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Chapter

Agricultural Activities and Restoration of Lake Chad

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Abstract

The disappearance of 90% of Lake Chad's surface has brought riparian countries to elaborate a restoration project for this natural asset. The aim of this study is to estimate the benefits and costs associated with the realization of this project, in order to determine if it is socially profitable. The methodological approach use data from the contingent valuation survey conducted in 2011 in the Cameroonian part of Lake Chad and appropriate statistical and econometric procedures. First, we estimate the middle and long term benefits of the project to be €5,549,576.832 and €38,543,518.56 respectively. Then, we evaluate the costs generated by the implementation of such a project to €37,960,149.12. Finally, the social profitability of this project depends on the temporal horizon used by decision-makers. It is negative for an economic horizon and positive for an ecological horizon.

Keywords: Lake Chad, costs-benefits analysis, contingent valuation method, social benefits, social costs, temporal horizon

1. Introduction

Situated at the heart of the African continent, in an arid Sahelian environment where every water point is a source of life, Lake Chad is at the heart of a complex issue related to the choice between economic activities and ecological balance. For a long time, priority was given to economic activities which, combined with the growing effects of global warming, have particularly led to the loss of 90% of its water surface area, thus going from 25,000 Km^2 (in 1964) to less than 2,500 Km^2 today and exposing the local resident populations that depend on it to climatic vulnerabilities [1]. NASA mapping surveys in 2001 (**Figure 1-A below**), corroborated by satellite imagery (**Figure 1-B** below), confirm this. These figures also allow us to note that the northern part of Lake Chad, integrating Niger and Nigeria, has completely disappeared, and is taken over either by vegetation or expanses of sand, or by human settlements.

Today, safeguarding Lake Chad is a major concern for the planet. This concern is reflected in the willingness of the riparian states to restore this natural asset, through the construction of an inland waterway through which it would be supplied with water. In addition to its very high cost of construction and despite a high proportion of favorable opinions, this project is not socially desirable in the sense of Pareto since it could generate another cost for society. Indeed, the restoration of Lake Chad is likely to have contrasting effects not only on the environment, but also on the population engaged in agricultural activities on its shores and surroundings.

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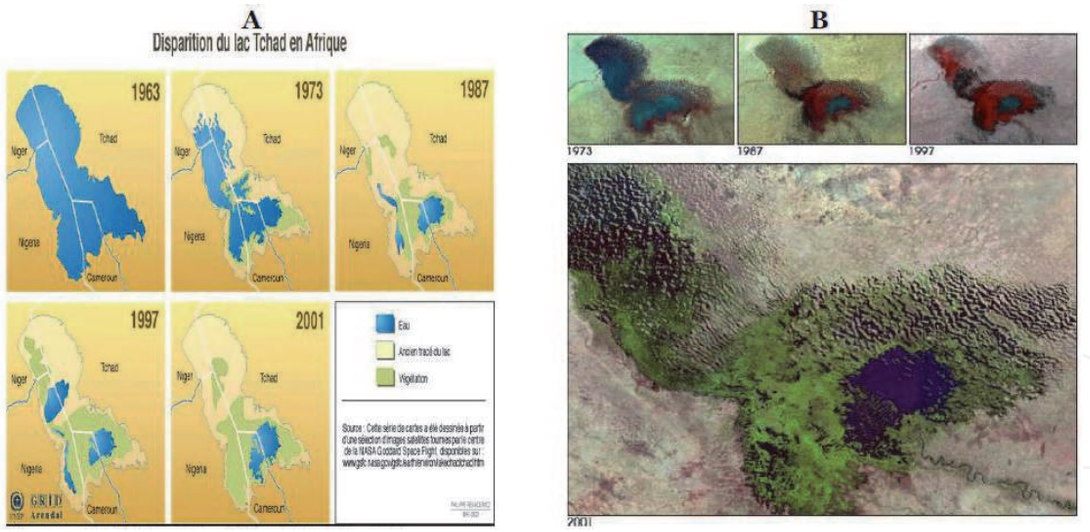


Figure 1.
Sources: NASA 2001, Internet images. Notes: (A) Changes in the surface area of Lake Chad from 1963 to 2001. (B) Satellite images of Lake Chad in 1973, 1967, 1997 and 2001.

In order to meet the Pareto criterion, these negative social consequences require compensatory transfers reflecting the loss incurred by the local population, mainly agricultural. How much should potential agricultural victims be compensated? What is the social benefit of such a project? These are two related questions that can be summarized in one main question, which is precisely the issue of this study: would the restoration of Lake Chad provide benefits that exceed the costs it would impose on farmers?

The aim of this study is precisely to answer these questions by carrying out an economic analysis of this project in order to clarify and justify the appropriateness of its implementation. Specifically, the study aims to estimate and compare the benefits and costs that the implementation of the Lake Chad Restoration Project would entail, considering only the preferences and motivations of the populations of the Cameroonian part of Lake Chad, notably the Logone and Chari departments of the Far North Region of Cameroon. This choice was mainly justified by the unavailability of time and resources to carry out a regional study including the four countries bordering the natural area which are: Cameroon, Niger, Nigeria and Chad.

The rest of this chapter is as follows: the next section sets out the analytical framework for the study. In sections 3 and 4, we carry out a monetary evaluation of the benefits and costs associated with the implementation of the project, specifying the methodological aspects specific to each part of the evaluation. Section 5 will allow us to compare these values and discusses the results obtained.

2. Analytical framework of the study

Safeguarding natural assets faces a complex dilemma to be resolved, because every choice, every option (to preserve the resource in its natural state, to let it degrade or to transform it for another use) has consequences in terms of gain or loss of value. Thus, it is only after carefully weighing all the values gained and lost under each used option that one can decide on the relevant option to be retained. For this, it is necessary to implement tools to facilitate the decision-making process. Among these tools, it is common to use cost–benefit analyses (CBA), which make it possible to shed economic light on the definition of a public objective, to make public

decisions more transparent and to take into account the opinions of all the stakeholders concerned by these decisions.

In our context, a CBA could be used to justify whether or not the project to restore Lake Chad should be carried out, as it allows a monetary comparison of the costs incurred and the resulting benefits for the population. Its theoretical foundations are essentially as follows: benefits and costs are defined respectively as gains and losses in human well-being or utility [2]. Thus, a project or policy satisfies the cost–benefit criterion if its social benefits are greater than the social costs it imposes on society[1] as a whole [2–4].

However, in the case of environmental policies, the monetary evaluation of costs and benefits is difficult given the non-market nature of these goods and the services they provide. To overcome this issue, CBA assumes that individual preferences for environmental goods should be considered as the source of value. These are measured by a willingness to pay (WTP) in the case of a benefit and by a willingness to accept compensation (WTA) in the case of a cost [2]. In other words, an increase in an individual's level of well-being can be measured by the maximum amount that the individual would be willing to pay to benefit from the policy. If, on the other hand, the policy results in a reduction in well-being, it will be measured by the amount of money that the individual in question would require as compensation for accepting the policy.

Among the range of methods for valuing non-marketable environmental goods, it is common to use the contingent valuation method (CVM) to reveal these preferences [5, 6]. It is a method of valuing non-marketable goods that allows an estimate to be generated of the measures that compensate for the change in individual well-being induced by the implementation of a given public policy. Its objective is to create and simulate a hypothetical market, based on a questionnaire, in which agents are led to reveal their preferences in terms of WTP to receive a benefit and/or WTA as compensation for tolerating a given cost [7]. Using these values, it would now be possible to quantify the benefits or costs of the change one wants to make to the good concerned.

However, although CVM is the most widely used method for valuing environmental goods today [2, 5, 8], it has been strongly criticized[2], calling into question the reliability and validity of the values obtained [9]. However, instead of stopping its use, these criticisms have instead made it possible for the work to perfect it both in terms of data collection techniques and the econometric treatment of responses [10]. Although still controversial, academics and policy makers increasingly recognize this approach as a flexible and powerful method for estimating WTP [2].

However, it is important to point out three orientations that set us apart from several studies using the methods presented above. Firstly, to our knowledge, with the exception of [11], most of the work on the use of CBA to evaluate policies for safeguarding wetlands has been mainly oriented towards a comparison between the benefits and investment costs, in order to determine the appropriateness of safeguarding them without seeing their potential productive use. Then, unlike [11][3],

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[1] In this study, as in the economic literature, the CBAs considers the costs and benefits for society as a whole, and not just for the industrialist or the community that decides whether or not to carry out a project. The aim is to assess the "social value" of the project, not its "rate of return".

[2] There are two types of criticisms: the first concerns validity, i.e. the method's capacity to estimate theoretical concepts, which leads to questions about the coherence of the results. The other criticisms relate to the reliability of the questionnaire. The latter plays a crucial role in the study.

[3] [11] Combined the use of CVM with an assessment of the benefits, at the firm level, generated by converting wetlands for industrial use.

we are interested here in the benefits of the potential agricultural use of wetlands and use CBA to measure both the benefits of restoring Lake Chad and the cost involved. Finally, we disregard the principle of discounting, which makes it possible to know whether a project is profitable by comparing different values observed at different times. Indeed, the problem that concerns us here is the difference in time between economic and ecological investments. However, economic time has nothing in common with biological or ecological time, which can extend over several hundred years. Consequently, the updating process has a clear bias against the future for long-term environmental problems, as it implies a reduced interest in the future compared to the present, and is thus a deterrent to the protection of the natural environment. Moreover, the omission of such a principle does not pose a major problem insofar as its use in the evaluation of environmental projects is still debated.

3. From the estimation of household WTP to the social benefits of the project

The monetary evaluation of the social benefits of the Lake Chad restoration project is based on two steps: the identification of the factors explaining the WTP of households wishing to participate in the Lake Chad restoration program and the calculation of the average WTP[4], which, when aggregated with the entire population concerned, enables us to obtain the said benefits.

3.1 Analysis of the factors explaining WTP

Before embarking on the analysis of these factors, we provide a brief overview of the methodology used.

3.1.1 Methodology

First of all, we present the data used. Next, the econometric model used to identify the factors relevant to explaining household WTP is presented.

3.1.1.1 Source of the data used

The data used are from a contingent survey on individual preferences for saving Lake Chad that we conducted in 2011 among households in the Cameroonian part of Lake Chad[5]. The sample is constructed through a combination of two reasoned choice survey methods, namely the quota method and the route method. The use of a probability survey requires a sampling frame (lists of households or dwellings), which unfortunately does not exist in the region, and it is impossible (limited time and means) to set it up. With this in mind, we set quotas for each itinerary and imposed on each respondent to follow a fixed itinerary (neighborhood), including stopping points for interviews. If an interviewer was absent or refused at a stopover point, the respondent moved on to the next point. This was one way to get around the problem of non-response generally observed in surveys. A total of 649

[4] This section is a synthesis of the article published in 2018 in the Revue d'Economie Politique by [12]. For more details on the methodology and results, see this article.

[5] The data collection used in this article was carried out thanks to a grant from the Research Fund for an Investment Climate and Business Environment (FR-CIEA), jointly financed by the TRUSTAFRICA Foundation and IDRC. We would like to express our sincere thanks to them.

households were asked to reveal their WTP to finance the restoration of Lake Chad through face-to-face interviews conducted in their homes. Due to the elimination of questionnaires with incomplete or missing information, 623 questionnaires are retained for the study.

The closed-ended question format with a simple dichotomous choice (yes/no) and the voluntary contribution were used in this survey as a means of formulating and revealing the WTP. The question asked, to which the respondent was asked to answer yes or no, is conveyed as follows: *"Would you agree to pay €*[6]C_i *per year, and for five years, to a special fund as a voluntary contribution, in the form of a donation, to ensure that Lake Chad is supplied with water? "*. The amount C_i offered to a respondent was chosen randomly from a vector of four bids (see **Table 1** below), but with a concern that each amount be distributed equitably in the total sample.

Proposed amount (€)	**1.83**	**3.66**	**9.16**	**18.32**	**Total**
Enrollment	158	155	155	155	**623**
Proportion (%)	25.36	24.88	24.88	24.88	**100**

Table 1.
Distribution of proposed amounts in the sample.

In addition to their WTP to finance the restoration of Lake Chad that could be carried out there, the respondents revealed other information about themselves: socio-economic characteristics and opinions on the safeguarding of Lake Chad. Using an econometric model, this information will allow us to test the theoretical validity of the contingent study and to predict the average WTP of our sample associated with the offer to restore Lake Chad.

Tables A1–A3 in **Annex A**, present descriptive statistics respectively on the socio-economic profile of households, the relationship between individuals and Lake Chad and the reasons for refusing to adhere to the contingent scenario.

3.1.1.2 Econometric modeling

- *Empirical specification of the econometric model*

In our situation, the respondent agrees $(Y = 1)$ to participate financially in the restoration of Lake Chad if the proposed amount (C) is less than her WTP, otherwise she refuses $(Y = 0)$. The discrete nature of the dependent variable leads us to model the probability that it will take the value 1 or 0. In this perspective, we choose to use the Logit model to estimate the coefficients of Eq. 1, i.e. the probability that individuals agree to pay the amount proposed in the referendum. On the basis of Pseudo R^2, the best form of regression is obtained by transforming the proposed amounts into a natural logarithm.

$$\boldsymbol{Prob}\ (\boldsymbol{Y_i = 1}) = \frac{\mathbf{1}}{\mathbf{1} + \boldsymbol{e}^{-\alpha - \beta_1 \ln (C_i) - \sum \beta_j X_j - \mu_i}} \tag{1}$$

With Y_i the dichotomous variable specifying the choice of individual i, α constant, $\beta_j (\ j = 1, 2, \ldots, n)$ the parameters to be estimated, C_i the value of the bid proposed to individual i, β_1 coefficient of the offer (C), X_j the vector of individual explanatory variables and μ_i the error term following a logistic law.

[6] 1 euro (€) = 655 FCFA

• *Data from the econometric analysis*

The estimation procedure is performed on the data from the descriptive analysis above, from which false zeros were excluded as well as individuals who did not report their income or did not comment on the reasons for their refusal to pay the proposed amount. Thus, only information from 502 households was considered.

• *Choice of explanatory variables*

In our study, we preferred to keep in the econometric analysis the variables most correlated with WTP. There are two main reasons for this choice. On the one hand, there is no consensus on the variables influencing the decision to pay or not to pay for wetland quality improvement and their signs. On the other hand, the elimination of irrelevant variables makes it possible to obtain a more efficient econometric model [13] and to reduce the problems of multicollinearity. Thus, out of thirteen potential variables represented by the individuals' responses to the questionnaire, Chi-2 tests revealed six variables with a significant influence on WTP. The specification of these variables as well as the Chi-2 values and their associated significance thresholds are transcribed in the following **Table 2**.

Variables	Specifications	Chi-2	Prob.
	Dependent Variable		
REPONSE	= 1 if the respondent agrees to pay for the proposed offer and 0 if not.		
	Independent Variable		
Ln(OFFER)	= natural logarithm of the amount proposed in the referendum	14.776	0.002
GENDER	= 1 if the respondent is a woman and 0 if not	8.758	0.003
SIZE	= Number of individuals in the household	45.207	0.048
INCOME	= 1 if the monthly household income is greater than €152.67 and 0 otherwise	3.563	0.059
VISIT	= 1 If the respondent has already been to Lake Chad and 0 otherwise	32.849	0.000
SENSITIVITY	= 1 if the respondent is sensitive to the preservation of natural assets and 0 if not.	72.588	0.000

Table 2.
Definition of explanatory variables.

Contrary to our expectations, the variables: age, level of education, marital status, household area of residence, nationality, distance from Lake Chad and awareness of Lake Chad's shrinkage lacked a significant relationship with WTP. However, we are somewhat surprised by the non-significance of the level of education, even though several French studies [13, 14] show that it has a considerable effect on WTP. Nevertheless, the results of studies conducted in developing countries are in our view, particularly those of [15] for Tunisia or [16] for China. This non-significance of the level of education can be explained by the fact that education is not the channel of transmission that enables the local resident populations to receive the knowledge required to appreciate the value of Lake Chad.

3.1.2 Identification of the meaning of the relationship between the explanatory factors and WTP

The results of the Logit model with the significant variables are presented in **Table 3**, along with their marginal effects.

Explicative Variables	Coefficient	z-stat.	P > |z|	Marginal effects
Ln(OFFER)	- 0.506*	- 3.60	0.000	- 0.074
INCOME	0.581**	2.35	0.019	0.083
GENDER	- 0.542**	- 2.10	0.035	- 0.085
SIZE	0.087*	3.35	0.001	0.012
VISIT	0.752*	3.14	0.002	0.117
SENSITIVITY	1.755*	7.01	0.000	0.316
CONSTANT	3.134*	2.58	0.010	
Pseudo R^2	0.2212	Prob> chi-2		0.0000
Log of Likelihood	- 215.91359	Number of observations		502
Correct predictions	82.47%			

*Notes: The model has been corrected for heteroskedasticity by White's method. The signs * and ** indicate the significance of the coefficients at 1% and 5% respectively.*

Table 3.
Logistic regression results.

The results show that the model is significant (Prob> chi-2 = 0.0000) and the correct prediction rate is estimated to be 82.47%, suggesting that the model is generally well-specified. Since the estimated model has satisfactory explanatory power, let us now examine its results. With this in mind, we choose to divide the significant explanatory variables into three categories: economic, socio-demographic and behavioral.

In the economic variable category, the referendum offer and household income have a significant effect on the probability that individuals reveal a positive willingness to pay. The amount offered has a negative effect, as expected, on this probability. Thus, the probability of answering positively to the WTP evaluation question decreases as the amount offered in the referendum increases. Several studies using the CVM with dichotomous choices confirm this finding, including [15, 16], who, in their respective studies, establish a negative relationship between the proposed offer and the probability of accepting to pay the offer.

Contrary to the effect of the offer, household income positively influences the probability of agreeing to pay. As a result, households with higher incomes are also more willing to accept the amount offered than others. This result thus reflects the role that a stable and sufficient income could play in motivating individuals to participate in saving Lake Chad. This result is consistent with the finding of [15] but contradicts with [16], who instead found an insignificant relationship between income and the probability of agreeing to pay. Using a Tobit model, [14, 17] find results that are in our direction, notably a significantly positive relationship between income and respondents' WTP.

The signs of the economic variables somehow reassure the rationality of households in their response since they are in line with the expectations of economic theory [2]; indeed, the probability of accepting to pay decreases with the value of the proposed offer and increases with income. This finding allows us to theoretically validate our contingent study and to conclude that saving Lake Chad is not an inferior[7] good for the local residents.

[7] In economics, an inferior good is a good for which the income elasticity is negative. That is, a good for which demand decreases as income increases.

Concerning the socio-demographic profile of households, only two variables are significant: the gender of the respondent and the size of the household. The first has a negative effect on the probability of accepting the proposed amount. Based on this result, it can be assumed that women are less likely to pay than men. This may be explained by the fact that women do not have equivalent control over, or access to, household financial resources as men do. Thus, they are often reluctant or unable to commit the household to a substantial financial obligation. This finding is also observed by [14] who reveals that women have lower WTP than men. The second has a positive effect on the probability of accepting the bid. This result probably reflects the willingness of households to pass on this natural heritage to future generations. This result corroborates that of [15] regarding the positive significance of household size in explaining the probability of agreeing to pay for the proposed auction.

With regard to the variables related to behavior in the face of Lake Chad, the results indicate a significant positive relationship between WTP and visiting Lake Chad. Individuals who have ever visited Lake Chad are certainly aware of the threat to it, and are therefore more willing to pay to preserve it than others. This finding is consistent with the work of [11], who finds a significant and positive relationship between the WTP revealed and visiting the Seine estuary. Similarly, environmental sensitivity has a positive effect on WTP, confirming the results of [14, 17]. As a result, individuals who feel concerned about the protection or safeguarding of natural environments tend to accept the bid offered more than others. These last two results highlight not only the positive role that environmental awareness and education can play in household policies to preserve Lake Chad, but also the value of media coverage of information on the negative effects of the degradation of this natural heritage.

3.2 Average WTP and project benefits values

The main difficulty with logistic regression is that it does not allow direct measurement of average WTP. A procedure for calculating average WTP is therefore necessary.

3.2.1 Procedure for calculating average WTP

The calculation procedure we have adopted to estimate average WTP is based on Eq. 1 above and the truncation of the maximum supply from the questionnaire[8]. The expression for the corresponding average WTP[9] is:

$$\boldsymbol{Average\ WTP} = -\frac{\mathbf{1}}{\boldsymbol{\beta_1}}\left[\ln\left(\mathbf{1}+\boldsymbol{e}^{\boldsymbol{\alpha}-\boldsymbol{\beta_1}\ln(C)}\right]_{\mathbf{0}}^{\boldsymbol{C^*}}\right.$$

$$\Rightarrow \boldsymbol{Average\ WTP} = -\frac{\mathbf{1}}{\boldsymbol{\beta_1}}\left(\frac{\mathbf{1}+\boldsymbol{e}^{\boldsymbol{\alpha}-\boldsymbol{\beta_1}\ln(C^*)}}{\mathbf{1}+\boldsymbol{e}^{\boldsymbol{\alpha}}}\right) \qquad (2)$$

The arguments of the other variables are not explicitly apparent[10] in Eq. 2, but their influence is exerted on the values of the parameters α and β_1.

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[8] $t_1 = 0$ *et* $t_2 = C^*$, with C^* the maximum offer of the referendum which is €18.32.

[9] See **annex C** for the procedure followed to obtain the expression of equation 2.

[10] Because they are constant and become null when the utility of the individual varies

3.2.2 Value of average WTP

Average WTP is calculated based on the econometric results of the estimation of the previous Logit model (**Table 3**). **Table 4** below gives the logarithmic value of mean WTP. Thus, the real mean WTP is obtained by applying the exponential function. The corresponding average WTP is estimated at €17 per household per year. This value is lower than those obtained in other studies carried out in developing countries and using CVM with dichotomous choices, such as those of [15, 16], who find an average WTP of €25 and $35 respectively. Also, it remains lower than French studies using payment cards: €25 for [14] or €45 for [11].

Constant (α)	**3.134**
Coefficient of the offer (β_1)	- 0.506
Ln (Average WTP)	**€0.014/year**
Average WTP	**€17/year**

Table 4.
Calculation of average WTP.

Over five years, as planned in the contingent scenario, we end up with an average WTP of €85 per household to help finance the restoration of Lake Chad. This value, aggregated across all households that value Lake Chad, allows us to obtain the benefits associated with the project.

3.2.3 Monetary evaluation of project benefits

In 2010, the population of this department was estimated at 551,718 individuals with an average of 7 people per household [18]. If we consider the national population growth rate (2.8%), we can estimate the population at 567,166 in 2011, which corresponds to an estimated 81,024 households. However, 502 households out of 623 value the preservation of Lake Chad, or 80.58% of the households in our sample.

The social benefits related to the restoration of Lake Chad are obtained by multiplying the average WTP by 80.58% of households, for an estimated monetary value of €5,549,576.832. This value represents what people in the region would be willing to give to save Lake Chad.

4. From the farmers' WTA estimate to the social costs of the project

The objective here is to estimate the farmers' willingness to receive financial compensation for the losses that would arise from the restoration of Lake Chad and to deduct the induced social cost[11]. This section is thus structured around these two main axes.

4.1 Identification and analysis of the determinants of farmers' WTA

In order to measure the farmers' willingness to receive financial compensation for the welfare losses that would result from the restoration of Lake Chad, we used the CVM.

[11] This section is a synthesis of the article published in 2014 in the Journal of Studies in Agriculture and Environment by [19]. For more details on the methodology and results, see this article.

4.1.1 Methodology

We successively present the data used, the econometric model used and the variables that could explain the farmers' WTA.

4.1.1.1 Data used

Data also come from the survey conducted in 2011 in the Cameroonian part of Lake Chad (presented above). This operation collected information on a sample of 98 farming households. The format of an open-ended question was used in this survey as a means of formulating and revealing the farmers' WTA[12] to bear the losses that would be related to the project's implementation.

In addition to their WTA, the interested parties revealed other information about themselves: socio-economic characteristics and opinions on the issues related to the safeguarding of Lake Chad. These indications, known as potential explanatory factors for the amounts expressed, are necessary for the econometric analysis of the latter, in order to predict an average WTA. By extrapolating the average WTA to the scale of the population concerned, this last calculation allows us to obtain the social costs resulting from the restoration of Lake Chad.

Tables A4–A6 in **Annex B** present the socio-economic profile of the farm households in our sample and their attitudes towards the project, respectively.

4.1.1.2 Econometric model

The objective of this model is to provide additional information that may help to better understand the formation of WTAs on household farmers. With this in mind, and depending on the ongoing nature of the WTA data, a simple regression model was chosen to identify the key explanatory factors for farmer WTA. The formulation of this model is as follows:

$$\ln(WTA_i) = \beta X_i + \mu_i \quad (3)$$

Where WTA_i is the approval to receive from individual i; β vector of parameters to be estimated, μ_i vector of error terms. Note here that preliminary regressions have shown that the semi-logarithmic model gives, in addition to reducing the potential effects of overestimating WTA values, better results than the others.

4.1.1.3 Specification of variables for the econometric analysis

The specification of the variables that may explain the value of the WTA is given in **Table 5** below.

4.1.2 Factors explaining the level of WTA

Estimation is performed on data from which false zeros have been excluded, including 7 farm households. In the end, information from 85 farm households is

[12] To obtain this value, the hypothetical scenario was conveyed as follows: "Let us assume, in a totally imaginary way, that the public authorities propose to abandon your agricultural fields located near Lake Chad in exchange for financial compensation. However, for budgetary reasons, only the inhabitants with the lowest compensation would be eligible for these subsidies. Personally, in this imaginary case, would you be willing to accept financial compensation for abandoning these fields? If so, how much would you be willing to accept to abandon these fields? ".

Variables	Specifications
STATUS	= 1 if the respondent is married and 0 if not
AGE	= 1 if the individual's age is between 30 and 60 years old and 0 if not
Ln(INCOME)	= natural logarithm of annual household farm income
SIZE	= Number of individuals in the household
DISTANCE	= 1 if the distance between the home and Lake Chad is >20 Km and 0 if not
FISHING	= 1 if the household participates in the fishing activity and 0 if not

Table 5.
Definition of the explanatory variables of the WTA.

taken into account. To this information, we applied the simplest and most immediate method of estimation, namely ordinary least squares. **Table 6** below presents the results obtained.

Explicative Variables	Coefficient	t-stat.	P > |t|
DISTANCE	- 0.176 NS	- 1.350	0.181
AGE	0.067 NS	0.900	0.369
STATUS	0.209*	1.860	0.067
SIZE	0.013*	1.730	0.088
FISHING	- 0.027 NS	- 0.280	0.781
LN(INCOME)	0.684***	10.600	0.000
CONSTANT	3.677***	4.210	0.000
R^2	0.7314		
F-Stat.	29.84		
Prob (F-Stat.)	0.0000		
Number of observations		**85**	

*Notes: The model has been corrected for heteroskedasticity by White's method. The ***, **, and * indicate the significance of the variables at thresholds of 1, 5, and 10 per cent, respectively. NS: Not significant.*

Table 6.
Results of the estimation of Eq. 3.

The results presented in **Table 6** above call for the following comments.

First of all, the WTA revealed by individuals is not a randomly announced value, but depends mainly on the level of farm income, probably reflecting the absence of strategic bias such as the desire to block the project or the announcement of compensation amounts that are totally disproportionate to the actual costs incurred by the project. The WTAs obtained should therefore be considered normal, as they are formulated in relation to the agricultural losses incurred. This result thus contradicts those often put forward in the literature, notably the abnormally high or infinite nature of the WTA values [20] or the popular conclusion that budgetary constraint does not play a role in the revelation of the WTA, but remains consistent with those of [21–23] who find a statistically significant and positive relationship between the levels of compensation requested by farmers and farm income.

Second, the positive sign of the coefficient indicates that households with high farm incomes tend to demand higher levels of compensation than others. This result is somewhat reassuring to the rationality of the households in their response, and is indicative of the close relationship between farm income and the level of WTA.

All factors being equals, the calculation of the income elasticity of the WTA shows that a 10% increase in income would result in a 6.84% increase in WTA, confirming the predominant role of agricultural income in the formulation of the WTA.

Finally, the results highlight the positive roles of marital status and household size on the WTA level. Couple households would thus require higher compensation than other households. Similarly, households with many members tend to express higher WTAs than others. These results can be partly explained by the strong tendency of these households to engage in agricultural activities [24], and therefore would be more vulnerable to the induced effects of the project. They also point to a greater loss of income for these farming households than would be induced by the project, and therefore suggest that any compensation should be modulated according to these criteria.

4.2 Econometric estimation of the average WTA and deduction of social costs

4.2.1 Econometric estimation of the average WTA

Econometric modeling provides, based on the estimated coefficients, the predicted WTA values for all individuals in the sample, even for those not included in the regression. The average WTA resulting from this modeling is thus estimated at €1,405.515 within a 95% confidence interval of [1,246.803; 1,564.226].

4.2.2 Estimating the social costs of restoring Lake Chad

The social costs associated with the Lake Chad restoration project are obtained by multiplying the average WTA by the number of potential victims. However, during data collection, it was not possible to determine the exact number of farming households that could be affected by the project. Therefore, this number was estimated based on the total agricultural population of the Cameroonian districts sharing Lake Chad, i.e., 27,008[13] agricultural households in 2010.

According to the data collected, the social costs are estimated at €37,960,149.12 with a 95% confidence interval of [33,673,656.87; 42,246,614.57]. This value represents the monetary assessment of the damage that the Lake Chad restoration project would impose on the riparian agricultural population.

5. Comparison of values and discussion

The average WTP is estimated (in the medium term) to be €85 per household, or a total benefit of €5,549,576.832 from the Lake Chad restoration project. On the other hand, the average compensation to be paid to potential victims is in the order of €1,405.515, so the total cost of the project would be around €37,960,149.12[14]. It thus appears that the costs of restoring Lake Chad clearly outweigh the benefits. This result is in line with the conclusions of [11, 25] on the trade-off between productive/non-productive uses of wetlands, but contradicts the work of [22], which highlights the superiority of the benefits (12.6 million euros) over the costs (2.3 million euros) for the preservation of 2000 hectares (ha) of natural habitats along the Garonne River. This difference in results can nevertheless be explained by the observed differences in the sizes of the beneficiary populations (250,000

[13] Data collected at the MINADER departmental delegation.

[14] It should be noted that this amount should be used with caution, as it takes into account all farm households in the districts concerned, and not the potential victims of the project.

households) and their standards of living. For the average WTP is around €50.4/year and the average WTA around €1150/ha/year.

We thus find ourselves in a paradoxical situation in which, in the medium term (5 years), the agricultural conversion benefits of Lake Chad are far greater than what the people of the region will be willing to give to save it. This result would therefore justify the trade-off to be made in favor of a productive use of Lake Chad's wetlands. However, this difference must be tempered given:

- The omission of negative externalities (water pollution, deforestation, etc.) in the calculation of the benefits induced[15] by agricultural activities;
- The overestimation of costs due to the impossibility of counting the potential victims of the project;
- The low representativeness of the sample[16] in relation to the total population living along the shores of Lake Chad;
- The time horizon: economic or ecological. For an economic horizon (5 to 10 years), it is not profitable to carry out the project. On the other hand, if the ecological horizon is chosen (from 35 years), it becomes profitable to carry out the project, because the benefit/cost ratio would then become greater than 1, since the benefits of the project would then be around €38,543,518.56.

The amounts announced are therefore indicative for all policy choices, and must therefore be taken with caution. That said, the results obtained can nevertheless serve as a basis for deliberation among the parties concerned, without being a sufficient or necessary condition for the decision to implement a policy to restore Lake Chad. Other reasons may justify this policy.

6. Conclusion

At the end of our study, it is very clear that the protection of Lake Chad is of crucial necessity, given the economic and environmental importance of this natural area. In economic terms, Lake Chad is much more than a source of recreation for its residents; it is the very foundation of their food security. It guarantees the economic and social dynamics of the region and constitutes, in a way, a pool of jobs linked to the economic activities that are found around it. From an environmental standpoint, the survey also reveals that Lake Chad is perceived by its neighbors and farmers as a true natural heritage and, as such, should be saved from its likely fate. To this effect:

- 73.51% of the riparian populations are in favor of the Lake Chad restoration project, and 63.40% would not hesitate to allocate a certain portion of their income to participate financially in the realization of such a project.

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[15] Taking externalities into account would significantly reduce the value of productive benefits. However, to our knowledge, no research has yet focused on the monetary quantification of these externalities. Yet, such an evaluation would make it possible to determine the net benefits of Lake Chad's agricultural use.

[16] The absence of a part of the population concerned deprives us of useful information on a possible contribution of this layer to the evaluation of the project. However, the transferability of values could lift this limit.

- Despite their dependence on the productive services it provides, 70% of riparian farmers are in favor of the project. This percentage rises to about 87% when financial compensation is offered in return.

Its statistics are thus proof that, from the population's point of view, there is a real benefit in preserving Lake Chad, even if the estimate of this benefit appeared low, or at least lower than that generated by the agricultural use of Lake Chad's shores. However, this difference does not mean that the economy should be favored over the environment, but it does make it possible to highlight the possible perverse effects that could result from carrying out the Lake Chad restoration project without taking into account its potentially negative impact on agricultural activities, and thus on the food security of the riparian populations. In view of the above, we propose a new approach to save Lake Chad from its probable disappearance, one that takes into account both economic and environmental objectives. Thus, rather than opposing the quality of the environment to the pursuit of economic development, we believe that these two objectives are in close interaction and that a policy to save Lake Chad should ideally take into account all of them rather than focusing on one or the other. The economic literature speaks of sustainable development.

Furthermore, we believe that restoring Lake Chad without addressing the causes that led to its dwindling could be an unsustainable solution because the same causes will produce the same effects. Indeed, even if this natural asset were to be restored, there is no guarantee that it will not dwindle again and endanger the river that provides it.

Thus, whatever the choice of decision-makers, it is essential to implement policies for the protection of this natural heritage. To this end, it is crucial to move from logic of supply management of the natural resources of the lake basin to logic of demand management of the said resources. This can be achieved by putting in place incentive mechanisms for the sustainable management of the wetlands of Lake Chad and the biodiversity associated with them.

Annex

Annex A. Some descriptive statistics of the WTP Revelation Scenario

Socio-Economic Profile		Enrolled	Percentage (%)
SEX	Male	436	69.98
	Female	187	30.02
AGE	Average of 30 years	187	30.02
	From 30 to 44 years	185	29.70
	From 45 to 60 years	208	33.39
	Above 60 years	43	6.90
MARRITAL STATUS	Married	321	51.52
	Divorced / Widow/Widower	118	18.94
	Single	184	29.53
LEVEL OF EDUCATION	None	151	24.24
	Primary	77	12.36
	Secondary 1st cycle	74	11.88

Socio-Economic Profile		Enrolled	Percentage (%)
	Secondary 2nd cycle	177	28.41
	Tertiary	102	16.37
	Not stated	42	6.74
AVERAGE MONTHLY INCOME	Less than €30.53	75	12.04
	From €30.54 to €76.34	147	23.60
	From €76.35 to €152.67	116	18.62
	From €152.68 to €305.34	97	15.57
	From €305.35 to €763.36	99	15.89
	Above €763.36	59	9.47
	Is not pronounced	30	4.82

Table A1.
Sample distribution by socio-economic profile.

	Number of observations	Percentage (%)
Sensitivity to the protection of natural environments	414	66.45
Visits to Lake Chad	382	61.32
Awareness of Lake Chad dwindling	499	80.10
Favorable to the Lake Chad Restoration Project	458	73.51
Agrees to pay the proposed amount	395	63.40

Table A2.
Relationship and preferences of individuals towards Lake Chad.

Reasons	Type of zero	Enrolled	Proportion
It's not up to you to pay	False zero	51	22.37%
You do not consider this action necessary	True zero	66	28.95%
Your financial means do not allow you to do so	True zero	51	22.37%
You do not have enough information to decide	False zero	25	10.96%
You are afraid to pay for others	False zero	13	5.70%
Other reasons	False zero	14	6.14%
No opinion	False zero	8	3.51%
Total		228	100%

Table A3.
Reasons for refusing to pay the proposed amount.

Annex B. Descriptive statistics of the Farmers' WTA Revelation Scenario

Socio-Economic Profile	Enrolled	Proportion
Average size of household	9.74	

Socio-Economic Profile		Enrolled	Proportion
Civil status	Married	77	78.57%
	Divorced	13	13.27%
	Single	8	8.16%
Sex	Male	86	87.76%
	Female	12	12.24%
Age	Age < 30	19	19.39%
	30 ≤ Age < 45	33	33.67%
	45 ≤ Age ≤ 60	25	25.51%
	Age > 60 years	21	21.43%
Level of education	None	53	54.08%
	Primary	32	32.65%
	Secondary 1er cycle	9	9.18%
	Secondary 2nd cycle	4	4.08%

Table A4. Sample distribution by socio-economic profile.

Surface area in hectares (ha)	Enrolled	Proportion	Average farm income (€)
Surface area < 1	4	4.08%	885.50
1 ≤ ***Surface area*** < 2	15	15.31%	1,548.09
2 ≤ ***Surface area*** < 5	18	18.37%	2,256.49
5 ≤ ***Surface area*** < 10	32	32.65%	2,297.71
Surface area ≥ 10	29	29.59%	3,734.35
TOTAL	**98**	100%	2,144.43

Table A5. Attribution of average farm income by surface area.

		Enrolled	Proportion
Opinion of the project	Very important	15	15.31%
	Important	54	55.10%
	Less important	26	26.53%
	Not important at all	03	3.06%
Favorable for compensation	Yes	85	86.73%
	No	13	13.27%
Reasons for Refusal	**Type of zero**		
I do not feel concerned	True zero	0 6	46.15%
I want to continue my activities	False zero	05	38.46%
This action is not necessary	False zero	02	15.38%

Table A6. Attribution according to individuals' attitudes towards the fictitious scenario.

Annex C. Procedure for obtaining Equation 2

Assume that the individual's utility depends on improvement in the quality of a good's environment q, its income R and other observable socio-demographic variables m. Based on these hypotheses, we retain the linear utility function as follows:

$$v(q,R,m) = \alpha_q + \beta R + \gamma m \qquad \text{q} = 0,1 \tag{A1}$$

In a closed question, the respondent agrees to pay an amount of money C in order to benefit from the restoration of Lake Chad, if

$$v(1,R-C,m) \geq v(0,R,m) \tag{A2}$$

The induced variation in utility (Δv) is therefore a function of cost C:

$$\begin{gathered} \Delta v = \alpha_1 + \beta(R-C) + \gamma m - \alpha_0 - \beta R - \gamma m = (\alpha_1 - \alpha_0) - \beta C \\ \alpha_1 - \alpha_0 = \alpha \quad \Longrightarrow \qquad \Delta v = \alpha - \beta C \end{gathered} \tag{A3}$$

Let F be the distribution function of a logistic law, then the probability (P_0) that individuals are willing to pay the amount C can be expressed by the following equation:

$$P_0 = F_\varepsilon(\alpha - \beta C) = \frac{1}{1+e^{-\alpha+\beta C}} = \frac{e^{\alpha-\beta C}}{1+e^{\alpha-\beta C}} \tag{A4}$$

From this equation (4), the average WTP is defined by:

$$\begin{gathered} \text{Average WTP} = E(WTP) = \int_{t_1}^{t_2} F_\varepsilon(\alpha - \beta C)dC \\ \Longrightarrow E(WTP) = \int_{t_1}^{t_2} \frac{e^{\alpha-\beta C}}{1+e^{\alpha-\beta C}}dC \end{gathered} \tag{A5}$$

In order to calculate this integral, it is necessary to look for a primitive of the function which is inside the integral.

First of all, let's assume:

$$u(C) = 1 + e^{\alpha-\beta C} \quad \Rightarrow \quad u'(C) = -\beta e^{\alpha-\beta C} \tag{A6}$$

Next, let's look for:

$$E(WTP) = \int_{t_1}^{t_2} \frac{u'(C)}{u(C)}dC \;\Leftrightarrow\; E(WTP) = \left[ln\left(u(C)\right)\right]_{t_1}^{t_2} \tag{A7}$$

In this perspective, we will multiply the numerator and denominator of the function within the integral by $-\beta$. We have:

$$\begin{gathered} E(WTP) = \int_{t_1}^{t_2} \frac{-\beta}{-\beta} * \frac{e^{\alpha-\beta C}}{1+e^{\alpha-\beta C}}dC = \int_{t_1}^{t_2} -\frac{1}{\beta} * \frac{-\beta e^{\alpha-\beta C}}{1+e^{\alpha-\beta C}}dC \\ \Longrightarrow E(WTP) = -\frac{1}{\beta}\int_{t_1}^{t_2} \frac{-\beta e^{\alpha-\beta C}}{1+e^{\alpha-\beta C}}dC \\ \Leftrightarrow E(WTP) = -\frac{1}{\beta}\int_{t_1}^{t_2} \frac{u'(C)}{u(C)}dC = -\frac{1}{\beta}\left[ln\left(u(C)\right)\right]_{t_1}^{t_2} \\ \Longrightarrow E(WTP) = -\frac{1}{\beta}\left[ln\left(1+e^{\alpha-\beta C}\right)\right]_{t_1}^{t_2} \end{gathered} \tag{A8}$$

Where:

$$E(WTP) = \int_{t_1}^{t_2} \frac{e^{\alpha-\beta C}}{1+e^{\alpha-\beta C}} dC = -\frac{1}{\beta}\left[ln\left(1+e^{\alpha-\beta C}\right)\right]_{t_1}^{t_2}$$

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