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Research article

Estimating the recreational use value of Tis-Abay Waterfall in the upstream of the Blue Nile River, North-West Ethiopia

Atalel Wubalem [a,*], Travis W. Reynolds [b], Amare Wodaju [a]

[a] Department of Agricultural Economics, Bahir Dar University, Ethiopia
[b] Department of Community Development and Applied Economics, University of Vermont, USA

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ABSTRACT

Tis-Abay Waterfall is a famous tourist destination in northern Ethiopia, attracting both domestic and international visitors. Although the site's recreation and tourism potential are enormous, the value of the waterfall remains underestimated; an application of economic valuation methods can provide information to better utilize the resource. This study estimates the recreational value of Tis-Abay Waterfall and analyzes the consumer characteristics associated with recreational demand. Drawing on data from 1044 on-site surveys, the study uses the Individual Travel Cost Method (ITCM) with a Zero-Truncated Poisson (ZTP) regression model. Results of the ZTP regression suggest that visitors' age, monthly income, and interest in alternative recreation sites like Lake Tana and Gondar Fasiledes Royal Castle are variables significantly and positively related with recreational demand for the Tis-Abay Waterfall. However, visitors' recreational demand is negatively associated with respondents' distance from the site, leisure time, and total cost of site access. The appraisal suggests that the Tis-Abay Waterfall has a significant annual recreational value of $9.5 million. But it also shows that the waterfall's value would increase significantly, up to $17.3 million, with hypothetical quality improvements in the waterfall settings. The value attachment suggests that estimating the recreation value for Tis-Abay Waterfall is a central component in the sustainable use and management of the resource. However, the presence of unfavorable trade-offs with the electric power plant and the inadequate infrastructure and services for reaching the site are major concerns that require immediate attention to make better use of Tis-Abay Waterfall's recreational services.

1. Background and justification

Social well-being can be enhanced when resources are managed and utilized in a more economically optimal, socially acceptable, and environmentally sustainable manner (Green, 2003; Stamou and Rutschmann, 2018; Guo et al., 2020; Shaw, 2021). To assess and integrate these parameters, an all-encompassing value attachment to the resource must be in place (Pearce et al., 2006; Russo and Smith, 2013; Champ et al., 2017).

In recent years, economic benefit-cost analysis has expanded its scope from traditional market-oriented approaches to more inclusive forms of resource valuation through non-market-based resource valuation techniques (Lipton et al., 1995; Pearce et al., 2006; van Zanten et al., 2016). Amenities from parks, forests, landscapes, lakes, coastal areas, rivers, and waterfalls are not exchanged on the conventional market, and therefore do not have market prices to be traded. However, they are valuable for human wellbeing (Lipton et al., 1995; Pearce et al., 2006; van Zanten et al., 2016).

Despite the fact that recreation is among the most common use-values of water bodies, nature-based recreational sites in particular are often undervalued in low and middle-income countries (LMICS) and instead regarded as public goods with non-excludable and non-rival characteristics (Zhu and van Ierland, 2012; Almaktar and Shaaban, 2021). In some cases, they are also used as open-access properties because there is no entry charge or enforcement of entry fees is weak (Ward and Beal, 2000; Boyer et al., 2017; Zhang, 2019). This suggests that traditional quantity-price-based market demand models cannot reflect the exact values and worth of recreational sites in LMIC contexts (Birol et al., 2006; Ward, 2012; Loomis et al., 2018).

* Corresponding author.
E-mail address: wubalematalel@yahoo.com (A. Wubalem).

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The issue is particularly important for the Blue Nile River's waterfall in northern Ethiopia, Tis-Abay Waterfall, which is heralded as a place of nature's wonder (Bruce, 1813; Brouwer et al., 2016; Addis Tessema et al., 2020). Though the waterfall has multiple benefits, among the most important today is its recreational value (Bruce, 1813; Hänsel, 2016). Despite the large recreational and economic potential, the flow of the water within the Blue Nile watercourse has been changed by other competing uses. The Chara-Chara weir on the outlet of the watercourse from Lake Tana and diversions to the nearby Tis-Abay hydropower stations have impacted the natural flow of the water (McCartney et al., 2010; Nurhusein, 2020). The construction of the electric power generating plants and the diversion of the natural water path on the waterfall's upper course has significantly lowered the volume of the water flowing over the Tis-Abay Waterfall. The limited water flow that these changes created has impacted one of the most prominent tourist attractions to the point of near destruction (Ehrlich and Reimann, 2010; McCartney et al., 2010).

Although Bruce (1813) described the Tis-Abay waterfall as "a magnificent sight that would not be effaced from memory," the waterfall now has negligible water flow as a result of upstream diversion towards the hydropower plant. These changes are expected to have significant economic, ecological, and societal effects unless cautious resource use and management decisions are made (McCartney et al., 2010).

The services associated with recreation and hydropower generation are both essentially non-rival. Therefore, these services do not completely consume the water and reduce its availability for alternative uses (Zhu and van Ierland, 2012; Almaktar and Shaaban, 2021). This means that if effective planning had been implemented, the water could have been used simultaneously for both purposes without impacting either. For example, water flow could be reverted to its natural course and flow to the waterfall after passing the hydropower turbine, or the hydropower station could be relocated downstream of the waterfall.

The traditional market resource valuation technique emphasizes directly traded commodities and services, which grossly underestimates the waterfall's non-market value components and, as a result, the total value of the resource (Pearce et al., 2006). The valuation of services for recreational use can help us better understand the total value that the waterfall provides (Folmer and van Ierland, 1989; Lipton et al., 1995; Brouwer and Pearce, 2005; Pearce, 2006; Blayac et al., 2012; OECD, 2018). Appraising the Tis-Abay Waterfall's use-value for recreational activity can promote more efficient and sustainable resource use and management and help minimize undesirable trade-offs (Brouwer et al., 2016; Stamou and Rutschmann, 2018).

Therefore, the study's objective is to estimate the Tis-Abay Waterfall's recreational use-value and identify the consumer characteristics associated with recreational visits based on actual and hypothetical visitor behavior using the ITCM (Torres-Ortega et al., 2018). While there is some prior research on the water flow of the site (McCartney et al., 2010; Nurhusein, 2020), no study has investigated the recreational value of the waterfall based on individual visitors' behavior or sought to estimate welfare measures through a reliable methodical approach, modeling, and estimation process (Haab and McConnell, 2002; Hanley et al., 2009; Tesfaye et al., 2016). Furthermore, to the best of our knowledge, this is the first study in Ethiopia to integrate standard ITCM with augmented ITCM in the valuation of a recreation site (Alberini and Longo, 2006; Filippini et al., 2018).

The rest of the paper is arranged into five main sections. Section two reviews the theoretical and empirical literatures with an emphasis on past applications of the ITCM. The third section includes a brief overview of the Tis-Abay Waterfall recreation site, as well as a description of the consumer sampling strategy, sample size determination, Zero-Truncated Poisson (ZTP) model specification, and welfare estimation. Section four reports the results of the analysis, followed by a discussion in section five. In section six, the main conclusions and their policy implications are addressed.

2. Literature review

2.1. Economic valuation and travel cost methods

Valuation methods consist of a series of techniques used to assess the economic value of non-market environmental resources in monetary terms (Lipton et al., 1995; Gunatilake, 2003; OECD, 2018). The non-market resource's value is described as the amount of money or commodities that would have an equivalent effect on the welfare (utility) of consumers (Bateman, 1993; Haab and McConnell, 2002; Gunatilake, 2003; Haab and Whitehead, 2014).

Non-market valuation is especially important for non-traded ecosystem services such as cultural values, aesthetic beauty, or recreational values since the traditional market-based approach is only able to estimate values where market data is available. This leads to the systematic undervaluation of many resources with services that are not exchanged in markets because they either do not have a market price (e.g., a scenic site enjoyed by all), or if they do, that market price does not accurately reflect their true value (e.g., a touristic site with an artificially low admission fee) (Gunatilake, 2003; Pearce et al., 2006; Hanley et al., 2009).

Revealed preference methods (RPM) and stated preference methods (SPM) are the two primary non-economic valuation methods (OECD, 2018). SPM uses the prices obtained from hypothetical market scenarios to estimate values—in other words, SPM attempts to infer people's preferences and willingness-to-pay for environmental benefits by asking them to directly indicate their preferences when there are very weak or no market proxies available (Gunatilake, 2003; Hanley et al., 2009). Though relatively easy to interpret, SPM results may provide inaccurate valuation estimates since they rely on hypothetical scenarios rather than real consumer choices. RPM, in contrast, uses the prices of related market goods and services to indirectly infer consumer willingness-to-pay for non-market resources. Such approaches have the advantage of incorporating actual consumer choices, such as the purchase of fuel, transport costs, and the use of time to travel to a recreational site.

Natural areas are often the center of recreational trips for people to access recreational amenities (Pearce et al., 2006). Many factors can influence trip decisions, including the recreational site itself, travel expenses to and from the recreational area, the distance between the recreational area and the visitors' residence, the visitors' income and related variables, and the presence of alternative recreational sites. Although some of these factors have unit measurements to quantify their economic value, many recreational areas themselves are unpriced items with no established monetary value to communicate their worth. As a result, methods of valuing non-market recreational sites such as lakes, beaches, rivers, forests, parks, landscapes, wildlife reserves, historical heritage sites, and waterfalls must rely on RPM/indirect approaches (Gunatilake, 2003; Pearce et al., 2006; Khoshakhlagh et al., 2013; Rietbergen-McCracken and Abaza, 2013).

In estimating the economic value of unpriced goods and services for a single recreational site, economists often employ travel cost methods (TCM) because travel cost is one major factor, among others, influencing an individual's trip decision. TCM is the first and oldest revealed-preference method and perhaps the most common model of environmental valuation, particularly for recreation site valuation analysis (Ward and Beal, 2000; Gunatilake, 2003; Hanley et al., 2009; OECD, 2018). Theoretically, TCM has been formalized since Trice and Wood (1958) and

Clawson and Knetsch (1966), though its origins can be traced back to Harold Hoteling's 1947 insights through his written letter to the office of the US Park Service. The approach has been widely used in recreation valuation modeling (Hanley et al., 2009; Clawson and Knetsch, 2011).

TCM tries to estimate the 'derived demand' for recreational sites based on the count of trips to a site and the travel costs incurred by consumers who access it (Lipton et al., 1995; Ward and Beal, 2000; Pearce et al., 2006). The travel cost is taken as the revealed willingness-to-pay of consumers accessing the site and hence used as a proxy for the recreational value – under the assumption that the market prices paid for travel to access the site reflect at least the minimum amount that a visitor is "willing to pay" to enjoy from the site's recreational services (Brouwer and Pearce, 2005; Pearce et al., 2006). Some authors have called attention to the potentially weak complementarity assumption between the recreational services of a natural site and the corresponding expenditure for its consumption (Freeman et al., 2014). However, the approach remains widely used (Torres-Ortega et al., 2018), and although the method is associated predominantly with the revealed behavior of visitors in terms of actual trips (Parsons, 2013), there are also many empirical approaches linking TCM with responses to contingent valuation methods relating to the site's attribute quality changes (Filippini et al., 2018). The contingent TCM is an augmentation of the standard TCM and aims to capture the intended trips consumers would make under hypothetical scenarios, allowing researchers to develop both hypothetical (stated) valuation estimates as well as revealed willingness-to-pay estimates based on actual travel behavior (Englin and Cameron, 1996; Layman et al., 1996; Filippini et al., 2018). In both actual and stated TCM methods, the trip frequency and the travel cost to visit the site indicate the "quantity demanded" and the "implicit price" of the site (Champ et al., 2017).

The TCM has two variants: the individual demand approach and the zonal approach. The ITCM analyzes the number of recreational trips made by individual users to a recreational site per year, whereas the zonal approach (zonal TCM) considers the number of visits taken by the population of a particular region or zone (Haab and McConnell, 2002). ITCM is more appropriate when considering individual visitor behavior and consumer characteristics associated with the use of a recreational site (Fleming and Cook, 2008). Therefore, this study uses ITCM to estimate the recreational use value of Tis-Abay Waterfall in northern Ethiopia.

3. Materials and methods

3.1. Description of study area

The Tis-Abay Waterfall (11033′14.51″N, 37024′3.20″E), also known as the Blue Nile Falls, is Ethiopia's largest waterfall. Called *Tis–Issat* in the Amharic language, meaning "smoking water", the waterfall is found on the upper bank of the Blue Nile and is formed by an estimated four billion m^3 (127 m^3/s) annual water flow of the river (Setegn et al., 2008). It is located close to Tis-Abay town, about 35 km southeast of Bahir Dar city and Lake Tana, and 587 km north of Addis Ababa (Fig. 1), with an elevation of 2744 m. The area has an estimated mean annual rainfall of 1280 mm and an annual average air temperature of 20 °C. The topography of the surrounding landscape varies significantly from lowland flood plains in the southwest to rugged mountains in the northeast, with a highly heterogeneous soil type dominated by agricultural lands (Tigabu et al., 2019).

The waterfall has historically drawn the attention of and been visited by a number of notable travelers, including Scottish traveler James Bruce and Britain's Queen Elizabeth II (Bruce, 1813). Today, the Tis-Abay Waterfall is amongst the most famous tourist destinations in Ethiopia due to its scenic views, hiking trails, the roaring sound of the water falling from an estimated height of 45 m, and the rainbows formed by droplets from the vast waterfall itself, which attains a width of some 400 m in the peak tourism season. The presence of Ethiopia's oldest bridge, which crosses the Blue Nile, as well as a newly constructed suspended iron bridge over a tributary river providing access to the foundation of the waterfall, add to the site's immense appeal to visitors.

Visitors' preferences for visiting the site vary seasonally, monthly, and daily depending on the level of water flow, which is mostly governed by rainfall upstream and by the volume of water consumed by the hydroelectric plant. The peak recreation season is from June to January, when the waterfall is at its full capacity. However, the water is regularly diverted to the nearby hydropower plant upstream of the Tis-Abay Waterfall during weekdays, therefore, Saturday and Sunday are the most favorite days for visitors. Attendance records from 2014-2019 suggest the waterfall is visited most in November, followed by October and September, while it is visited the least in March-May. On average, more than 43,000 tourists visited Tis-Abay Waterfall annually between 2014 and 2019 (ANRS-BoTC, 2019). However, tourism records documenting the number of visitors to the waterfall have been limited in recent years, especially since the emergence of conflict in the surrounding region in 2016/17 (ANRS-BoTC, 2019).

According to ANRS-BoTC (2019), around $47,185.82[1] of annual revenue has been collected from admissions fees for the waterfall since 2014. In addition, the site is known to provide a means of income for many local handcraft producers, tour guides, and other service providers. This study aims to enhance our understanding of the recreational value of the Tis-Abay Waterfall based on a combination of qualitative and quantitative data collected from users of the site.

3.2. Methods

3.2.1. Sample size determination and sampling strategy

This study employed both primary and secondary data sources but it mainly used qualitative and quantitative primary data collected through in-person interviews. Ahead of the main survey, a pretest was piloted on 30 randomly selected visitors to the Tis-Abay Waterfall to refine the clarity of the draft questionnaire and increase the rate and accuracy of responses to the full survey (Bowden et al., 2002; Nisbet and Zelenski, 2014). The full survey was then conducted using a three-stage sampling technique (Leggett, 2017), sampling across different months in the year, across different days of the week, and across subsets of specific respondents (Cochran, 1977; Leggett, 2017). We first categorized months into three groups: peak period, medium period, and low period of visitations based on the distribution of visitors across months for the year 2019 (ANRS-BoTC, 2019). Then, we selected one month randomly from each period: November for the peak, July for the medium, and March for the low visitation categories. We then sampled exclusively from weekend visitors for these three months, primarily because the diversion of water to the local power plant results in fewer visitors to the waterfall Monday through Friday. Finally, as the potential visitor population size of Tis-Abay Waterfall is unknown, according to the Cochran sampling formula for infinite population size (Cochran, 1977), the minimum required sample size "n" was determined using equation (1).

[1] At the average 2019 exchange rate, 1 USD ($) equals 29.1545 Ethiopian birr (ETB).

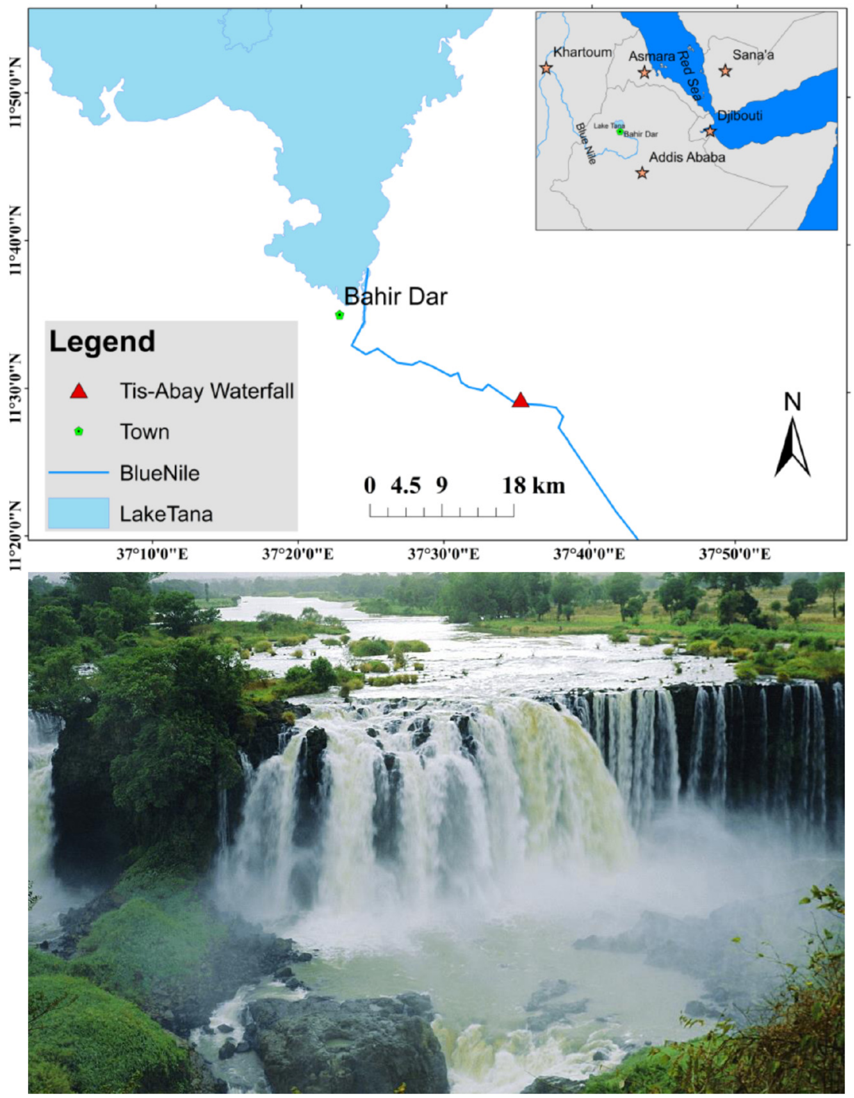

Fig. 1. Map of Tis-Abay Waterfall.

$$n = \frac{Z^2 P(1-P)}{e^2}; \tag{1}$$

where "n" is the minimum sample size, Z is the Z-score, P is the estimated ratio of the population with the desired attribute, P(1–P) is the estimated ratio of the population without the desired attribute, and e is the margin of error. A small sample size is not recommended for regression analyses applying a ZTP approach[2] (UCLA, 2021). We thus used a high precision level (e = 3%), resulting in a correspondingly large sample size (Creel and Loomis, 1990). In total, 1,067 sample respondents were drawn proportionally from the three sample months (November = 520, December = 395, and March = 152), using an on-site random intercept sampling process (Lamhamedi et al., 2021). The survey was conducted voluntarily after informed consent was obtained from the respondents. Survey questionnaires from 23 sample respondents were deemed invalid due to incomplete responses and consequently removed from the analysis, leaving a remaining valid sample size of 1,044 that is consistently used across the data analysis process.

The subsequent data analysis employed a combination of descriptive statistics and statistical analyses using Stata 16.0. A comparison of results from the pretest survey and the full survey to test the reliability and validity of the data collection instruments (Nisbet and Zelenski, 2014) suggests that the data collection instruments provided consistent results.

3.2.2. Model specification

TCM estimates the economic value of a resource by inferring a revealed demand curve based on the theory of consumer utility maximization. The first presumption is that an individual has to make a choice to consume non-market environmental goods in the form of paying the market price of travel associated with visitation to a recreational site (hence giving up the opportunity to consume other market goods). As a result, the consumer (i) will have a utility function (U) that includes a vector of market goods (X) and non-market environmental goods (Q) (Freeman et al., 2014).

[2] A truncated data set is a portion of a data distribution that is above or below a certain value, and an estimation process for data without zero counts is done using a zero truncated model (Hilbe, 2014).

$$U_i = f(X_i, Q_i) \tag{2}$$

The vector of non-market environmental goods in equation (2) may comprise many value components, such as a recreation value (Y) and other non-market values (q). Therefore, an individual's utility maximization function can be further summarized as:

$$U_i = f(X_i, Y_i, q_i) \tag{3}$$

However, our emphasis is on the recreational value of the resource (Y). This value is affected by the quality of the recreational site, but may also relate to consumer characteristics such as the value of the traveler's time, the travel distance, income, access to alternative recreation sites, and so forth.

We assume each trip to the site is constrained by income (I) and time (T) (Perman et al., 2013; Freeman et al., 2014). An individual's income (I) is $I = I_0 + wT_w$, where I_0 = non-wage income, w = wage rate, and T_w = work hours. Income (I) can be spent either on market goods or on access to recreational services. An individual is also constrained by time (T), where $T = T_w + T_y$, where T_y is the time spent on leisure; i.e., time may be spent on recreation (leisure) or on work. In this situation, the opportunity cost of recreational time is approximated using the wage rate. Visitors selecting among j alternative leisure activities thus aim to maximize the utility function subject to their time and income constraints. That is, the utility function $U_i = f(X_i, Y_i)$ is maximized subject to total income $I = P_x X + P_y Y$ and time $T = T_w + T_y$ restrictions, where P_x = price of market goods, P_y = cost of recreation, T_w = work time, and T_y = recreation time.

By rearranging and simplifying, it is possible to rewrite these constraints into equation (4).

$$I_0 + wT - Y(wT_y + P_y) - P_x X = 0 \tag{4}$$

Then, by formulating the Lagrange equation (L) (equation (5)) based on equations (4) and (3), we can compute the partial effects of each variable in the visitors' utility maximization equation.

$$L = u(X_i, Y_i) \pm \lambda(I_0 + wT - Y_i(wT_y + P_y) - P_x X_i) \tag{5}$$

We can obtain the Marshallian demand function through the first-order conditions (Parsons, 2013; Perman et al., 2013; Freeman et al., 2014; OECD, 2018).

$$X_i = g(P_x, P_y, I) \tag{6}$$

$$Y_i = f(P_x, P_y, I) \tag{7}$$

Equations (6) and (7) represent the Marshallian demand functions for market goods (X) and recreational services (Y), respectively. The latter is the observed and relevant Marshallian demand function for our interests. We can also further differentiate between j for different hypothesized recreational site quality change scenarios (e.g., changes to infrastructure, water flow volume, etc.), as presented in equations (8) and (9).

$$X_i = g(P_x, P_y, I, q_j) \tag{8}$$

$$Y_i = f(P_x, P_y, I, q_j) \tag{9}$$

Thus, the valuation of a recreational site involves the estimation of the demand for recreation and the calculation of the associated consumer surplus (CS[3]) in both the status-quo and through hypothesized quality change scenarios of the waterfall (Gunatilake, 2003; Parsons, 2013; Champ et al., 2017).

3.2.3. Model estimation: zero-truncated Poisson model

The number of visits taken to the recreation site is a nonnegative integer number and generates count data with a Poisson distribution (Haab and McConnell, 2002; Cameron and Trivedi, 2005; Perman et al., 2013; Hilbe, 2014). The Poisson and Negative Binomial regression models are the most prominent count data models depending on the level of data dispersion (Heberling and Templeton, 2009). However, Poisson and Negative Binomial and even the Poisson inverse Gaussian distributions include zeros and are inappropriate for count data, which structurally excludes zero counts. An example of count data that inherently precludes zero counts is "on-site" survey data, where respondents are actual visitors and thus by necessity have at least one trip count in the data set.

An econometric model which accounts for data without zero counts is the zero-truncated count model (Cameron and Trivedi, 2005; Hilbe, 2011, 2014). Given the likelihood that an individual will have positive trips is $\Pr[Y_i > 0]$ the conditional density function becomes $g\,(Y_i/Y_i > 0) = \frac{g(Yi)}{\Pr[Yi>0]}$, where Y_i is the count of recreational trips by visitor i. The normalization by the likelihood of a positive observation enables the density function of the zero truncated model to integrate into one (Haab and McConnell, 2002). A typical feature of zero-truncated count models is that the mean of the distribution is shifted left, resulting in under-dispersion (Hilbe, 2011, 2014). The dispersion measure for our trip count data collected from the Tis-Abay Waterfall recreation site was under-dispersed with variance (0.54) lower than the mean (1.39 trips per respondent). As a result, the ZTP regression model with vce (robust) option in Stata 16.0 was applied to provide unbiased estimations (Haab and McConnell, 2002; Parsons, 2003; Cameron and Trivedi, 2010).

Based on the Poisson log-likelihood function (equation (10)), the likelihood of a zero count is exp $(-\mu)$ where μ is the intensity or rate parameter (Hilbe, 2011, 2014).

$$L(\mu; y) = \sum_{n=1}^{n} y_i ln(\mu_i) - \mu_i - ln\left(y_i!\right) \tag{10}$$

To exclude the probabilities of zero counts from the probability distribution function, the value of a zero-count probability (exp $(-\mu)$) is subtracted from 1 and then the residual probabilities are rescaled by dividing the probability distribution function by $1-\exp(-\mu)$.

[3] A consumer surplus, or access value, is the difference between the maximum amount the visitor is willing to pay to make a visit to the recreation site and the total cost incurred by the visitor to the site ((*Parsons, 2003*).

Table 1. Summary of explanatory variables' descriptions and expected effects.

Variable	Description	Measure	Expected effect
Tc	Travel cost	Total cost in $	Negative
Age	Age of visitors	Age in years	Indeterminate
Sex	Visitors' sex as a dummy variable	1 = Male, 0 = Female	Indeterminate
Distance	Visitors' distance from the site	Distance in kilometers	Negative
Income	Visitors' monthly income	Income in $	Positive
Education	Visitors' education status as a categorical variable	0 = Basic 1 = Intermediary 2 = Advanced	Positive
TE	Visitors' trip experience	Counts/frequency of trips throughout visitors' lifetime	Positive
LT	Leisure time of visitors	Leisure time in a number of days per year	Positive
ARS	Access to alternative recreation site - Lake Tana (ARSLT), Gondar Fasiledes Royal Heritage (ARSGFRH), and Saint Lalibela Rock Church (ARSSLRC)	Total expenditure in $	Positive

$$F(y;\mu)=\frac{e^{-\mu_i}\mu_i^{y_i}}{1-exp(-\mu_i))y_i!} \tag{11}$$

Equation (11) enables the withdrawal of zero counts from each element of the Poisson probability distribution function. Using $\mu = \exp(x\beta)$, the resulting log-likelihood function is presented in equation (12).

$$L(\mu;y_i/y_i>0)=f\left(x_i\right)=\sum_{n=1}^{n}\{y_i(x_i'\beta)-exp\left(x_i'\beta\right)-ln\Gamma\left(y_i+1\right)-\ln[1-\exp\left(-\exp(x_i'\beta)\right)]\} \tag{12}$$

Thus, the model is estimated using a full maximum likelihood algorithm, which is parameterized in terms of $x\beta$ instead of the General Linear Model (GLM) parameterization μ (Hilbe, 2011, 2014).

3.2.4. Model variables: variable description and expected signs

Variables in our model include a combination of socioeconomic characteristics of respondents and site-related variables hypothesized to relate to consumer demand for recreational services from the Tis-Abay Waterfall.

The outcome variable in our ITCM regression analysis is the count of recreation trips per respondent (Y_i) to the waterfall. This represents the frequency of trips made by individuals to consume a recreational service within the necessary financial constraints (Haab and McConnell, 2002). The number of recreation trips taken by visitors at a given price level is referred to as "quantity demanded," and it is used interchangeably with "recreation demand" for the site.

The key explanatory variable in the analysis is Travel cost (Tc), which is the aggregate of all expenditures related to the recreational trip from the start of the trip back to home after each visit. It constitutes various expenditure components such as transportation, accommodation, and opportunity costs of time. A number of substantial transportation costs are incurred for round trips to and from Tis-Abay Waterfall, including boat travel through the Blue Nile River. Additional accommodation costs include costs related to hotel rooms and food, as well as entrance fees to the waterfall itself and other related services. The opportunity cost of time is approximated by multiplying one-third of the respondent's projected hourly income by the round-trip travel time (Shaw and Feather, 1999; Lamhamedi et al., 2021). The travel cost is the aggregate of all measured and approximated costs. Poor and Smith (2004) and several other subsequent studies have shown the cost of recreation given by the travel cost estimate is inversely related to the demand for recreation. Thus, its sign is expected to be negative and significant (Poor and Smith, 2004; Blayac et al., 2012; Alam and Hossain, 2017; Bigirwa et al., 2021; Shah and Islam, 2021).

Other potential explanatory variables taken into account in our model include visitors' sex, age, distance from the site, education level, income status, leisure time, trip experience, and access to alternative recreation sites (Table 1).

Given the variables considered in this model, the recreation trip function of Tis-Abay Waterfall takes a log link functional form, and since the log-link exponentiates the linear predictors, it can be expressed in natural logarithmic or exponential forms in equations (13) and (14), respectively.

$$\begin{aligned}\ln(\mathrm{Y_i}) = {}&\beta_0+\beta_1\mathrm{Sex}+\beta_2\mathrm{Age}+\beta_3\mathrm{Education}+\beta_4\mathrm{Distance}+\beta_5\mathrm{Income}+\beta_6\mathrm{TE}+\beta_7\mathrm{ARS}+\beta_8\mathrm{LT}\\ &+\beta_9\mathrm{Tc}+\mathrm{e_i}\end{aligned} \tag{13}$$

$$\begin{aligned}\mathrm{Y_i} = {}&\exp(\beta_0+\beta_1\mathrm{Sex}+\beta_2\mathrm{Age}+\beta_3\mathrm{Education}+\beta_4\mathrm{Distance}+\beta_5\mathrm{Income}+\beta_6\mathrm{TE}+\beta_7\mathrm{ARS}+\beta_8\mathrm{LT}\\ &+\beta_9\mathrm{Tc})+\mathrm{e_i}\end{aligned} \tag{14}$$

Thus, the demand functions for the initial waterfall level and after some quality improvements are presented in equations (15) and (16).

$$\mathrm{Y_{q0}}=\exp(\beta_0+\beta_1\mathrm{Sex}+---+\beta_9\mathrm{T_c})+\mathrm{e_i} \tag{15}$$

$$\mathrm{Y_{q1}}=\exp(\beta_0+\beta_1\mathrm{Sex}+---+\beta_9\mathrm{T_c})+\mathrm{e_i} \tag{16}$$

3.2.5. Welfare estimation

Consumer surplus (CS) is given by the difference between the highest price a visitor is willing to pay to make a visit to a recreational site and the total travel costs incurred (Lipton et al., 1995; Rosenberger et al., 2017). CS is estimated by integrating the area of the demand curve that lies between the limits of the current travel cost (travel cost at mean) and $T_c = \infty$ (the choke price where trip demand eventually equals zero) (equation (17)) (Alberini and Longo, 2006; Perman et al., 2013; Champ et al., 2017).

$$\mathrm{CS}=\int_{\mathrm{Tci}}^{\infty}(\mathrm{e}^{\beta0+\beta1\mathrm{Sex}+---+\beta9\mathrm{Tc}})\mathrm{dTc} \tag{17}$$

where ∞ = choke price and Tc_i = mean travel cost of visitor i.

The indefinite integral form is given by equation (18) (Khoshakhlagh et al., 2013; Perman et al., 2013).

$$CS = \left[\frac{e^{\beta 0+\beta 1Sex+---+\beta 9TC}}{\beta_{Tc}} \right]_{Tc=Tci}^{Tc=\infty} \tag{18}$$

And the estimation of the CS per person per trip is carried out with a formula:

$$\text{Individual CS} = -\frac{1}{\beta_{Tc}} \tag{19}$$

where β_{Tc} is the regression coefficient associated with the travel cost variable (Parsons, 2003; Alam and Hossain, 2017). Equation (19) shows the CS per trip is the inverse of the travel cost coefficient.

To estimate the recreational value of the site to visitors, we can follow two alternative steps. The first is to multiply the CS for an average trip by the total number of visitors per year, and the second is to multiply the CS per trip by the total number of trips per year. The total number of trips per year is simply the result of multiplying the total number of visitors per year by the mean number of trips made to the site (Perman et al., 2013). Thus, given λ is the expected trips to the site per year, we compute a measure of the CS for an average trip of visitors per year using equation (20).

$$\text{CS for average trip} = -\frac{\lambda}{\beta_{Tc}} \tag{20}$$

We then calculate the site's annual recreational value (equation (21)) as the total annual CS, which is a multiple of the CS per person per trip and the total number of visits (n) recorded during a year (Creel and Loomis, 1990; Englin and Shonkwiler, 1995; Rosenberger et al., 2017).

$$\text{Total Annual CS} = -\frac{1}{\beta_{Tc}} * \text{n} \tag{21}$$

3.2.6. Welfare estimation for quality change

We estimate two types of recreational demand for the Tis-Abay Waterfall: the first is the recreational value of the waterfall at the status-quo level, applying the standard TCM. The second uses the contingent TCM, which estimates the recreational value of the waterfall under four hypothetical scenarios simulating changes in the quality of different site attributes ((1) allowing the natural volume of water, (2) promoting full capacity water flow at any time, (3) investing in 50% improvement in infrastructure and services such as roads, standard hotels and lodges for accommodation services, and (4) 50% improvement in the quality of the vicinity area of the waterfall). The results of the contingent TCM are interchangeably used as hypothetical TCM and augmented TCM (Filippini et al., 2018). Then, the difference in CS between "with a quality change" and "without a quality change" (equation (22)) measures the value of the overall quality change (Parsons, 2013; Champ et al., 2017).

$$CS_\Delta = CS_{q1} - CS_{q0} \tag{22}$$

$$CS_\Delta = \int_{\text{Tci}}^{\infty^{q1}} (\text{e}^{\beta 0+\beta 1\text{Sex}+---+\beta 9\text{Tc}})\text{dTc} - \int_{\text{Tci}}^{\infty^{q0}} (\text{e}^{\beta 0+\beta 1\text{Sex}+---+\beta 9\text{Tc}})\text{dTc}$$

where CS_Δ is change in CS, CS_{q0} is a CS before change in waterfall quality and CS_{q1} is the CS after some improvement in site's quality.

The measures of individual, average, and annual CS for a quality change of the site will be $-\frac{1}{\beta_{Tc}}$, $-\frac{\lambda}{\beta_{Tc}}$, and $-\frac{1}{\beta_{Tc}} * \text{n}$ respectively.

4. Results

4.1. Descriptive analysis

Descriptive features of the sample are provided in Table 2. There were more female respondents than male respondents. The average age of visitors was 31.9 years, and visitors' family sizes ranged from one up to seven, with an average of two members per family group. The majority of visitors (80.5%) had received advanced education, and those with more education were much more likely to have made more than one trip to the Tis-Abay Waterfall ($p<0.001$). The majority of visitors (83.3%) were employed (with employment positively associated with the number of visits), and over half of the respondents were unmarried (with marital status showing no association with the number of visits). The mean monthly income of visitors to the site was $323.1. Most respondents (95.4%) visited Tis-Abay Waterfall in a group instead of alone, and a significant portion of visitors (87.9%) used public transportation, followed by air transport (6.9%), and own/rental vehicles (5.2%) (Table 2). Visitors had an average of 58.6 days of total free time for leisure per year.

Respondents' choice of the most favorite attributes of the site predominantly emphasized the waterfall's intrinsic and distinguishing features (94.4%), such as watching the eye-catching water falling over the cliff along with a thunderous sound and the mist (classified as "a scenic view of the waterfall"). An insignificant section of visitors (4.5%) also emphasized the neighboring attractions, such as the historic stone bridge, suspended iron bridge, a boat traveling across the Blue Nile River, and the beauty of adjacent landscapes. Services and infrastructure associated with the site were rarely cited as primary motivations for visiting (Table 2) (Ezebilo, 2016).

Visitors have traveled a mean distance of 359.8 km to reach the Tis-Abay Waterfall. In aggregate, the mean cost of undertaking recreational trips to the site was $130.7. The time reported by visitors at Tis-Abay Waterfall was never more than a single day (Table 3).

Respondents on average visited the site 1.39 times per year (Table 3), with the majority (75%) of visitors making a single trip (Fig. 2) (Ortaçeşme et al., 2002; Whitehead et al., 2008; Alvarez and Larkin, 2010).

4.2. Econometric analysis

We estimate the count of annual recreation trips as a function of the socioeconomic profile of the visitor and other recreation-related variables.

Table 2. Respondent socioeconomic characteristics (frequency, percentage, $\chi 2$, n = 1,044).

Variables	Category/Dummy	Frequency	Percent	$\chi 2$ (P-value)
Sex	Female	558	53.5	1.83(0.401)
	Male	486	46.5	
Occupation	Employed	870	83.3	5.29(0.071)*
	Unemployed	174	16.7	
Education	Basic	24	2.3	96.04(0.000)***
	Intermediary	180	17.2	
	Advanced	840	80.5	
Marital Status	Unmarried	582	55.7	3.66(0.453)
	Married	450	43.1	
	Divorced/widow	12	1.2	
Group	No	48	4.6	4.77(0.092)*
	Yes	996	95.4	
Transport mode	Public transport	918	87.9	27.53(0.001)***
	Own/rental car	54	5.2	
	Airplane	72	6.9	
Attribute choice	A scenic view of the waterfall	986	94.4	
	Adjacent attractions	47	4.5	74.61(0.000)***
	Services and infrastructure	11	1.1	
Total		1,044	100	

Note: Significant $\chi 2$ values denote respondent characteristics which have statistically significant differences in frequency of recreation (*** = 0.01, ** = 0.05, and * = 0.1).

Table 3. Socioeconomic profile of the respondent visitors (min, max, mean and standard deviation, n = 1,044).

Variables	Minimum	Maximum	Mean	Std. Deviation
Age	18.0	73.0	31.9	9.6
Family size	1.0	7.0	2.0	1.3
Distance (km)	3.0	1090.0	359.8	296.5
Monthly income ($)	13.7	2154.7	323.1	397.5
Leisure Time	10.0	3195.0	58.6	239.1
Trip Experience	10.0	120.0	40.6	16.8
Recreation trip	1.0	4.0	1.4	0.7
Time at the site (days)	1.0	1.0	1.0	0.0
Total cost	17.8	410.6	130.7	65.2

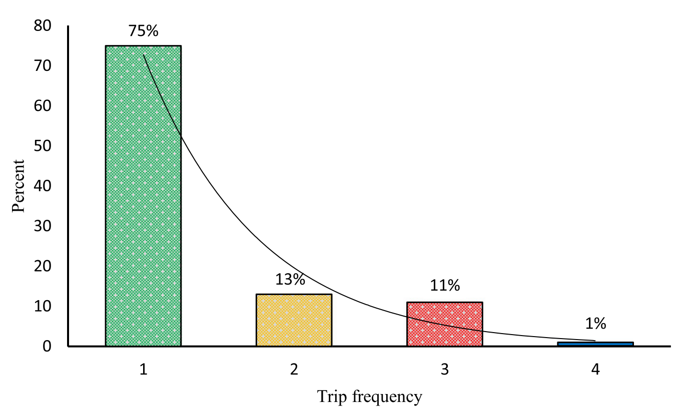

Fig. 2. Trip frequency (proportion of respondents).

Besides the theoretically profound suggestions about the appropriateness of the ZTP regression model for count data, which excludes zero counts by its nature, comparisons among alternative models are made via Akaike and Bayesian Information Criteria (AIC and BIC). According to these criteria, the lower the estimated value of both AIC and BIC in relative terms, the more efficient the model is in parameter estimation (Hilbe, 2014). From both model assessments, ZTP is found to be a plausible model for the data analysis process (Table 4).

The results of the ZTP regression model (Table 5) suggest several different explanatory variables are significant in predicting an individual's recreation trip decision to the Tis-Abay Waterfall recreation site.

Men are significantly less likely than women ($p<0.05$) to engage in recreational trips, consistent with past studies (Khan, 2011; Luke and Amujo, 2011; Blayac et al., 2012).

The age of the visitor is statistically significant ($p<0.01$) and positively related to the number of recreation trips. The number of recreation trips per year increases by a factor of 1.026[4] for every year increase in the age of the respondent (Blayac et al., 2012; Khoshakhlagh et al., 2013).

[4] If $Ln(Y) = \beta_0 + \beta_1 X_i \ldots$ or $Y = exp(\beta_0 + \beta_1 X_i \ \ldots)$, where Y and X are outcome and explanatory variables respectively. Therefore, the change in Y as a result of a change in X is $\exp(\beta)^* Y$.

Table 4. Akaike and Bayesian Information Criteria for model comparisons.

Model	Obs	11(null)	11(model)	df	AIC	BIC
Poisson Regression Model (Poisson)	1,044	-1,317.654	-1,179.052	12	2,382.104	2,441.514
Generalized Poisson Regression Model (GP)	1,044	-1,189.527	-709.999	13	1,445.997	1,510.358
Zero-Truncated Regression Model (ZTP)	1,044	-1,018.879	-486.603	12	997.206	1,056.615
Zero-Truncated Negative Binomial Regression Model (ZTNB)	1,044	-1,317.654	-1,179.052	12	2,382.104	2,441.514
Zero-truncated Poisson inverse Gaussian (ZTPIG)	1,044	-863.655	-486.603	12	997.206	1,056.615

Table 5. Zero-truncated Poisson regression result of the determinants of Individuals' recreation demand without quality change.

Trip Frequency	Coefficient	Robust Std. Err
Sex (Female = 0)		
Male (1)	-0.242***	0.072
Age	0.026***	0.004
Education (Basic = 0)		
Intermediary	-0.175**	0.085
Advanced	0.095	0.080
Distance	-0.003***	0.000
TE	-0.001	0.001
LT	-0.003***	0.000
Income	0.001***	0.000
ARS-LT (1)	0.352***	0.072
ARS-GFRH (2)	0.597***	0.182
ARS-SLRC (3)	0.029	0.091
Tc	-0.007***	0.001
Constant	-0.543**	0.217
Number of obs (n)	1044	
Pseudo R^2	0.5244	
Log-likelihood	-484.6261	
Wald chi2(11)	1543.15	
Prob > chi2	0.0000	

Note: *** 1% significant level, ** 5% significant level and * 10% significant level

Respondents' residential distance from the site is negatively associated with visit frequency ($p<0.01$). The estimated coefficient (-0.003) implies that visitors' count of recreation trips decreases by a factor of 0.997 for every additional kilometer away from the Tis-Abay Waterfall. Leisure time, which is the total free time of visitors per year available for recreation trips (Rolfe and Gregg, 2012; Ezebilo, 2016), is also negatively associated with the number of trips to the waterfall ($p<0.01$).

The monthly income of respondents was significantly and positively related with recreation trips ($p<0.01$). The log count of recreation trips increases by 0.001 for every dollar increase in the respondent's income, consistent with many past studies suggesting recreation trips positively correlate with income (Jones et al., 2010; Vicente and de Frutos, 2011; Khoshakhlagh et al., 2013; Bigirwa et al., 2021).

The coefficient for expenditures on alternative recreation sites (ARS) revealed mixed results in influencing recreation trips to the Tis-Abay Waterfall. Expenditures on alternative recreation sites such as Lake Tana and Gondar Fasiledes Royal Heritage were significantly and positively related with engaging in recreation trips to Tis-Abay Waterfall ($p<0.01$). The estimated number of recreation trips to Tis-Abay Waterfall increases by 1.42 for every dollar increase in costs associated with accessing Lake Tana. Similarly, a one-dollar increase in expenditures on Gondar Fasiledes Royal Heritage Site increases the count of Tis-Abay Waterfall recreation trips by 1.82 (Bigirwa et al., 2021; Houngbeme et al., 2021).

The effect of the travel cost on respondents' number of visits to the Tis-Abay Waterfall recreation site was negative and strongly significant ($p<0.01$). The estimation coefficient for total cost suggests that a one-dollar increase in respondents' travel cost reduces the count of annual recreation trips by 0.993 (Blayac et al., 2012; Twerefou and Ababio, 2012; Bigirwa et al., 2021).

4.3. Consumer surplus analysis

Individual visitors' demand function for the Tis-Abay Waterfall recreation site is estimated by considering visitors' frequency of visits to the Tis-Abay Waterfall recreation site (Y_i) and their travel costs (T_c) (Rosenberger et al., 2017). The estimated demand function is: $\ln(Y_i) = -0.543 - 0.007T_c$. Integrating the inverse demand function between one and the estimated mean trip ($\lambda = 1.39$), the recreational value of Tis-Abay Waterfall is estimated to be \$198.7 for the average number of visits, and the recreational value of the site per visit per person is estimated to be \$142.9. Consequently, the estimated annual recreation value of Tis-Abay Waterfall is roughly \$9.5 million (based on total visitor registrations for the 2019 fiscal year, for which the survey was undertaken) (Parsons, 2003; Alam and Hossain, 2017).

4.4. Value analysis for quality change

The Tis-Abay Waterfall is not operating at its full capacity for a multitude of reasons, which impacts the site's attraction to potential visitors and its immense recreational potential. Based on an anticipated change in the quality of the site, visitors were asked to state how their number of

Table 6. Zero-truncated Poisson regression result of the determinants of individuals' recreation demand with quality change.

Trip Frequency	Coefficient	Robust Std. Err
Sex (Female = 0)		
Male (1)	-0.244***	0.071
Age	0.024***	0.004
Education (Basic = 0)		
Intermediary	-0.186**	0.080
Advanced	0.041	0.079
Distance	-0.003***	0.000
TE	0.001	0.002
LT	-0.003***	0.000
Income	0.001***	0.000
ARS-LT (1)	0.316***	0.065
ARS-GFRH (2)	0.529**	0.196
ARS-SLRC (3)	-0.036	0.101
Tc	-0.004***	0.001
Constant	-0.793**	0.203
Number of obs (n)	1044	
Pseudo R^2	0.5214	
Log-likelihood	-523.84538	
Wald chi2(11)	2974.27	
Prob > chi2	0.0000	

Note: *** = 1% significant level, ** = 5% significant level and * = 10% significant level

Table 7. Summary of average recreational values "with" and "without" attribute quality changes.

Values	CS per trip per person	CS for average number of trips	CS for annual visitors
CS without quality changes (CS_{q0})	142.9	198.7	9,498,131.8
CS with quality changes (CS_{q1})	250.0	362.5	17,326,775.0
Difference in CS (CS_{Δ})	107.1	164.8	7,828,643.2

trips would change over the year. Following a similar estimation method to the regression procedure, which was applied to the revealed data, the regression result was found to be related to the initial regression result, which is shown in Table 6.

Based on the regression results, the T_c coefficient (T_c = -0.004) is a statistically significant correlate of estimated values resulting from hypothesized changes in the quality of the waterfall. Changes in the mean count of recreational trips and the annual number of visitors are also associated with these simulated changes (Parsons, 2003, 2013; Alam and Hossain, 2017).

The recreational value of Tis-Abay Waterfall per visitor with improvements in site quality was estimated to be $250 per visit (Table 7). The total recreational value of the site for the average number of visits was estimated to be $362.5 with improvements in site quality, corresponding to an estimated annual recreation value of the site after hypothetical quality changes of more than $17.3 million. Therefore, the increased value of the waterfall as a result of quality improvements is estimated at $107.1 per person per trip and at $164.8 total for an average number of person-trips (Parsons, 2013; Champ et al., 2017).

5. Discussion

Study findings estimate a high recreational use value for the Tis-Abay Waterfall under status-quo conditions as well as under a contingent scenario with enhanced site quality.

The Tis-Abay Waterfall site has a variety of appealing surroundings, ranging from its own intrinsic features to nearby touristic opportunities, linked services, and infrastructure. Qualitative responses suggest the most preferred attributes of the site are the mist, the spectacular sound, and the flow of the waterfall (Tardieu and Tuffery, 2019), whereas services and infrastructure for accessing the site appear less desirable. Such findings support calls for interventions, including investment in site development activities, services, and infrastructure improvements. Previous research by Tardieu and Tuffery (2019) has emphasized the relevance of a recreation site's biophysical aspects, while White et al. (2020) pointed out the necessity to boost tourist appeal by improving access and facilities at recreation sites. Our study supports both the existing natural environment's value as well as the potential enhanced value of the local supporting infrastructure at the Tis-Abay Waterfall.

Among consumer demographic characteristics associated with visits to the site, we find the visitor's level of income, distance from the waterfall, expenditures on alternative tourism sites, and total travel cost are all associated with the number of Tis-Abay Waterfall visits, with estimates in line with expectations based on previous research in terms of significance levels and directions of relationships with recreation trips. The significant and positive association between visitor monthly income and trip frequency to Tis-Abay Waterfall implies that higher-income individuals are more likely to afford the recreational trip's cost, consistent with past studies in other contexts (Jones et al., 2010; Vicente and de Frutos, 2011; Khoshakhlagh et al., 2013; Bigirwa et al., 2021). Respondents' residential distance from the site was, as expected, significantly and negatively associated with the count of recreation trips (Becker et al., 2005). The result is in line with the theoretical foundation of a negative relationship between distance and visit frequency in studies applying TCM (Gunatilake, 2003; Becker et al., 2005; Rolfe and Gregg, 2012; Brida et al., 2017).

Expenditures on other recreation sites such as Lake Tana and Gondar Fasiledes Royal Heritage were also positively associated with recreational trips to Tis-Abay Waterfall. The higher the expenditures on recreation at these sites, the higher the recreation demand at Tis-Abay Waterfall, which is supported by theoretical and empirical evidence. Moreover, the data suggests greater expenditures on recreation at Gondar Fasiledes Royal Heritage site, which is slightly farther from Tis-Abay Waterfall than Lake Tana, were associated with even more recreation trips to Tis-Abay Waterfall as opposed to consumers visiting Lake Tana alone (Bigirwa et al., 2021; Houngbeme et al., 2021).

The total travel cost, which comprises transportation, accommodation, and opportunity costs of time, is the fundamental explanatory variable in our ZTP model, as the model's foundation relies on the hypothesized relationship between trip frequency for recreation and travel costs as a proxy for the price of accessing the site (Haab and McConnell, 2002). As hypothesized, the travel cost coefficient estimate is significant and negative, indicating an inverse relationship with the count of recreation trips (Blayac et al., 2012; Alam and Hossain, 2017; Bigirwa et al., 2021; Shah and Islam, 2021). An indirect relationship between travel cost and trip frequency is in line with the quantity demanded and price relationships in the basic theory of consumer behavior (Varian, 2014), which implies a higher travel cost results in a lower level of trips for recreation and vice versa (Blayac et al., 2012; Bigirwa et al., 2021).

The travel cost coefficient further allows us to estimate the potential recreational value of the Tis-Abay Waterfall site (Rosenberger et al., 2017). Based on the coefficient of travel cost, the mean count of recreational trips in the sample, and total annual visitor records for the site, we estimate the value of Tis-Abay Waterfall. The estimated results of $298.7 per visitor for the average number of visits, $742.9 total per visitor, and $9.5 million for annual recreation value overall suggest that the waterfall is an economically important recreation site (Parsons, 2003; Alam and Hossain, 2017). This estimated total annual recreational value is far higher than the reported annual revenue of the site, which is approximately $47,000 collected by the site office for entrance fees and related service charges for the 2019 calendar year (ANRS-BoTC, 2019, 2021).

We compared our findings to a few studies based on modeling and site similarities (Ortaçeşme et al., 2002; Mulwa et al., 2018; Lamhamedi et al., 2021). A study from Kenya's Maasai Mara National Park also employed a single-site ITCM approach and found a CS of $115 per visitor per person and an overall valuation of the site at $73.1 million per year (Mulwa et al., 2018), roughly in line with the results of our study. More recently, Lamhamedi et al. (2021) employed ITCM at Morocco's Val d'Ifrane forest at Ifrane National Park, and found a recreational value of $89.3 per visit per person and $13.2 million for the annual recreational value of the site, again relatively consistent with our findings. Of course, the reported empirical results are subject to methodological modeling, estimation, and assumption differences. As a result, the comparisons of CS estimates cannot be expected to be absolutely similar, though our findings are within the acceptable estimated value ranges (Clara et al., 2018).

The other important finding of our study is the result from the hypothetical TCM, considering the value estimation of Tis-Abay Waterfall under different possible resource management scenarios. As suggested by the study findings, the estimated value of the Tis-Abay waterfall under hypothetical quality improvements is $250 per visit per person, with an estimated $17.4 million of annual economic benefit. This hypothetical analysis suggests improvements in the attributes of the waterfall could result in an 82% increase in valuation for the site.

The gap between the estimated total annual recreational value at the status-quo level and under the hypothetical improvement scenario represents a possible efficiency loss that resulted from a few historical trade-off decisions (Fleming and Cook, 2008; Ezebilo, 2016). If decisions in water use and management had factored in the economic value of flows to the Tis-Abay Waterfall, the economic value of the waterfall for recreational use purposes could have been as much as $17.4 million, higher than the actual estimated value by roughly 82% (Parsons, 2013; Champ et al., 2017). The estimated annual recreational value result from contingent ITCM is therefore a reflection of how much money may have been lost when less attention was given to the recreational prospects of the waterfall, which inadvertently led to the status-quo where the tourism sector around the waterfall must compete with the electric power plant.

Our findings are consistent with similar studies which integrate the standard and hypothetical ITCM, such as Filippini et al. (2018) in Switzerland, Lankia et al. (2019) in Finland, Pueyo-Ros et al. (2018) in Spain, and Anciaes (2022) in Wales. However, because results from on-site data cannot give information on prospective new visitors induced by the hypothetical quality change, the estimated CS result from the contingent ITCM in this paper only reflects the lower bound of the genuine change in welfare (Whitehead et al., 2008; Filippini et al., 2018).

For sustainable, effective resource usage and management to be implemented, the whole economic worth of the Tis-Abay Waterfall must be known. Estimating the waterfall's total value necessitates a thorough effort to account for all multidimensional values. This study's primary interest in estimating the recreational use value of Tis-Abay Waterfall is only one segment of the whole economic benefit of the waterfall, which includes a variety of use and non-use values as well as economic and non-economic benefits. As a result, it is important to conduct further studies on the remaining waterfall values to determine the total economic value of the Tis-Abay Waterfall and avoid unnecessary trade-offs in the utilization of resources (Gonzalez-Ollauri and Mickovski, 2017; Lagergren and Jönsson, 2017; Pang et al., 2017; Aanesen et al., 2018).

Though TCM is recognized for its strength in measuring recreational benefits, it can be complicated (Haab and McConnell, 2002; Hanley et al., 2009). Key problems are associated with multipurpose trips, travel time estimations, and the treatment of nearby residents and faraway visitors. As a result, the application of the valuation framework and treatment of these difficulties will determine the credibility of the research findings (Shaw and Feather, 1999; Pearce, 2006). Nevertheless, the present study offers valuable insights into the substantial economic value of the recreational services provided by the Tis-Abay Waterfall in an under-studied LMIC context.

6. Conclusion

The estimated total annual value of the Tis-Abay Waterfall suggests that visitors have attached a very high value to the site. Taking the reported annual visits into consideration, the lower-bound annual total recreation value of the Tis-Abay Waterfall recreation site is estimated to be $9.5 million. However, the annual recreational value under a hypothetical improvement in the quality of the waterfall site conditions is estimated to be $17.4 million, almost twice the current recreational value based on TCM, and vastly exceeding the value of the site based on recorded admission fees alone.

The study's findings also imply that the site is predominantly visited by women rather than male visitors, and employed people travel to the site in greater numbers than the unemployed. Attendees with a higher level of education largely outnumber those with a lower level of education, and working-age group visitors exceed the number of young and elderly visitors. The intrinsic qualities of the Tis-Abay Waterfall draw more visitors than the accompanying infrastructure and services.

The ZTP regression result also indicates that visitors' age, monthly income, and access to alternative sites significantly relate to increased visitation decisions. However, visitors' recreation decisions on the site are significantly and negatively associated with distance and the total cost of visitation. This implies that demand for recreation in the Tis-Abay Waterfall is inversely related to travel costs.

Despite the Tis-Abay Waterfall's immense recreational value, tradeoffs in water use between recreational and hydropower services create conflict between opposing shareholders. Increased attention to the nonmarket values of the Tis-Abay Waterfall, accompanied by investments in infrastructure and related services associated with increased visitor trips and longer visits, could enhance the overall economic benefits arising from this valuable and iconic natural resource.

Declarations

Author contribution statement

Atalel Wubalem: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed, materials, analysis tools or data; Wrote the paper.

Travis W. Reynolds; Amare Wodaju: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Data will be made available on request.

Declaration of interests statement

The authors declare no competing interests.

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Appendix A. Survey questionnaire

Part I: Interception questions

1. Are you visiting the Tis-Abay Waterfall for recreation or leisure?
   ☐ Yes ☐ No (If no, please conclude the interview process)
2. Do you live in Ethiopia?
   ☐ Yes ☐ No (If no, please conclude the interview process)

Part II: Respondents' Socioeconomic Information

3. Gender: ☐ Male ☐ Female
4. Age: __________ years
5. Education: ☐ Basic ☐ Intermediary ☐ Advanced and _____ years of education
6. What is your nationality: _________
7. Your address: where do you live? Region_______; City ______
8. Distance: How far away is Tis Abay Waterfall from your home? _______ Kms.
9. Marital status: ☐ Single ☐ Married ☐ Divorced/Separated
10. How many family sizes are in the household? ________ members
11. Occupation: ☐ Employed ☐ Unemployed
12. Income: What are your earnings from each item?

Income sources	*Employment income*	*Business income*	*Other sources (house rent, land rent, pocket money from parents, relatives, friends etc)*	*Total income*
Income per month				

12.1 What is the minimum wage per day you earn? ___________ Birr per day (if applicable)

Part III: Past, actual and planned trip related questions

13. How many recreational trips did you make to the Tis Abay Waterfall during the last 12 months? ______ trips
14. How long are you planning to spend at Tis Abay Waterfall? (or did you spend)? ______ day, ______ hrs, and _____ minutes
15. Which month(s) did you prefer to visit Tis Abay Waterfall and have fun?

Months	Sep	Oct	Nov	Dec	Jan	Feb	Apr	Mar	May	Jun	Jul	Aug	Pag
Trips													

16. At which time did you visit the site most often? (ranking for more than one choice)

Time	Working days (Monday – Friday)	Weekends (Saturday & Sunday)	Public holidays	If other

17. What type of recreation service or attribute did you most enjoy at Tis Abay Waterfall? (ranking for more than one choice)

A scenic view of the waterfall (watching the eye-catching water falling over the cliff along with a thunderous sound and the magnificent mist)	Adjacent attractions (historic Portuguese stone bridge, suspended iron bridge, boat traveling across the Blue Nile River and adjacent landscapes)	Services and infrastructure (cultural handcrafts availability, accessibility, transportation, accommodation)	Other

Part IV: Questions related to alternative sites

18. Have you ever visited other similar recreation sites before? ☐ Yes ☐ No

18.1. If yes, specify the number of trips you made to these sites and please rank your preference among these alternative recreation sites.

Recreation sites	Tis Abay Waterfall	Lake Tana	Gonder Fasiledes Palace	Semein Mountains National Park	Saint Lalibela Churches	If others (please specify)
Trip & rank	___;___	___;___	___; ____	___; ____	___; ____	___; ____

19. How many times have you visited each of the following sites during the last 12 months?

Recreation sites	Tis Issat (Tis-Abay)	Lake Tana	Gonder Fasiledes Palace	Semein Mountains National Park	Saint Lalibela Churches	If Others (please specify)
Trip frequency						

20. Do you come here, to Tis Abay Waterfall, only to visit the waterfall, or do you have any other plans to visit other nearby recreation sites?
   ☐ Yes, only Tis Abay Waterfall ☐ No, Tis Abay Waterfall plus other sites

20.1 If No, which recreation sites?
   ☐ Lake Tana ☐ Saint Lalibela Churches
   ☐ Gonder Fasiledes Palace ☐ other (specify)
   ☐ Semein Mountains National Park

21. How many days do you stay there and what does it cost you to visit these alternative sites?

Recreation sites	Lake Tana	Gonder Fasiledes Palace	Semein Mountains National Park	Saint Lalibela Churches	If others (please specify)
Day and total cost	___; ___	___; ____	___; ____	___; ____	___; ____

22. Typically, how many days per year do you spend on recreation trips to similar places other than the Tis Abay Waterfall recreation site? _______days per year

Part V: Questions related to travel costs

23. Where is your city departure from which you made the trip to Tis Abay Waterfall purposefully? ______________
24. Did you come to the site alone or in a group? ☐ alone ☐ in-group
25. Which mode of transport have you used to get to and from Tis Abay Waterfall?
   ☐ Public transport ☐ own vehicle/private car
   ☐ airplane ☐ others (please specify)

25.1. What was the amount of the cost you incurred for transportation in question (21) above?

25.1.1. _______ birr (based on public transportation and air travel tariffs)

25.1.2. _______ birr (based on opportunity costs/forgone income of rental payment of the vehicle)

25.1.3. _______ birr (cost of fuel, etc., for government, non-governmental, and commercial vehicles)

26. How much did you pay for boat service for round trips? ____________birr. (if applicable)
27. How much did you pay for the entrance fee? ____________birr
28. How much do you spend on other accommodation services per day (bedrooms, food, taxies, guide services, and any other sorts of payment related to a recreational trip? _______ birr
29. If you were not on the recreation trip, what would you most likely be doing?
   ☐ Working at job ☐ free
   ☐ Housework or shopping ☐ other, specify_______
30. How many days per year are you free from other obligations so that you can undertake recreation? _________days per year

31. What is your total time (in hours) away from home on a typical trip to Tis Abay Waterfall recreation site? ______ days or hours
32. What is the total cost to you for a trip to the Tis Abay Waterfall, including round-trip transportation, equipment, supplies, food, accommodation, etc.? _______birr
33. How important is it for you to just visit Tis Abay Waterfall?
    ☐ Very important ☐ Neutral ☐ Not important
    ☐ Important ☐ Somewhat important
34. In general, how do you see your recreational utility in relation to all associated financial, time, and opportunity costs?
    ☐ Very satisfied ☐ Neutral ☐ Unsatisfied
    ☐ Satisfied ☐ Satisfactory
35. Do you have any intentions of visiting the waterfall sometime in the future?
    ☐ Yes ☐ No
36. If the quality of the waterfall in terms of different attributes increased from the statuesque level by;
    • The natural volume of water flowing over the cliff (100%)
    • Water flow at full capacity (100%) at any time.
    • 50% improvement in infrastructure and services such as roads, standard hotels and lodges for accommodation services.
    • 50% improvement in the quality of the vicinity area of the waterfall
    • Then, how many times are you willing to visit Tis Abay Waterfall per year based on the quality improvements? _______ trips per year
37. What do you point out as the strength of the services and infrastructure of Tis Abay Waterfall recreational site?
    ____
    ____
38. What do you recommend that needs improvement in Tis Abay Waterfall sustainability and better recreational service delivery?
    ____
    ____

Thank you once again for your patience and cooperation. Have a joyful time at Tis-Abay Waterfall!

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