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Research Article

Groundwater Preservation in the Logone River Basin

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Abstract

Water resources are a valuable asset for agricultural and industrial consumption, as well as for household needs. It is widely recognized that groundwater must be protected from all forms of pollution to maintain healthy biodiversity. The Logone River provides users with economic benefits: irrigated agriculture, fishing, groundwater, and recreational opportunities. Water property rights are complex to define, and a water market is difficult to establish. In the absence of property rights and a market, conflicts among users are inevitable. Although a market for property rights exists, we do not know how water resources are allocated among different users. In this sense, water resource management models must address these issues. This study therefore attempts, firstly, to examine the determinants of households' willingness to pay to preserve the water table in the Logone basin, and secondly, to estimate the value of households' willingness to pay (WTP). To achieve our objectives, we used the logit model, which allowed us to identify the variables that influence or do not influence household WTP. Subsequently, the Cameron and James method from 1987 guided us in estimating the average value of household WTP. We deduce from this study that the only decision-making variable is essentially income. All surveys indicate that their WTP would increase as long as their income remained high.

Keywords

WTP, Groundwater, Water Ressources, Logonr River Bassin

1. Introduction

Water resources are essential for human existence and for species whose dependence on water resources is evident. From an economic perspective, water resources constitute an asset for consumption and productive activities. However, the degradation and scarcity of this resource are two serious problems in developing countries. This is due to an asymmetrical distribution of precipitation across the globe Wetzel et al [22], the increase in the world's population, and the degradation of water quality UN-CSD [24]. As a result of climatic conditions, the scarcity of water resources is increasing Wang [23]. It is estimated that by 2025, 5 billion people will not have access to safe drinking water for domestic use Wei et al [21].

Water resource management related to these problems involves conflicting and contradictory interests among water users Kilgour et al [27]. The Logone River provides users with economic benefits: irrigated agriculture, fishing, groundwater, and recreational opportunities. Water property rights are complex to define, and a water market is difficult to establish. In the absence of property rights and a market, conflicts among users are inevitable Pethig [26]. Although a market for property rights exists, we do not know how water resources are allocated among different users. In this sense, water resource management models must address these issues. Another problem that arises is finding a balance between the development

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of economic activities and the preservation of water quality. Indeed, water, which is essential for the production of agricultural goods, is also necessary for direct human consumption. To avoid the risk of contracting diseases from polluted water, humans must preserve clean water. From an economic perspective, there is a relationship between an individual's health and their productive capacity. To produce, one must be healthy. Good quality water is therefore essential for humanity [1]. Controlling efforts to preserve good water quality by governments is not easy. In fact, the major contributors to water pollution are industries, farmers, and other domestic activities. The search for the economic optimum by Producers are driven to boost their production at the expense of the environment, thus degrading water quality.

To be clear, we asked ourselves whether the socioeconomic and environmental well-being of the Logone sub-basin is optimal. Specifically, we asked ourselves the following questions:

1) Can we identify the determinants of households' willingness to pay to preserve the Logone sub-basin aquifer?
2) Can we assess water quality to raise awareness among users about the degradation of this resource?

To be clear, we have the following specific hypotheses:

Household income determines their willingness to pay to preserve the Logone sub-basin aquifer;

The average willingness to pay of households can be estimated.

This paper contributes to the literature in the field of water resource management. Water is an economic good, due to demographic pressure and the rise of capitalism, is deteriorating in both quantity and quality. Through this paper, we directly raise awareness of this degradation among the water users directly affected. Furthermore, this paper also contributes to drawing the attention of governments to water management decisions.

2. Literature Review

Reddy and al. [15] assess the economic costs of (industrial) water pollution in rural communities in terms of losses to agricultural production, human health, and livestock. The cost estimates are based on household surveys from an intensive study of two villages, one severely affected by pollution and the other unaffected. The most impacted village is located in one of the industrial belts in Andhra Pradesh, South India. The cost estimates revealed that the impact of industrial pollution on rural communities is quite significant in monetary terms.

Dowd and al. [6, 14] provide information on environmental threats to the Poyang Lake region and survey households' willingness to pay for the lake's environmental conservation. They collected primary and secondary data through a questionnaire distributed to 270 households. They conclude that the main threat in the Poyang Lake region is water pollution from nitrogen, phosphorus, and nitrates.

Zhao [19] in this article addresses problems with the current MPSPR and then proposes a new model. Based on four assumptions, including the assumption that pollutant discharges or transfer within the river basin are strongly controlled by individual administrative regions, a descriptive model of transboundary water pollution was developed for a Chinese basin. Based on these assumptions, the author developed a Collective Cooperation and Benefit Reallocation (MCCRB) model to resolve transboundary conflicts. The findings of his study will be useful in developing an environmental policy that resolves water pollution conflicts across regional borders in the Chinese river basin. However, certain factors affecting the MCCRB need to be considered by the river basin administrator.

Salvador and al [28] developed a hydro-economic model to determine optimal management of nitrate pollution in waters. groundwater. The overall optimization model, which determines the spatial and temporal application rate of fertilizers, maximizes net agricultural benefits under the constraints of groundwater quality requirements at various control sites. Haro and al. [9] apply this model within the framework of hydro-economic modeling of the El Salobral-Los Llanos aquifer (eastern Manche region of Spain), where nitrate concentrations exceed those permitted by the Water Framework Directive and the Groundwater Directive due to intensive fertilizer use in irrigated crops. The approach allows for the definition of the optimal distribution of fertilizer economic standards in agricultural basins using a hydro-economic model that links fertilizer application with groundwater nitrate concentrations at different control sites, while maximizing net economic benefits.

According to Jiang and al. [12] diffuse pollution in upstream areas of a watershed has become a serious threat to urban drinking water security in China. Payment for environmental services (PES) is considered a promising instrument for addressing this problem, with the Willingness to Pay (WTP) of urban water users being the key factor. Using a contingent of data from an assessment survey, the city's WTP for pollution control was estimated by livestock farms located upstream of the river. It was found that WTP varies considerably with income, highlighting the pricing and distribution issues relevant to water tariff reform.

According to Zhen and al. [20] the rapid development of industries and the rising living standards of the population have generated considerable interest in the problem of river pollution. Working on the case of the Yangtze River, he comes to the conclusion that the economic loss caused by the pollution of the river is significant.

Hu and Cheng [10], industrial transition and population growth in China have placed significant strain on the country's limited freshwater resources. Meanwhile, water pollution during industrialization has exacerbated water scarcity. Their research provides an overview of water scarcity and water pollution in China. It also analyzes the root causes of increased pollution stemming from pollutant discharges from industrial, municipal, and agricultural sources, poor water resource management, and the enforcement of pollution control regulations.

Wong and al. [25] in their article, analyze annual data for four water quality indicators (phosphorus, dissolved oxygen, ammonium, and nitrates). Their objective was to determine, using previously unstudied indicators, whether an environmental Kuznets Curve (EKC) is evident for a transboundary river in a developing country and whether this curve depends on the pollution model specification in the lower Mekong basin region.

Jessoe [11] tests the hypothesis that expanding improved drinking water supply in rural India reduces household expenditures for water quality preservation by partially offsetting the benefits of source protection. Demand for home treatment using geological features to predict household drinking water sources was estimated, and behavioral choices partially offset the water quality gains from source protection.

Roebeling and al. [16] developed a deterministic optimal control approach to explore the social assistance rate by maximizing the remediation of bound catchment and freshwater.

Villarreal and al. [17] propose, in their article, a mathematical programming model for pollution negotiation between different pollution sources that considers the sustainable development of the surrounding basin. The formulation involves minimizing the costs associated with implementing the technology needed to meet environmental constraints in order to achieve optimal water quality conditions.

Jiang and al. [13] conducted a study using data from the Chinese manufacturing sector [4]. Their study focused on the important factors related to the intensity of emissions of three pollutants in China (sulfur dioxide, wastewater, and soot). They conclude that better institutions, in the form of more effective law enforcement and barriers to entry in various regional markets, are solutions for mitigating China's urgent environmental problems at its current stage of economic development.

Duncan [7] in his study in New Zealand, examines how land-use regulation can help regulate water quality pollution. Within a conceptual framework of scientific studies, he assesses the implementation of a regime to ensure respect for resource limits. His research highlights the epistemological, institutional, and practical challenges of the manageability and applicability of policy regimes that seek to regulate pollution.

3. Methodology

3.1. The Logone River Basin and Its Relevance to the Study

The Logone River, 960 km long, originates in Cameroon and flows into the Chari River at N'Djamena after passing through the towns of Doba, Moundou, La ï and Bongor. The Logone is formed by the confluence of two rivers, the Vina and the Mbere, which flow from the Adamawa Plateau in Cameroon and meet at the border between the two countries.

3.2. Aquifer Overview

The Logone aquifer is the most important groundwater reservoir in the Lake Chad Basin. This aquifer is characterized by its currently relatively good water quality. However, intensive agricultural activity is developing in this basin, which, over time, risks degrading its quality.

Faced with such a scenario, public decision-makers have two alternatives: either artificially recharge the aquifer or allow irrigation of an agricultural area. To decide between these two options, a cost-benefit analysis is necessary. This analysis requires estimating the value of preserving the aquifer. However, since the asset being valued is a non-market good, the contingent valuation method is required. This method is based on creating a hypothetical market. It was used and applied, according to best practices in sampling, with a sample of 130 households.

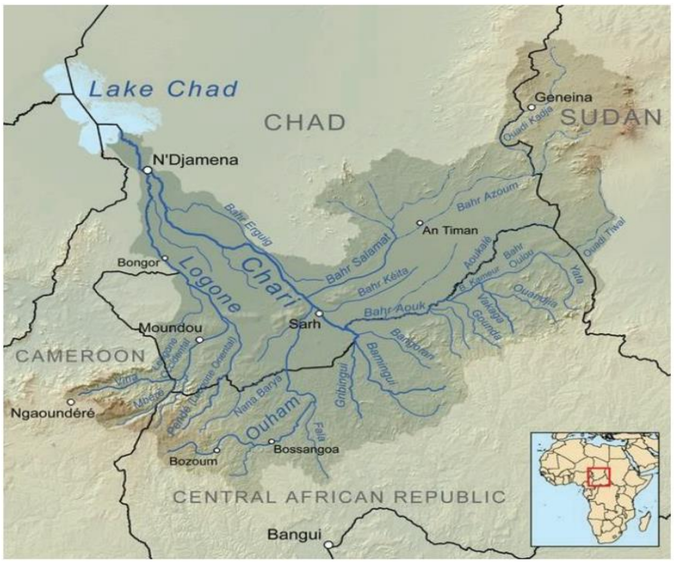

Figure 1. Hydrography Map of the Logone River Basin.

3.3. Choice and Justification of the Study Method

In our study, we have chosen the Contingent Valuation Method (CVM). This method involves assessing, ex ante, the change in well-being that would result from implementing an improvement in water quality. This is expressed as a willingness to pay (WTP) for an improvement or a willingness to receive (WTR) for a deterioration [2, 3]. Thus, it is the most suitable method for measuring the existence values attributed to this asset. However, it should be noted that the WTP and WTR diverge, and that the WTR amount is higher than the WTP Desaigues et al. [5] because the individual is naturally inclined to receive more than they are willing to pay. For this reason, the WTP is the one used to evaluate water quality in our watershed [18]. Better still, the aim is not to compensate users but rather to determine what they are willing to pay for improving the quality of the groundwater.

3.4. Sampling and Data Collection

The main objective of the contingent valuation survey, which we conducted during May 2025, was to estimate the value of preserving the water quality of the Logone aquifer and to determine the significant explanatory variables of users' willingness to pay.

This survey was conducted using direct interviews for at least two reasons:

1) This method produces far more robust results than others.
2) Direct and indirect interviews are the available alternatives in this region (email, telephone ...).

3.5. Presentation of the Theoretical Model

Consumers are rational and seek to maximize their satisfaction, which is a function of bundles of economic goods. In our case, the consumer maximizes their utility, which is a function of the goods available on the market and the public good available. This is the water consumption by the user, denoted Q. The consumer will always prefer a high level of water quality. The consumer's economic program in this case is written as follows:

$$Max\ \ U(X,Q)\ \ \ under\ \ Y = PX \tag{1}$$

Y represents household income and P the price vector. For simplicity, we will neglect other variables affecting the consumer's utility function; these variables will be considered in the empirical analyses. A consumer i is assigned a utility level U0 for a given water quality level Q0.

The individual willingness to pay (WTP) for a change in the state of the environmental resource can be defined by a utility function. The change in water quality from the expected level Q0 to the expected level Q1 reveals a willingness to pay such that:

$$VAP = d(P,Q_1,U_0) - d(P,Q_0,U_0) \tag{2}$$

P is the price vector, U0 is an individual's utility, and d is the function representing the minimum expenditure required to achieve utility level U0.

Rewriting the equation, we find

$$VAP = m_0 - d[P,Q_1,V(P,Q_0,m_0] \tag{3}$$

Utility functions and expenditure functions are assumed to be continuous and of class C^2 on P, Q and m.

The utility function is non-decreasing and almost concave in Q; the expenditure function is also non-decreasing and convex in Q. Since prices are assumed to be fixed during the analysis, we do not consider prices as variables in the remainder of the analysis.

We consider the Hicksian compensatory variation (VC), which gives the maximum amount a household is willing to pay for an improvement in water quality from Q_0 to Q_1. Equivalently, the Hicksian equivalent variation (VE) is the minimum amount a household would be willing to accept as compensation.

Note also that the VC assumes that individuals have a right to water quality Q_0, while the VE assumes they have a right to ownership of Q_1.

For k households, the VC of the improvement in water quality from Q_0 to Q_1 is given by

$$CV^k(Q_1,Q_0,m_k) = m_k - d(Q_1,V(Q_0,m_k) \tag{4}$$

Taylor's serial expansion in Q0 and the average income m gives this equation below:

$$CV^k = CV(Q_1,Q_0,\bar{m}) + (Q_1-Q_0)\frac{\partial CV}{\partial Q} + (m_k-\bar{m})\frac{\partial CV}{\partial m} + \frac{1}{2}(Q_1-Q_0)^2\frac{\partial CV}{\partial Q}\frac{\partial CV}{\partial Q} + \frac{1}{2}(m_k-\bar{m})^2\frac{\partial CV}{\partial m}\frac{\partial CV}{\partial m} + (Q_1-Q_0)(m_k-\bar{m})\frac{\partial CV}{\partial Q}\frac{\partial CV}{\partial m} + R \tag{5}$$

Where R is the rest of Taylor's development.

We can then have:

$$VAP = \propto_0 + \propto_1 \Delta Q + \propto_2 \Delta Q^2 + \propto_3 (m_k-\bar{m}) + \propto_4 (m_k-\bar{m})^2 + \propto_5 \Delta Q(m_k-\bar{m}) + \varepsilon_k \tag{6}$$

The equation above is obtained by setting:

$\propto_0 = CV(Q_1, Q_0, \overline{m}) = 0$ since VC in the initial state is zero.

$$\propto_1 = \frac{\partial CV}{\partial Q}$$

$$\propto_2 = \frac{\partial CV}{\partial m}$$

$$\propto_3 = \frac{1}{2}\frac{\partial CV}{\partial Q}\frac{\partial CV}{\partial Q}$$

$$\propto_4 = \frac{1}{2}\frac{\partial CV}{\partial m}\frac{\partial CV}{\partial m}$$

$$\propto_5 = \frac{\partial CV}{\partial Q}\frac{\partial CV}{\partial m}$$

And $R = \varepsilon_k$

The empirical model is further refined by considering social factors, age, household size, and others.

3.6. Econometric Model

The analysis of environmental valuation cannot be limited to a descriptive analysis of the data. Indeed, if we want to be able to derive from a study or survey the fairest average willingness to pay (WTP) for the environment, it is necessary to interview individuals and examine all the factors likely to explain a given WTP. These factors are obviously quantitative but also qualitative. After all, aren't we trying to assess the quality of the environment? Therefore, the analysis of individual behavior cannot stop at a descriptive analysis, at simply observing results. It is necessary to analyze the effects of each variable. Thus, econometric analysis proves necessary and indispensable.

***Table 1.** Description of our variables.*

Variables	Variable names	Expected sign
WTP	Willingness to pay	Dependant variable
age	Age	+
rev	Revenue	+
edu	Education	+
health	Health	+
bill	bill	-
aw	Alternative water	-
poll	Pollution	-
size	Size of household	+

Source: author

3.6.1. The Logit-Probit Model

This model allows us to estimate the probability of an event occurring or not. In our case, the event is represented by the decision to pay. The Logit model will therefore model the relationship between the binary variable, i.e., "I pay" or "I don't pay" (0 or 1), also called the dependent variable, and explanatory or independent variables, represented by the individuals' responses to our questionnaire.

In our surveys, we are likely to encounter different types of variables:

1) Dichotomous variables, which take only two values: 1 if the individual decides to perform the action, 0 otherwise.
2) Ordered polytomous variables, whose various modalities take what can be called a "natural" order (for example: often, rarely, never).
3) Unordered polytomous variables. These models will incorporate all of these variables. They will be based on the principle that an observed event is the result, the consequence, of a latent variable, called Z, a function of a set of characteristics denoted X (each weighted by an importance coefficient denoted b) and a random term denoted u. Therefore, we have:

$$Z = bX_i + \mu \quad (7)$$

If we consider Y as dichotomic dependent variable, it will take the value of 0 or 1.
then,

$$P_i = P[Y = 1] = P[Z > 0] \quad (8)$$

$$P_i = P[-\mu < bX_i] = F(X, b)$$

F is the cumulative distribution function of $-\mu$ defined by F(w)=$P[-\mu < w]$

With regard to the PROBIT model, F is the cumulative distribution function of the standard normal distribution:

$$F(w) = \varphi(w) = \int_{-\infty}^{\omega} \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{t^2}{2}\right) dt \quad (9)$$

and then

$$P[Y = 1] = \varphi(Xb) = \int_{-\infty}^{Xb} \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{t^2}{2}\right) dt \quad (10)$$

In the LOGIT model, F is the cumulative distribution function of the logistic distribution:

$$F(w) = L(w) = \frac{\exp(w)}{1+\exp(w)} = \frac{1}{1+\exp(-w)} \quad (11)$$

Then the probability will be

$$P[Y = 1] = L(Xb) = \frac{1}{1+\exp(-Xb)} \quad (12)$$

Using this last equation, we can calculate the average WTP of individuals.

However, the equation must be simplified for all significant characteristics of the model by setting these characteristics to their mean, except for the proposed amount.

For LOGIT model, we have: $Z = \alpha + M\beta + \mu$ where α denotes the sum of the means of the explanatory variables multiplied by their coefficient. It is therefore possible to use the Hanemann method (1984). The willingness to pay is equal to:

$$WTP_{moyen} = \int_0^M \frac{1}{1+\exp(-(\alpha+M\beta))} \quad (13)$$

for PROBIT model, we get: $Z = \alpha + M\beta + \mu$. The use of Cameron et James (1987) method is prefered to that of Hanemann. [8] thus:

$$WTP_{moyen} = -\frac{\alpha}{\beta} \quad (14)$$

These two models therefore allow us to know probable willingness to pay.

3.6.2. The Maximum Likelihood Method

When conducting a study, it is essential to estimate several models, such as LOGIT or TOBIT, because each model has a different significance level, depending on whether or not certain variables are included or on the processing method. However, to determine which of these models is the best, it is necessary to use the "maximum likelihood" method.

Let's revisit the LOGIT model equation:

$$P_i = P[Y = 1] = L(Xb) = \frac{1}{1+\exp(-Xb)} \quad (15)$$

We can rewrite it as:

$P_i = \frac{1}{1+\exp(-Xb)} = F(X_i b)$ then

$P_i = P[Y = 0] = 1 - P_i = 1 - F(X_i b)$ we have then

$$P_i = P[Y = 1]$$

$$1 - P_i = P[Y = 0]$$

If we consider that we have N observations, sometimes with the probability of the action occurring (P[Y = 1]) and sometimes not (P[Y = 0]), and if we denote Y as the number of observations of Y=1 and 1-Y as the number of observations of Y=0, then the likelihood (LF) is written:

$$LF = \prod_1^N P_i^Y (1 - P_i)^{1-Y} \quad (16)$$

$LF = \prod_1^N F(X_i b)^Y (1 - F(X_i b))^{1-Y}$ with $\prod$ the product operator

The best model will therefore be the one whose estimated "b" values maximize the likelihood.

This is a regression model with censored variables. Since negative responses are impossible, this model involves "handling" the "zero" responses. We present here the method of (Heckmann, 1979).

This model consists of two steps. The first step involves modeling, through a PROBIT model, the probability of providing a positive answer to the question, that is, of agreeing to pay. Thus, this first step allows us to eliminate the zero responses.

Once this is done, there is no longer a problem using ordinary least squares (OLS). Depending on the individuals who will agree to pay for the good, we will then calculate their level of consent. The TOBIT model is then written as follows:

$$Y_i = \alpha + bX_i + \mu_i \text{ si } Y_i > 0$$

$$Y_i = 0 \text{ si } Y_i \leq 0$$

Once this distinction has been made, we will estimate the amount of the WTP (Willingness to Pay) of the individuals surveyed using the OLS (Ordinary Levels of Reduction) method (linear regression model), but incorporating, in addition to the variables considered explanatory, the inverse of Mills' ratio, denoted λ, a variable derived from the PROBIT estimation.

4. Results and Discussion

4.1. Administrative Unit of Njamena

Table 2. *OLS and Logistic regression (Ndjamena).*

variables	WTP			
	OLS regression	**Signi.**	**Logistic regression**	**Signi.**
age	.8071633	(0.176)	.0487374	(0.659)

variables	WTP			
	OLS regression	Signi.	Logistic regression	Signi.
rev	.3414415	(0.000)***	.0845003	(0.019)*
edu	7.497069	(0.473)	2.487366	(0.583)
health	7.458818	(0.489)	-2.246893	(0.617)
bill	-4.418739	(0.615)	-5.860126	(0.253)
aw	-46.20426	(0.000)***	-1.482442	(0.388)
poll	-14.53996	(0.322)	1.836694	(0.923)
size	-5.34825	(0.156)	-.3024576	(0.680)
cons	474.8376	(0.000)***	-14.21579	(0.472)
R^2	0.76		0.8627	
Prob (F-STAT)	0.0000		-	
Prob (Chi2)	-		0.0000	
loglikelihood	-		-9.4459065	

Source: author. (***) Significant at 1%, (*) significant at 5%

For the linear regression, the model is generally significant for this locality. It shows that household income significantly and positively affects willingness to pay (WTP). It is therefore evident that households would increase their WTP as their income increases. As for alternative water sources, they significantly and negatively impact households' WTP. This is explained by the fact that the presence of other sources does not encourage households to seek water, nor does it increase their WTP.

The logistic regression model also indicates that the model is significant. Only the household income variable remains consistently significant.

4.2. Administrative Unit of Kousseri

Table 3. OLS and Logistic regression (Kousseri).

variables	WTP			
	OLS regression	Signi.	Logistic regression	Signi.
age	.3073913	(0.629)	-.018889	(0.873)
rev	.3053813	(0.000)***	.0803764	(0.016)*
edu	8.249258	(0.462)	3.21325	(0.553)
health	4.382551	(0.703)	-3.163554	(0.569)
bill	-4.5167	(0.630)	-8.349266	(0.197)
aw	-59.70845	(0.000)***	-1.120962	(0.493)
poll	-12.90302	(0.409)	.54049	(0.954)
size	-.8215694	(0.838)	.7922662	(0.498)
CONS	389.6885	(0.000)***	-14.57333	(0.169)
R^2	0.72		0.87	-
Prob (F-STAT)	0.0000		-	

variables	WTP			
	OLS regression	Signi.	Logistic regression	Signi.
Prob (Chi2)	-		0.0000	
loglikelihood	-		-8.4775911	

Source: author. (***) Significant at 1%, (*) significant at 5%

For linear regression, the model is generally significant for this locality. It shows that household income positively affects households' willingness to pay significantly. It is therefore evident that households would increase their WTP as their income increases. As for alternative water sources, they negatively impact households' WTP significantly. This is explained by the fact that the presence of other sources does not encourage households to seek water, nor does it increase their WTP.

The logistic regression model also indicates that the model is significant.

4.3. Administrative Unit of Yagoua

Table 4. *OLS and Logistic regression (Yagoua).*

variables	WTP			
	OLS regression	Signi.	Logistic regression	Signi.
age	-.5384373	(0.155)	-.0890877	(0.605)
rev	.5346182	(0.000)***	.2116922	(0.054)*
edu	-20.82136	(0.104)	-	-
health	34.44968	(0.000)***	4.069616	(0.032)**
bill	-19.33976	(0.001)***	-	-
aw	1.524614	(0.857)	.2305019	(0.914)
poll	-2.079283	(0.873)	-	-
size	3.555956	(0.177)	.1870341	(0.849)
CONS	325.2294	(0.000)***	-39.6101	(0.041)**
R^2	0.84		0.87	
Prob (F-STAT)	0.0000		-	
Prob (Chi2)	-	-	0.0000	
loglikelihood	-	-	-7.8512964	

Source: author. (***) Significant at 1%, (*) significant at 5%

For the linear regression, the model is generally significant for this locality. It shows that household income significantly and positively affects households' willingness to pay (WTP). It is therefore clear that households would increase their WTP as their income increases. As for the bill amount, it significantly and negatively impacts households' WTP. This is explained by the fact that a high bill amount reduces household income and thus lowers their WTP. The health variable positively affects households' WTP, which is explained by the fact that households suffering from health problems are more inclined to pay higher water prices.

The logistic regression model also shows that the model is significant. Only the household income variable remains consistently significant.

This analysis concludes that income remains a decision variable for households' WTP.

4.4. Administrative Unit of Bongor

Table 5. OLS and Logistic regression (Bongor).

variables	WTPLOG			
	OLS regression	Signi.	Logistic regression	Signi.
age	.292972	(0.598)	-.0439388	(0.695)
rev	.3959599	(0.000)***	.0928099	(0.023)**
edu	-.4628921	(0.961)	3.126102	(0.607)
health	4.050013	(0.679)	-.6797143	(0.735)
bill	-11.86095	(0.140)	-5.969923	(0.314)
aw	-27.00697	(0.003)***	-2.160244	(0.133)
poll	-15.69269	(0.239)	-.60585	(0.954)
size	-3.450751	(0.302)	.1972832	(0.755)
CONS	473.0369	(0.000)***	-11.92646	(0.304)
R^2	0.73	-	0.85	-
Prob (F-STAT)	0.0000	-	-	-
Prob (Chi2)	-	-	0.0000	-
loglikelihood	-	-	-10,2331	-

Source: author. (***) Significant at 1%, (*) significant at 5%

For the linear regression, the model is generally significant for this locality. It shows that household income significantly and positively affects household Willingness to pay (WTP). It is therefore clear that households would increase their WTP as their income increases. As for alternative water sources, they significantly and negatively impact household WTP. This is explained by the fact that the presence of other sources does not encourage households to seek water, nor does it increase their WTP.

The logistic regression model also shows that the model is significant. Only the household income variable remains consistently significant.

Household income is by far a decisive determinant of household WTP.

4.5. The Average WTPs Assessed by the Different Municipalities

Table 6. WTP estimation value for different municipalities.

	Average WTP via the logit model	Average WTP via OLS model
NDJAMENA	522	511
BONGOR	490	501
KOUSSERI	412	413
YAGOUA	438	415

Source: author

The average willingness to pay (WTP) estimated by the logit and OLS models are similar.

5. Conclusion and Discussion

In conclusion, the analysis of households' willingness to pay confirms their predisposition to pay for access to a healthy groundwater source. Given water quality often bordering on WHO standards and frequently aggressive water restriction policies, these variables appear to explain a significant portion of the amount declared by subscribers. Indeed, analyzing the willingness to pay of a sample of 130 subscribers, income, bill amount, and alternative water sources emerge as highly influential variables. Having another water source would reduce the amount declared by the subscriber. This result is likely due to potential substitution between tap water and water from other sources (wells and springs). This situation can be explained by subscribers' mistrust of the quality of the distributed water, but could also be a consequence of the restriction policy and the costs of these alternative resources.

The income variable is significant and has a positive sign. In other words, the amount declared by the household is proportional to its income, and this result is consistent with those found in empirical literature (Casey et al., 2006). It reflects both water consumption and household living standards.

Household size has no impact on the willingness to pay reported by subscribers. This situation is undoubtedly the result of a shared unease experienced by subscribers regardless of household size. Therefore, it would seem that subscribers' willingness to pay is explained more by variables related to management than by variables related to their socio-economic characteristics. Finally, the estimation of subscribers' willingness to pay indicates that residents along the Logone River are prepared to pay an additional 522 AFC/m^3. This result is both an indication of the economic value attributed to water by local subscribers and a means of forecasting future investments.

Abbreviations

WTP	Willingness to Pay
WTR	Willingness to Receive
MPSPR	Model of Proportional Share of Pollution Reduction
MCCRB	Model of Collective Cooperation and Reallocation of Benefits
EKC	Environmental Kuznets Curve
CVM	Contingent Valuation Method
AFC	African Financial Community
PES	Payment for Environmental Services

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Maya Ernest: Formal Analysis, Methodology, Supervision, Writing – original draft

Conflicts of Interest

The author declares no conflicts of interest.

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