region in which it is located is part of the Guiana Shield, the northern region of the South American continent and the northwest of the state. It has a high level of endemic local biodiversity and a high degree of social and environmental vulnerability. Access to the park is limited, as the quality of the road network is considered poor. For this reason, the rivers are extremely important. Considering two forms of access, the park can be reached via a land-river route at five points, as shown in Figure 1.

Figure 1 | Main access routes to the Tumucumaque Mountains National Park.

Source: ICMBIO (2009).

Difficult access to the park is one of the main factors that limit activities for visitors. Although the area covers many municipalities and has a large proportion of their respective areas, the inhabitants are not potential visitors as the park is hard to reach.

DATA AND SAMPLING

The study was conducted in eight municipalities in Amapá State, whose territory is covered by the park and its buffer zone. According to the census by the Brazilian Institute of Geography and Statistics (IBGE, 2010), the estimated population of the municipalities is 102,267, used as a reference for calculating the sample size. The population sizes are: Laranjal do Jarí (39,942), Oiapoque (20,509), Calçoene (9,000), Serra do Navio (4,380), Pedra Branca do Amaparí (10,772), Amapá (8,069), Pracuúba (3,793) and Ferreira Gomes (5,802).

The sample size formula presented by Fávero and Belfiore (2017) for large or infinite populations was used, as shown below:

$$n = p(1-q).[\frac{Z_{\alpha/2}}{E}]^2 n = p(1-q).[\frac{Z_{\alpha/2}}{E}]^2 \quad (1)$$

Where:

n = sample size;

$Z_{\propto/2}$ = critical value of normal distribution for the desired degree of confidence;

p = q = 0.5 represents the maximum variability of the proportion;

E = maximum estimate error.

The optimal sample size, using a 95% confidence level and a maximum estimate error of 7.06%, was 167 respondents for the 8 municipalities. Considering simple stratified probabilistic sampling with proportional allocation, the following formula was used: $n_m = \frac{n_p}{N} * n n_m = \frac{n_p}{N} * n$. Where n_m is the sample by municipality, n_p represents the total number of residents of each municipality, N the total population of all the municipalities, and n is the optimal sample size.

BINARY LOGIT MODEL

In this study, the binary logit econometric model or binary logistic regression was used, considered the simplest model involving qualitative dependent variables. It is used when the dependent variable has discrete values, zero or 1 (binary variable). In this study, the variable assumes the value 1 when it represents the respondent's willing to pay for the destination, or 0 otherwise (Gujarati; Porter, 2011; Woldridge, 2011; Fávero; Belfiore, 2017; Zidora, 2020).

The binary logit model is estimated using the following equation:

$$L_i = l_n\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1\, x_{i1} + \cdots \beta_k\, x_{ik} + u_i;\;\; i = 1,\ldots,n;\; j = 0,\ldots,k \qquad (2)$$

L_i = Logistic distribution function;

l_n= Natural logarithm;

P_i = Probability of the fact occurring;

$1 - P_i$ = Probability of the fact not occurring;

$â_j$ = Parameters (set of explanatory variables);

x_{ij} = Characteristics considered relevant to estimate the probability of an event occurring; and

u_i = Random error.

Considering the regression, the probability of the fact occurring, P_i, is represented by the following equation:

$$P_i = \frac{1}{1+e^{-(â_0+â_1\, x_{i1}+\cdots\, â_k\, x_{ik})}} \qquad (3)$$

Where P_i is the probability of the interviewee *i* answering "YES" when asked about willingness to pay for the destination (park), $\boldsymbol{X}$ is the vector of explanatory variables, and **β** the unknown parameters to be estimated. "The P_i variable is not observed. If the individual answers "YES", Y = 1; and if the answer is "NO", Y = 0. The β variable must be estimated by maximum likelihood" (Silva, 2003; Rodrigues *et al.,* 2018). The beta (β) parameters were estimated using the maximum likelihood method.

$$LOGIT\ (P_i) = l_n\left(\frac{P_i}{1-P_i}\right) = â_0 + â_1 GEN + â_2 SCH + â_3 MAS + â_4 AGE + â_5 PRO + â_6 NOC$$

$$+ â_7 AFS + â_8 MLE + â_9 AFI + â_{10} DQULpku + â_{11} PKU + â_{12} DOA + â_{13} DOI + u_i \qquad (4)$$

Where *Pi* is the expected probability, 1- *Pi* is the complementary probability, β_0, is the intercept, β_j are the estimated coefficients of each variable and $u_i u_i$ the random error. The explanatory variables of the model considered determining factors of WTP are: Gender (GEN); Schooling (SCH); Marital Status (MAS); Age (AGE); Profession (PRO); Number of Children (NOC); Aggregate Family Size (AFS); Monthly Leisure Expenditure (MLE); Monthly Income (MIN); Destination Quality (DQU); Park User (PKU); Degree of Attachment (DOA) and Degree of Involvement (DOI).

In logistic regression models, the contribution of a variable to increasing or decreasing probability is obtained by interpreting the results of the marginal effect (or elasticities) of each variable. To determine the marginal effects of the model variables, the formulas described below are used (Wooldridge, 2011; Gujarati; Porter, 2011, Zidora, 2020).

$$ME = [\frac{e^{\hat{a}_j x_j}}{1+e^{\hat{a}_j x_j}}(1-\frac{e^{\hat{a}_j x_j}}{1+e^{\hat{a}_j x_j}})]\hat{a} \text{ or } ME = [p_i(1-p_i)]\hat{a}_j \quad (5)$$

Where:

ME = Marginal Effect;

p_i = probability of occurrence for the individual *i*;

x_j = explanatory variable *j*;

$\hat{a}_j$ = the estimated coefficient associated with the explanatory variable *j*;

e = the Neperian number.

The Akaike Information Criterion (AIC) was used as a method for selecting and validating the fit. One of the main advantages of the AIC is the possibility of comparing models from different families of distributions; nor does it require further inferences about the model to strengthen its result, in addition to being an easy-to-evaluate model.

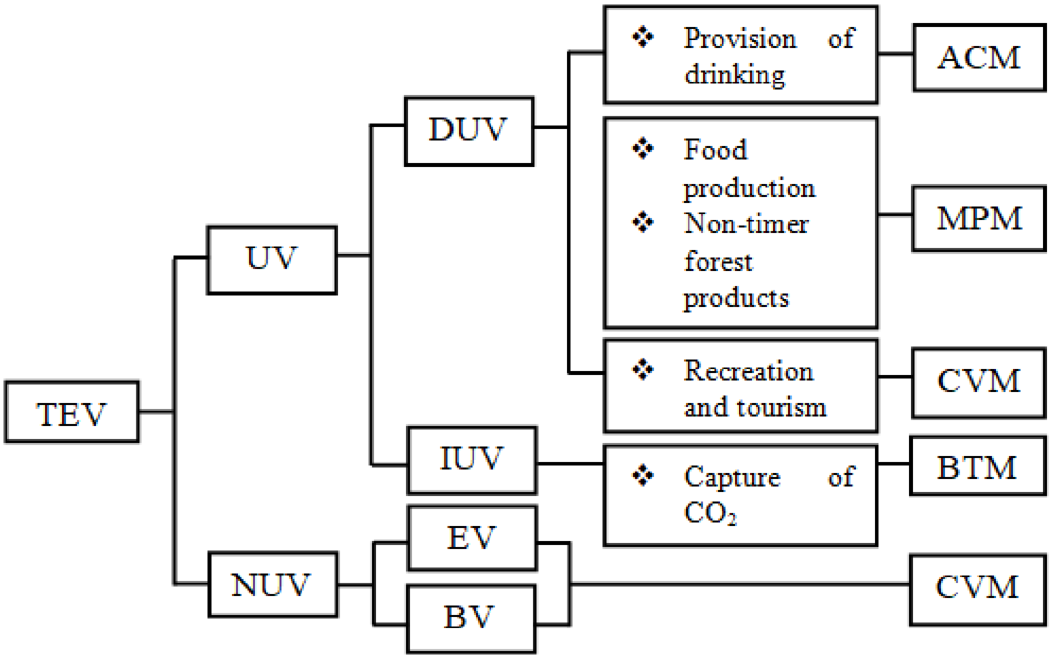
Generalized models present what is called the pseudo-R^2. The interpretation of this value is not similar to the R^2 value of a linear model. However, it is considered analogous, ranging from 0 to 1, and indicates that the model is well adjusted and explanatory according to the result obtained. There are several types of pseudo- R^2. However, this study used the Nagelkerke value, the aim of which is to adjust the Cox-Snell index in a metric that considers values from 0 to 1. According to Field (2009), "it is suggested that the Pseudo-R^2 be used only as an approximate measure of the predictive power of each model".

TOTAL ECONOMIC VALUE

The components of the TEV (UV and NUV) are determined by identifying individuals who have used ecosystem goods and services from the park directly and indirectly, defined as UV, and those who did not visit the park, identified as NUV.

Figure 2, below, describes the classification used and identifies the methods employed to estimate each of the value components that make up the TEV.

Figure 2 | The Total Economic Value of the Tumucumaque Mountains National Park.



Source: Prepared by the authors.

The Use Values include the Direct Use Value (DUV), Indirect Use Value (IUV) and the Option Value (OV). The DUV is determined by applying three methods. The Avoided Cost Method (ACM) is used to estimate drinking water consumption, considering that the communities do not have a private or state-owned logistics structure for water collection and depend directly on the use of services offered by the park.

According to Costa (2016), there are various forms of applying the method, including the use of tropical forest services to purify water, measuring the cost of filtering and chemically treating it. In this study, the costs for the community to obtain drinking water are determined, whether through an independent river capture system or a well, and what additional costs would arise if there were no supply.

To measure food production services and non-timber forest products, the Market Pricing Method (MPM) is used, as suggested by Landolt and Mogrovejo (2018). The method consists of estimating local production values according to regional reference market values, based on information from both indigenous and traditional communities living in the park areas, such as Vila Brasil and Ilha Bela in the municipality of Oiapoque. Prices are set by interaction between producers and consumers through supply and demand (Figueroa, 2010; Gonzales *et al.,* 2015).

The values of recreation and tourism are estimated by applying the Contingent Valuation Method (CVM), based on park users' WTP, with the results based on the construction of hypothetical markets through the questionnaire. The individuals who answered "yes" with regard to visiting the park determine users' WTP (Carneiro *et al.,* 2017). The equation estimates the park's recreational use value (RUV). The total number of positive responses will be subtracted from the number of respondents willing to pay but have not visited the park. The result is multiplied by the number of visitors per year.

In turn, the Indirect Use Value is obtained using the Benefit Transfer Method, measured based on potential CO_2 emissions from the park. The work of Dias (2013) is used as a reference by applying the adjusted unit value with the inflation variable (Melo *et al.,* 2016).

The Non-use Value (NUV), including the Bequest Value (BV) and Existence Value (EV), is estimated using the CVM through non-users of the park, with positive WTP. The CVM captures interviewees' preferences for public goods through questions on WTP. The resulting constructed hypothetical market is fundamental for capturing the WTP values (Mitchell; Carson, 1990; Martínez-Paz; Perni, 2011). Having obtained the TEV component estimates, it is necessary to update the income to perpetuate its value over time, considering its importance to economic valuation in protected areas. The values are analyzed as constant and perpetual incomes using the income update method (Santoyo, 2012).

The update rate used responds to the formulation by Aznar and Estruch (2007), which is the result of the aggregation of the Real Risk-Free Rate (RRFR) and the Benefit Rate (BR). The real risk-free rate is the public debt financing rate, which for Brazil the geometric average of the last five years is equivalent to 5.50% (National Treasury, 2020), minus the annual inflation rate determined by the geometric average of the last 5 years, estimated at 4.23%, according to data from the IBGE (2020), resulting in an RRFR of 1.27%. According to Aznar and Estruch (2007), the benefit rate determines the risk of not obtaining revenue from the use or exploitation of the park's ecosystem services. The study uses a benefit rate value of 2%. Therefore, the update rate value is 3.27%.

ANALYSIS AND DISCUSSION OF THE RESULTS

SOCIOECONOMIC CHARACTERISTICS OF THE INTERVIEWEES

The interviewees' profiles were obtained through the questionnaire. They were needed to obtain the results used for determiners of WTP and the econometric model. The analysis considers the following variables: i) gender; ii) average income; iii) age group; iv) education; v) marital status, and others. They were chosen to help explain the WTP of visitors to the park.

Regarding the population of Amapá State, the Continuous PNAD census of the IBGE (2019) indicates that 52% of the population are female and 48% male. Regarding the interviewees' schooling, which constitutes an important variable for understanding a user's possible perception of the park's goods and services, the largest group had completed higher education 58.68%, (complete high school education 40.12% and incomplete higher education 18.56%), followed by completed higher education 19.16% (complete higher education 18.56%, incomplete specialization 0.60% and complete specialization 4.79%), followed by complete and incomplete elementary education 17.37% (incomplete elementary education 11.38%, complete elementary education 3.59% and incomplete high school education 2.40%).

For the number of household residents, the average value was 3.17 per residence, and for the number of children the average was 1.75 per respondent. The analysis of the interviewees' profile showed that the average income was R$1,500, with a minimum value of R$400. and a maximum of R$15,000. In this case, the average income of the interviewees was R$2,272, higher than the minimum wage, considering the last Minimum Wage stipulated by the Federal Government, in December 2020, of R$1,100 (Brasil, 2020).

Regarding knowledge of the park, 61.08% of the responses were positive. In other words, they had already heard of or visited the park. Although most of the people knew of the park, only 8.38% had visited it.

Of the sample of 167 interviewees, 14 had visited the park. When asked about its quality for recreational use, 42.86% of the interviewees said it was excellent and 28.57% said good or average. The average number of visits per year was 4.35, for various reasons, such as taking advantage of the opportunity for tourism on business trips (64.29%), vacations and weekend excursions (21.43%). Illegal activities were also a reason for visiting the park (14.29%), such as illegal gold mining and poaching. The main activities were hiking, contact with nature, bathing in the river, enjoying the scenic beauty, camping and fishing. The main environmental problems perceived by visitors were the river polluted with mercury due to gold prospecting, poaching animals for commercialization and dumping of solid waste.

ESTIMATES OF WTP

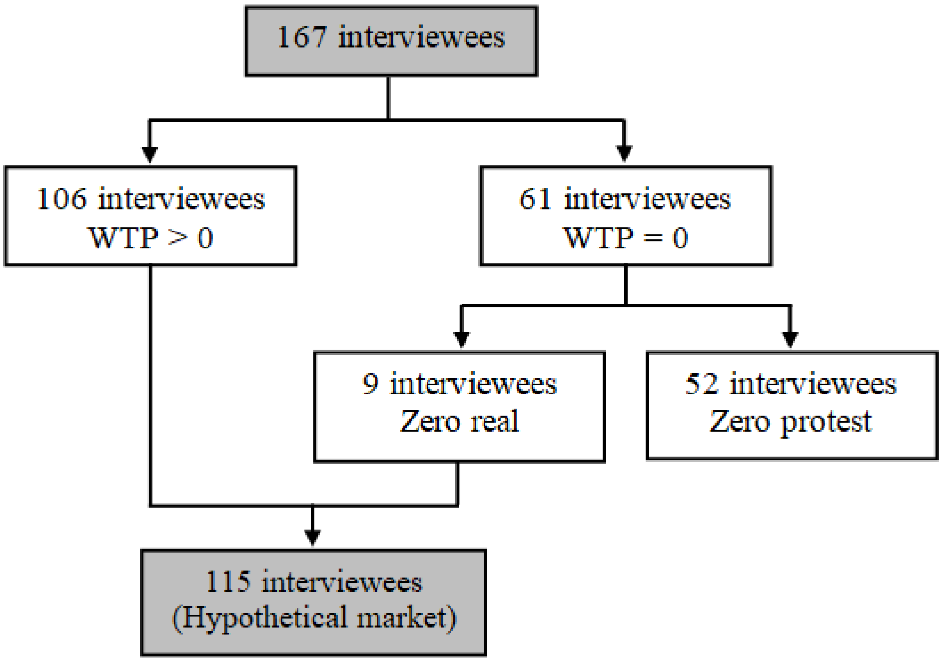
When determining the WTP value, it is necessary to analyze the negative responses on willingness to pay to identify possible votes that can be considered protests, deviating from a WTP determinant with pure motivation given by the interviewee. Among the reasons for negative WTP, 24.59% of the interviewees said they did not have sufficient resources for preservation, 19.67% believed that the conservation of the park was the duty of the government (federal, state and municipal), 16.39% already believed they paid too much tax, 14.75% had no interest in the subject and the other reasons obtained values below 10%.

Based on the reasons for the negative response on willingness to pay, the existence of a protest vote was identified, making it necessary to separate the reasons considered real for not paying and those considered as protests. According to Ulrich and Pirscher (2019), when using the contingent valuation method, null responses are common and, in most cases, correspond to zero protests. Protest votes are negative responses motivated by several factors not purely induced by the simple and true desire not to contribute.

The survey used non-identification as a protest of justifications related to non-payment due to lack of resources and the simple fact of not being interested, which respectively obtained values of 24.59% and 14.75%, with a total value of non-protest responses of 39.34%.

As shown in Figure 3, from the identification of votes considered protests, two examples of WTP are identified. The first consists of a database with all the respondents, whether they have positive WTP, are individuals willing to pay, or negative WTP, being unwilling to pay for the maintenance or conservation of the park, protest votes or not. The last is the data set determined by the process of excluding responses considered as zero protests. Negative WTP determines responses considered as zero value (0).

Figure 3 | Composition of hypothetical market.



Source: Adapted from Martínez-Paz and Perni (2011).

The first model presents the WTP estimate of all 167 respondents, indicating that 63.47% are willing to pay to preserve and maintain the park, with a positive WTP of R$46.89, averaging R$29.43 among all the respondents. The average WTP is determined by values declared by respondents who have already visited the park and those who have never visited. The average WTP value of the 14 visitors is R$32.85 and the value of non-visitors is R$29.11.

The survey identified protest votes, which biased the results of the work. However, considering this reason and its use in the literature, it was decided to remove the protest votes from the database, which resulted in a second database identified as a real hypothetical market.

In the real hypothetical market, with 115 individuals, an average WTP of R$42.73 was identified, and a WTP of non-users of R$43.25. The visitors' WTP is calculated for the number of interviewees who visited the park and is determined by the response of 12 respondents. The variable used to associate the value of the average WTP was the quality of the destination for recreational use. Considering the perceived value, the total points obtained by the respondents in the question was 49, out of a maximum of 60 points, which determines a proportion that the respondents obtained 81.66% of the total possible points. With this, the research assumed that the visitors' WTP value is equal to 81.66% of the average WTP of the real hypothetical market, R$42.73, Therefore the visitors' WTP is R$34.89.

After determining the variables used in the regression, a strong correlation was obtained between Degree of Attachment (DOA) and Degree of Involvement (DOI) with a value of 0.6 and Average Family Income (AFI) and Monthly Leisure Expenditure (MLE) with a value of 0.6, Number of Children (NOC) and Age (AGE). These results were relevant for decision-making in choosing the variables used to adjust the final model. Given the importance of these variables, it was decided to create a new variable or choose the easiest variable for the interviewee to understand. Correlation between AFI and MLE indicated perfect collinearity in this study. Given this situation, the variable MLE_PCT was created (since the correlation between the two is high, to have a more powerful model, it was attributed to a variable that captures the interaction between the two variables). This was characterized as Percentage of Monthly Leisure Expenditure (PCT). In solving the correlation between DOA and DOI, the latter was considered because it was easier for the interviewee to understand.

In Table 1, the binary logit model that includes protest votes, the variable Degree of Involvement was significant, with a p-value of 0.0942 ($p < 0.10$). According to the $R^2_{Nagelkerke}$ value, the model with protests explains only 6% of the variability. It is important to mention that from the estimates, a model was obtained with one variable selected through the AIC and Stepwise method, with only one significant variable. The AIC value obtained is 220.0, which will be compared later to see which of the two is more significant. The variable β_{13} (DOI) presented significance of 0.10.

Table 1 | Result of the estimation of the model with protest votes.

Coefficient	Estimate	Std. Error	Z Value	Pr(>|z|)
$\hat{a}_0$	0.1197	0.2986	0.401	0.6885
$\hat{a}_{13}\hat{a}_{13}$ (DOI)	0.2082	0.1244	1.674	0.0942*
$R^2_{Nagelkerke}$	0.06			
H_L	0.25			
AIC	220.3			

Source: Prepared by the authors based on the research results.
"***" significant at a 0.001, "**" significant at 0.01, "*" significant at 0.05. "*" significant at 0.10.

From this estimate, the influence of zero protests can be observed in such a way that it is biasing the model, making its result unfeasible. However, neither a 0 nor a 1 are considered as a response. In the binary model, the binary response assumes a response of 0 or 1. It is important to emphasize that in this model, only the DOI is significant. Considering that the protest votes biased the model's results, it was decided to create a new model, as shown in Table 2, an estimate with the true WTP, considering only 115 respondents from the hypothetical real market. For the logit regression model without protest votes, the adjusted model indicated significance in a larger set of variables.

Table 2 | Result of the model estimation without protest votes.

Coefficient	Estimate	Std. Error	Z Value	Pr(>|z|)
$\hat{a}_0$	0.89357	2.12371	0.421	0.6739
_$\hat{a}_4\hat{a}_4$ (AGE)	0.20119	0.09805	2.052	0.0402*
_$\hat{a}_6\hat{a}_6$ (NOC)	-0.51825	0.32052	1.617	0.1059
_$\hat{a}_7\hat{a}_7$ (AFS)	-0.49544	0.25055	1.977	0.0480*
_$\hat{a}_{14}\hat{a}_{14}$ (MLE_PCT)	-7.15671	2.89714	2.470	0.0135*
$R^2_{Nagelkerke}$	0.36			
H_L	0.07			
AIC	56.551			

Source: Prepared by the authors based on the research results.

"***" significant at 0.001, "**" significant at 0.01, "*" significant at 0.05 and "*" significant at 0.10.

The model shows that Age has a p-value = 0.04 ($p < 0.05$), Aggregate Family Size, p-value = 0.10 ($p < 0.05$) and Percentage of Monthly leisure expenditure ($p < 0.01$), are predictors for the WTP, all with significance of $p < 0.05$. In the second model, there was an improvement in prediction, models without protest votes, with $R^2_{Nagelkerke}$ explaining 0.36 of the variability. In terms of predictive validity, the Hosmer-Lemeshow test indicates a p-value > 0.05, determining that there are no significant differences between the results predicted by the model and those observed. However, it is important to point out that despite having an acceptable fit according to the p-value statistic, the result is very close to the limit value of the test, which may indicate possible better adjustments. The model without protests is considered the best-fit model, presenting the lowest AIC 56.551.

The estimated model for WTP for the Tumucumaque Mountains National Park was:

$$WTP = 0.8936 + 0.2012\text{AGE} - 0.5183\text{NOC} - 0.4954\text{AFS} - 7.1567\text{MLE\_PCT} \quad (6)$$

Regarding the beta signals of the variables, age (AGE) was the only one with a positive beta coefficient signal, which represents that with each unit increase in age there is an increase in the probability of being willing to pay. According to Desta (2018), an increase in the unit of dependents in the household reduces the probability of a positive WTP. Households with fewer dependents are more likely to pay for conservation or access to the park. Regarding the number of family members and the interviewee's number of children, both had a negative coefficient signal, -0.51 and -0.49. As a justification, it is understood that the higher the number of dependents or family members, the lower the probability of positive WTP. To understand proportional spending on leisure, the beta coefficient signal is negative, meaning that the greater the proportion of spending on leisure, the lower the probability of paying for a park admission fee, or even its conservation. (Desta, 2018).

Regarding the marginal effects, the results show that the average marginal effect for age determines that each increase in units per year increases the probability of WTP being positive by 1%. For the number of family members, each increase in the units reduces the probability of positive WTP by 2%. Furthermore, for percentage of monthly leisure expenditure, the effect is a reduction in the probability of 42% with increases in the percentage of monthly leisure expenditure.

Considering the significant variables selected from the AIC method, the maximum probability of occurrence was calculated from the observed sample:

$$p(x) = \frac{\exp(\beta_0+\beta_1 x_1+\cdots+\beta_k x_k)}{1+\exp(\beta_0+\beta_1 x_1+\cdots+\beta_k x_k)} \quad (7)$$

As:

$$\exp(0.8936 + 0.2012 * 34.47 - 0.5183 * 1.71 - 0.4954 * 3.13 - 7.1567 * 0.19) = 56.36$$

Thus: $$p(x) = \frac{56,36}{1+56,36} = 98,25\% \quad (8)$$

The result shows that interviewees who indicated in their profile variables determined by the model as significant, and that have values equal to or close to the average values of the variables, are more likely to be willing to pay for the maintenance, preservation and structuring of the park by up to 98.25% compared with those who did not interact in the indicated variables. It is important to emphasize that there is an infinity of variables that can have a direct influence on the minimization or maximization of the probability of occurrence, although the present study was based only on characteristics observed through variables indicated in the model.

ESTIMATION OF THE TOTAL ECONOMIC VALUE

For the DUV, the study estimated provisioning values from the production and cultivation of food in the community of Vila Brasil. In an interview with community residents, a production quantity of 2.5 tons of cassava per year was obtained and to estimate market values, a telephone survey was conducted with market vendors in the municipality of Oiapoque, where they were asked about the price of raw cassava. The response was an average price of R$4.00 per kilo. The production cost of a cassava crop is estimated at R$1,882.72ha. Using variables shown in Equation 8, the production quantity of 2.5 tons was multiplied by the market price, obtaining a gross revenue value of R$10,000.00, subtracting the production cost of R$1,882.72, this left a net revenue of R$8,117.28, which corresponds to production per year. Table 3 presents the values according to the community's production (CONAB, 2021).

Table 3 | Market price for agricultural products.

Crop	Market price	Quantity (Kg)	Production cost (R$)	Net value (R$)
Cassava	R$ 4/kg	2.500 kg	R$ 1.882,72/ha	R$ 8.117,28

Source: Prepared by the authors.

The partial value of the food provision service was R$8,117.28 per year. Applying an update rate of 3.27%, the updated value of the service is R$248,190.02.

Table 4 shows the non-timber forest products identified in the Vila Brasil community, namely cupuaçu and açaí, extracted through the subsistence production model.

Table 4 | Market price for non-timber forest products.

Product	Market price	Quantity (Kg)	Production cost (R$)	Net value (R$)
Cupuaçu	R$2.67 c/u	1,500 kg	R$801.00	R$1,869.00
Açaí	R$1.20 /kg	22.400 kg	*	R$26,880.00

Source: Prepared by the authors.

Note: *There is no production cost for açaí as it is an extractive activity.

Applying the 3.27% update rate to the value of cupuaçu and açaí cultivation for the community, which was R$28,749.00, the value of use of non-timber forest products was found to be R$879,015.49.

The community of Vila Brasil, located on the right bank of the Oiapoque River, within the limits of the park in the Brazilian Amazon, has a population of 271, with most living along 1.7 km of the riverbank (ICMBIO, 2020). Vila Brasil does not have basic sanitation infrastructure, whether for drinking water supply or sewage. According to ICMBIO (2020), to obtain drinking water, the natives seek water from other communities, use water from the river, or from caves with springs near the community.

Based on the identification of water consumption rates charged by the Amapá Water and Sewage Company, the ACM was used to estimate the amounts avoided by offering water supply services for consumption and irrigation. To define the rate used in the equation, approximately 120 family units were considered, which represent a consumption and income unit (ICMBIO, 2020). There are on average 2.25 residents in each family unit. This number, multiplied by 200 liters of water per day, which is the average individual consumption in Brazil, means 450 liters a day, multiplied by 30 for monthly consumption. This means a consumer unit of 13,500 liters a month. This value falls within a consumption rate of R$24.96, with R$22.6 as the minimum rate and R$2.36 as the excess rate. These values mean that the monthly values of the community are approximately R$2,995.20 per month, which multiplied by 12, determine an annual estimate of R$35,942.40. Applying an update rate of 3.27%, the updated value of the service is R$1,098,957.41.

To determine the Recreational Use Value (RUV) of the park, the WTP value of the users in the real hypothetical market is considered, which is R$34.89. This is multiplied by the number of visitors to the park in a year, which according to the ICMBIO (2020), was 32 visitors.

$$RUV = 34.89 * 32 = 1{,}116.48 \quad (9)$$

Applying the value found for the RUV of R$1,116.48, at an update rate of 3.27%, results in an updated value of R$34,136.95.

The benchmark for the estimate of the IUV, through the capture of CO_2, was the study by Dias (2013), which considers that the area of the units is not totally forested, using an approximate forest value of 90% of the park's area. Based on these premises, the State Forestry Institute (IEF, 2012) and

Dias (2013) use 4 modules of the Amapá State Forest as a reference for determining the potential carbon value, obtaining a value of 182.10 tC/ha, multiplying this value by US$ 2.00. Estimating for the 19 conservation units of Amapá, a value of 62 million tC/year was found. For the park, potential carbon emissions of 13,944,937.57 tC were estimated at a value per ton of carbon of US$ 2.00.

At the National Petroleum Agency (ANP) the CBIO on the B3 varied from R$20 to R$37.35 in September 2020. The value of the dollar at the time was R$3.64, according to the CETIP (2020). The annual value to be generated by the economic potential of the park's carbon reserves is 13,944,937.57 tC/year. In monetary terms, the estimated value of the park's CO_2 capture, calculated as a CBIO reference CO_2 value of R$37.35, with the value applied in October 2020, was R$520,843,418.24. Applied to an update rate of 3.27%, the value is equivalent to R$15,925,055,977.82.

The existence and bequest values are defined in this research by applying the WTP of non-users of R$43.25, multiplied by the number of residents. According to the IBGE Demographic Census (2010), in the eight municipalities of Amapá there are 102,267 people. Applying the values found, the NUV defined by BV and EV is R$4,423,047.75. At an update rate of 3.27% the value results in R$135,236,964.79.

Thus, the Total Economic Value (VET) estimated for the Tumucumaque Mountains National Park is R$16,062,553,242.47, formed by a DUV of R$2,260,299.87, IUV of R$15,925,055,977.82 and a NUV of R$135,236,964.79. This approach, as stated by Lujan *et al.* (2023), provides reliable information that can facilitate the inclusion of the concept of ecosystem services in current conservation policies, as well as explore policy alternatives focused on the sustainable use of natural resources. In this sense, the present research can support policy makers like the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) and the Chico Mendes Institute for Biodiversity Conservation (ICMBIO), administrative agency in charge of park management.

From a social perspective, this environmental economic valuation for ecosystem goods and services offered by the TMNP means being able to have an indicator of its importance in the welfare of society, specifically as a natural heritage for the Amapá State. Thus, this study demonstrates that the economic valuation of said assets is in order to make better use of public resources and enable the distribution of the public budget among the different public investment alternatives, as well as among the different initiatives for the conservation, preservation or restoration of environmental assets resources (Lujan *et al.,* 2022).

The estimated TEV highlights the importance of the ecosystem goods and services offered by the park, considering the greatness and importance of the biome. Some authors such as Romero *et al.* (2020), argue that the TEV methodology makes it possible to show that environmental assets can be granted an economic value, not as a commercial asset, but rather to clarify the amount they represent for the services provided, whether to the public or private sector. It is also a tool that is used to gather the highest number of criteria present in the area to be studied, generating a real assessment.

Analyzing the results and discussions presented, it is possible to identify, as Nijkamp (1997) points out, that there are many analytical connections between regional and environmental economic phenomena. This thought is based on the nature of such interaction, because it depends on ecosystems and human behaviour and at the same time, on spatial-environmental policy. Environmental policy has a direct bearing on regional and urban development, while regional and urban policies have immediate implications for environmental quality.

CONCLUSIONS

The aim of the present article was to estimate the Total Economic Value of ecosystem goods and services offered by the Tumucumaque Mountains National Park. The study enabled the verification of the conceptualization of the TEV as a joint function of multiple Use Values (Direct Use Value, Indirect Use Value and Recreational Use Value) and Non-Use Value (Bequest Value and Existence Value).

The methodology was based on applying a method of declared preferences, specifically the Contingent Valuation Method, using a binary logistic regression model to estimate the Willingness to Pay (WTP) of 167 interviewees from eight of the nine municipalities in the area of the park. Economic, sociological and psychological explanatory variables and their respective marginal contributions were considered. Only age had a positive beta coefficient sign, meaning that each unit increase in it means a greater probability of being willing to pay. Regarding the interviewees' number of family members and number of children, both presented a negative coefficient sign, so that the greater the number of dependents or family members, the less likelihood of a positive WTP. In turn, proportional expenditure on leisure activities had a negative beta coefficient sign, meaning that the greater the proportion of expenditure on leisure, the less likely an individual is willing to pay to visit or maintain the park.

The estimation of the TEV components was enriched by the use of other methods such as the Avoided Cost Method, Market Price Method and Benefit Transfer Method. Regarding the ACM, activities that required water consumption were identified in the community of Vila Brasil, a community in the municipality of Oiapoque. The avoided cost value identified in the study was R$1,098,957.41. To identify values provided by the park for food and extraction of non-timber resources, the Market Price Method was used, which consists of identifying the production obtained by the residents of the conservation unit and applying market price values. Production values of cassava as a food product and non-forest products, cupuaçu and açaí, were identified, valuing R$1,127,205.51. The method used to identify the Indirect Use Value was the Benefit Transfer Method, which consists of using values already defined in previous work in similar areas and spaces, or in the same space, with updates at the time of application used. Thus, the Indirect Use Value was R$15,925,055,977.82.

Identifying and obtaining the Recreational Use Value, Bequest Value and Existence Value was achieved through the Contingent Valuation Method, based on constructing a hypothetical scenario for individuals' willingness to pay for the conservation unit. The values found were R$34,136.95 for the RUV and R$135,236,964.79 for the NUV, which includes the Bequest Value and Existence Value. The estimate of the Total Economic Value (TEV) for the Tumucumaque Mountains National Park had a total value of R$16,062,553,242.47.

This study contributes to contemporary economic science in favor of reorganization in the conceived need to incorporate environmental problems into its analytical framework. It can be used as a benchmark for future research in environmental conservation units and as a support tool for decision making, aiding institutional, political, economic and environmental dialogue for better management and sustainable use of integral preservation areas such as the Tumucumaque Mountains National Park.

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