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Table of Contents: Volume 9 Number 7 August 2017

## ARTICLE

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*Full Length Research Paper*

# Accounting for the environmental costs of hydropower station on local communities: A case study of Jebba Lake of Niger River Watershed, Jebba, Kwara State, Nigeria

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**Hydropower has been the main source of energy in Nigeria, until recently when thermal and fossil-fuel driven turbines and other alternatives are becoming commonplace. The concern for power generation tends to becloud environmental and natural resource degradation that accompanies execution of hydropower projects or plants. One of the principal resources concerned is the watershed of hosting rivers. These impacts reflect on fishery, navigation, domestic and agricultural water supplies. This study examined the impacts of hydropower plants on watershed of Jebba Lake on Niger River and evaluates the environmental cost of that impact on the various facets of the watershed. It also assessed the efficacy of remediation in respect of hydropower plants hosting communities. Contingent valuation method was adopted through a survey of local communities and the Jebba lake of Niger River watershed, Jebba, Nigeria. Stratified samples were drawn from fishers, farmers and dwellers of neighboring communities. Data were tabulated and percentages, mean scores, variances and standard deviations were computed. The hypotheses were tested using ANOVA, F-statistics and the t-test. Results shows that beyond the marketed cost of producing power there are myriads of environmental costs, often concealed by the difficulty of determining the non-market values of the benefits and cost associated therewith. It was concluded that the environmental impact of hydropower plants/projects is significant and calls for critical study during its environmental administration process. Thus, the total cost of producing electricity should reflect environmental components in order to serve as adequate basis for pricing units of production.**

**Key words:** Accounting, environmental costs, hydropower, watershed.

## INTRODUCTION

### Background to the study

The need for increased energy generation is global. Statistics abound to justify increased energy demand, considering population growth and growth in economic activities generally. The projected population growth rate for the world for 2009 to 2035 was put at 0.9%, with 1.1% growth rate for the periods 2009 to 2020 and a slower growth rate of 0.8% between 2020 and 2035. In Africa, a growth rate of 2.3% was projected for 2009 to 2020 which is expected to slow down to 2% between 2020 and 2035 to average 2.1% overall for 2009 to 2035 (OECD/IEA, 2011). Nigeria's population is estimated at 173.6 million (2013) and growing at the rate of 2.7% annually (World

Bank Group, 2015). Similarly, economic activities had risen over the years, with global GDP growth and Nigeria's economic growth at 6.3% between 2011 and 2015. This economic growth has brought with it increased economic activities that require energy consumption. The estimated Total Global Primary Energy Supply in 2012 was estimated by The International Energy Agency (IEA) at 155,505 terawatt-hour (TWh) or 17.7 TW (Mtoe 13,371); up from 71,013 terawatt-hour (TWh) (Mtoe 6,106) in 1973 over a 100% increase (OECD/IEA, 2014). As observed by Kaunda et al. (2012), "the global energy is still dominated by fossil fuel," providing about 80% of total energy supply. The environmental implications of fossil fuel paints a gloomy future for the world, hence the search for a more sustainable energy source.

Sustainable energy system is one that extracts, converts and utilizes energy in a manner that its current generation does not lead to significant environmental degradation, and its use does not compromise those of future generations in meeting their needs (Kaunda et al., 2012). Environmental degradation and climate change has occupied the focus of the world considering the threat to livelihoods and biodiversity, especially food diversity and security. The looming consequences of global climate change have created a strong imperative to move away from fossil fuels and to develop more sources of renewable energy. This had encouraged the adoption of renewable sources that is carbon neutral and creates less air pollution. Hydroelectric power is one of such sources. It is a renewable energy source. Hydropower is one of the important renewable energy resources for generating electricity and hydropower occupies global position in sustainable energy generation.

A discussion on global environment and climate change is crucial because they constitute the main concerns for energy systems. It was noted by Ebinger and Vergara (2011),that energy sector emits about 70% of the total Green House Gases (GHG) emissions with electricity generation being responsible for a larger share of global energy consumption. But, hydroelectricity generation technology seems to resolve the problem of GHG and in addition is one of the cheapest in terms of electricity generation costs (USA Department of Energy, 2012). Hydroelectric power systems are judged to be highly efficient in energy conversion- mechanical work is directly converted into electricity. This technology may achieve 85% efficiency as contrasted with thermal-electric plants which achieve less than 50% on the average (Roth, 2005).

Wang et al. (2009) observed that "although hydropower is usually regarded as a kind of clean energy, its negative impacts on water quality, estuary sedimentation, habitat, landscape, biodiversity and human health during development are generally well known and critically studied" (Puff et al., 1997; Jansson et al., 2000; WCD, 2000; Andreas et al., 2002; Gehrke et al., 2002; Dudgeon, 2005). They further noted that hydropower development has many negative impacts on watershed ecosystems. Determining the costs of hydropower plants on the environment, especially the livelihoods of downstream communities and their economies, may not be so easily determined because environmental degradation cannot be so easily quantified and valued. To successfully estimate the costs of environmental impacts requires measurement of the impact in terms of its occurrence or the probability of occurrence; and, developing valuation bases for the measured impacts. The procedure involved is akin to what is often adopted in cost-benefit studies with the adoption of various methods such as the contingent valuation like Willingness to Pay or Accept Compensation, the Travel Cost and some Hedonic measures. Such hypothetical values are subjected to empirical analysis and the mean values are adopted for the population targeted. The extrapolated values have significant effects on policy in respect of the project and the pricing of services provided.

## The problem

The significance of hydropower projects in curtailing climate change cannot be overlooked, in that when compared to other sources of electrical power it is one of the least direct contributors to climate change. However, when examined closely, a hydropower project produces social and environmental impacts during construction and operation phases of the project. The construction of the plant could involve making of roads, dam, weirs, tunnels, power plants structures, and electricity transmission lines. Often, land is cleared, forest removed and some communities displaced to make room for such constructions. Flooding of land by the reservoir may disrupt ecosystem, destroy infrastructure, and displace settlements.

The various activities involved in construction and operating a hydropower project "result in localized air and water pollution, loss of biodiversity, destruction of infrastructure, change of landscape, destruction of settlements, and loss of livelihood and cultural identity in the direct project affected areas" (Kaunda et al., 2012). There is a consensus of opinions as to the degradation of the environment and livelihoods around the projects, especially downstream, what constitutes problem in

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literature is how to ascribe meaningful values to these impacts in a manner that would be acceptable globally. This gap is a formidable challenge in research on natural assets accounting and management. It is the thrust of this study. In resolving this issue, the questions were:

1. What is the nature of impact of hydropower plant operations in Jebba on the watershed?
2. To what extent has hydropower plant dam affected the ecosystem downstream?
3. What is the perceived cost of hydropower plant to communities?

Arising from these questions, the main objective of this study was to evaluate the costs of Jebba lake hydropower plant on the Niger River watershed of Jebba. Accordingly, it was aimed to:

1. Determine the nature of impacts of Jebba hydropower plant on the Niger River watershed of Jebba;
2. Assess the impacts of the dam on ecosystem downstream;
3. To evaluate the costs of hydropower plant on communities.

This study was able to apply the contingent valuation method, through the Willingness to Accept Compensation, to provide a pointer to metrics to consider in such valuation process.

## CONCEPTUAL AND THEORETICAL CLARIFICATIONS

There are various definitions to climate change. Intergovernmental Panel on Climate Change (IPCC) defined climate change as “any change in climate system over time which can be identified (e.g., using statistical tests), whether due to natural variability or as a result of human activity” (IPCC, 2001). United Nations Framework Convention on Climate Change (UNFCCC) (2012) also defined it as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.”

From these definitions, the question of climate change in a country or region can be answered through research, by examining both natural causes and human-induced aspects over long time periods. Climate change is the result of global warming when human-induced gases (or emissions) trap heat from solar energy in the atmosphere similar to a “greenhouse.” These gases are referred to as Greenhouse Gases (GHGs), with Carbon dioxide being the major greenhouse gas; others are methane, nitrous oxide, and carbon-fluorinated gases (Kaunda, et al., 2012).

Contingent valuation methods refer to those methods which ascribe values to objects, process or activities contingent on survey of stakeholders. An hypothetical market value is assigned to the object, process or activities and the readiness of stakeholders to accept compensation in that sum is assessed.

## METHODOLOGY

### Research design

A descriptive research design was adopted for the study. This calls for resolving issues around research questions and tests of hypotheses. The survey method was combined with exploratory tools that seek to provoke further discoveries of latent issues/ variables for consideration.

### Study area

This study was carried out at the watershed of the Jebba Lake of Niger River and the host communities for Mainstream Hydropower station. The watershed comprise of three towns and several smaller settlements downstream of the plant within ten kilometers distance. Djebba, as the towns are sometimes called comprise of Jebba North in Niger State, Jebba South in Kwara State and Gana in Niger State. Its coordinates are 9°7'60" N and 4°49'60" E in DMS (Degrees Minutes Seconds) or 9.13333 and 4.83333 (in decimal degrees). Its UTM position is GL01 and its Joint Operation Graphics reference is NC31-12 (Get-A-Map.net, 2015). It is a major connecting settlement between Southwestern and Northern Nigeria.

Jebba South located in Kwara State is predominantly Yoruba ruled by an Oba, while Jebba North and Gana on both banks of the river are Nupes ruled by Etsu Nkpa. These communities live harmoniously among themselves with the settlers who dwell among them. The power plant is located between three and five kilometers from the towns by road. The main occupations of the dwellers are farming and fishing supported with trade. It had been a stop over town for travellers and tourist attractions including the historical Mungo Park cenotaph, the scenery of the lakes and river and the mountain.

### The hydropower station

Jebba hydropower station is one of four hydropower plants in Nigeria, the other three being Kainji, Shiroro and Zamfara power stations. Other hydropower projects under construction are Kano, Kiri and Mambilla power stations. Jebba Hydropower station was the second to be commissioned for operation in Nigeria in 1985, the first being Kainji in 1962; the third being Shiroro in 1990; and, the fourth, Zamfara in 2012. The installed capacity of the plant was 540 mw. Due to the desire of the Federal Government of Nigeria to increase power generation, transmission and distribution, the power sector reform was pursued and power generation and distribution subsectors were privatized. Jebba Hydroelectric Station is run by Mainstream Energy Solutions Limited.

### Population and sampling

Conflicting statistics of the population of residents were obtained from various websites; however Jebba South is more densely populated than Jebba North. A sample of two hundred and seventy respondents was selected from the three immediate neighbouring

**Table 1.** Willingness to pay for the benefits of hydropower plant.

| Benefits of hydropower plant | Yes | % | No | % | Total |
|---|---|---|---|---|---|
| Power supply | 251 | 94.4 | 15 | 5.6 | 266 |
| Employment opportunities | 252 | 94.7 | 14 | 5.3 | 266 |
| Collaborations | 218 | 81.9 | 48 | 18.1 | 266 |
| Improved commerce | 236 | 88.7 | 30 | 11.3 | 266 |
| Irrigation | 194 | 72.9 | 72 | 27.1 | 266 |
| Flood control mechanism | 187 | 70.3 | 79 | 29.7 | 266 |

Source: Research Survey, 2015.

communities to the power plant downstream for a survey to determine a willingness to accept compensation.

### Research instrument

Questionnaire was designed and administered to dwellers in the riparian communities of Jebba. The first part focused on socioeconomic characteristics of the residents, while part two sought information on the perceived benefits of the power plant and part three, on the adverse effects. Parts two and three examined the willingness to pay (WTP) for furtherance of benefits and a willingness to accept (WTA) compensation for the losses suffered. These questionnaires were explained in local tongues, that is, Yoruba and Hausa, although most respondents preferred to answer in English.

### Methods of analysis

The data collected were analysed using various descriptive and inferential tools of analysis. The percentages, mean scores and standard deviations of responses were calculated. Furthermore, the LOGIT regression model was used to determine the willingness to pay/willingness to accept compensation while the amount indicated as willingness to pay were aggregated, averaged and expressed per unit of power generated.

## RESULTS AND DISCUSSION

For the first part of evaluation, that is Willingness to Pay, the Independent Variables (Respondents Attributes) were: $X_1$: Gender; $X_2$: Marital Status; $X_3$: State of Origin; $X_4$: Education; $X_5$: Size of farm;
$X_6$: Occupation; $X_7$: Average Annual Income; $X_8$: Age; $X_9$: Size of family; $X_{10}$: Location; $X_{11}$: Distance from Power Plant; And the dependent variables are the benefits provided by power plants. These are: ENG- Energy; EMP- Employment; COL- Collaborations; COM- Commerce; IRR- Irrigation; FCM- Flood Control Mechanism.

For the second part of evaluation, that is, Willingness to Accept Compensation, the Independent Variables (Respondents Attributes) were: $X_1$: Gender; $X_2$: Marital Status; $X_3$: State of Origin; $X_4$: Education; $X_5$: Size of Farm; $X_6$: Occupation; $X_7$: Average Annual Income; $X_8$: Age; $X_9$: Size of Family; $X_{10}$: Location; $X_{11}$: Distance from Power Plant; And the dependent variables are the benefits provided by power plants. These are: FLD- Flooding; WPL- Water Pollution; FSD- Fish Diversity loss; FSQ- Fish Size and Quantity Loss; VFD- Vegetables and Fruits Diversity loss; GLL- Grazing Land loss; WLD- Wildlife loss; RCL- Riparian Crops loss; FOR- Forest Cover loss; ERS- Erosion; YLD- Lowered Crop Yield

Questions raised elicited a dichotomous response of Yes or No, in respect of the willingness of respondents to pay or accept compensation for environmental benefits and damages of hydropower plant as identified. That is, to each of the identified environmental benefit and costs, the respondents indicated their willingness to pay as shown in Tables 1 and 2 and Figures 1 and 2.

### Analysis of data

The data in respect of the dichotomous responses on environmental services were analysed with the use of LOGIT Regression Model. However, to overcome the problems of crowding out of important details in the analysis, each response was subjected to the evaluation, using the model as follows:

$$In\frac{Pi}{1-Pi}=\frac{\mathrm{f}(X1+x2+x3+\cdots+Xn)}{fi, or\ mi}$$

Where; $X_1$ = Gender of respondents; $X_2$ = Marital Status of respondents; $X_3$ = State of origin of respondents; $X_4$ = Education of respondents; $X_s$ = Size of farm of respondents; $X_6$ = Annual Income of respondents; $X_7$ = Age of respondents; $X_8$ = Size of family of respondents;
$X_9$ = Distance from Power Plant. Fi, could be $F_1$, or ENG- Energy; $F_2$, or EMP- Employment;`$F_3$, or COL- Collaborations for Development; $F_4$, or COM- Improved Commerce; $F_5$, or IRR- Irrigation; $F_6$, or FCM- Flood Control Mechanism. Mi, could be $M_1$, or FLD- Flooding; $M_2$, or WPL- Water pollution; $M_3$, or FSD- Fish diversity loss; $M_4$, or FSQ- Fish size and quantity loss; $M_5$ or VFD- Vegetables and fruits diversity loss; $M_6$ or GLL- Grazing land loss; $M_7$ or WLD- Wildlife loss; $M_8$ or RCL- Riparian crops loss; $M_9$ or FOR- Forest cover loss; $M_{10}$ or ERS- Erosion; and $M_{11}$ or YLD- Lowered crop yield. The results

**Table 2.** Willingness to accept compensation for environmental impacts.

| Impacts / costs | Yes | % | No | % | Total |
|---|---|---|---|---|---|
| Flooding | 236 | 88.7 | 30 | 11.3 | 266 |
| Water pollution | 194 | 72.9 | 72 | 27.1 | 266 |
| Fish diversity | 187 | 70.3 | 79 | 29.7 | 266 |
| Fish sizes and quantity | 244 | 91.7 | 22 | 8.3 | 266 |
| Vegetable and fruits diversity | 184 | 69.2 | 82 | 30.8 | 266 |
| Grazing land loss | 199 | 74.8 | 67 | 25.2 | 266 |
| Wildlife loss | 255 | 95.9 | 11 | 4.1 | 266 |
| Riparian plants decline | 252 | 94.7 | 14 | 5.3 | 266 |
| Forest loss | 218 | 81.9 | 48 | 18.1 | 266 |
| Erosion | 236 | 88.7 | 30 | 11.3 | 266 |
| Poor farm yield | 194 | 72.9 | 72 | 27.1 | 266 |

Source: Research Survey, 2015.

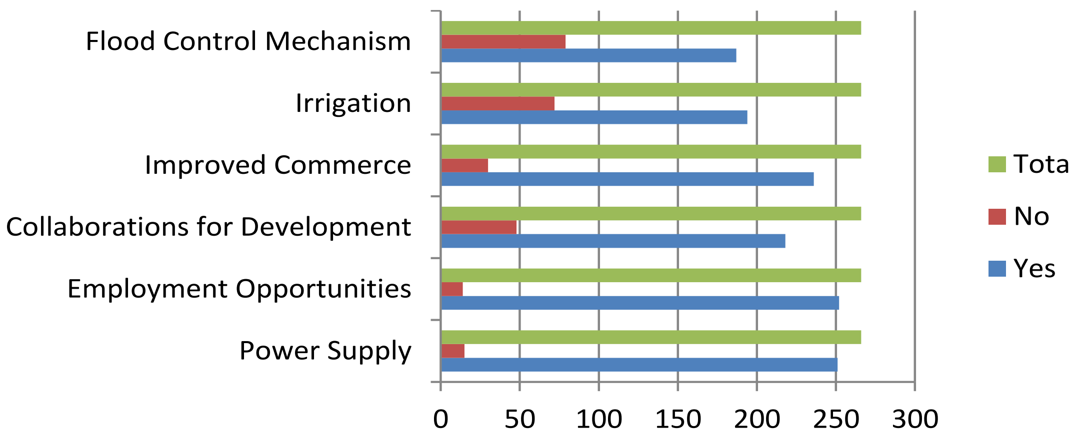


**Figure 1.** Willingness to pay for the benefits of hydropower plant. Source: Research Survey.

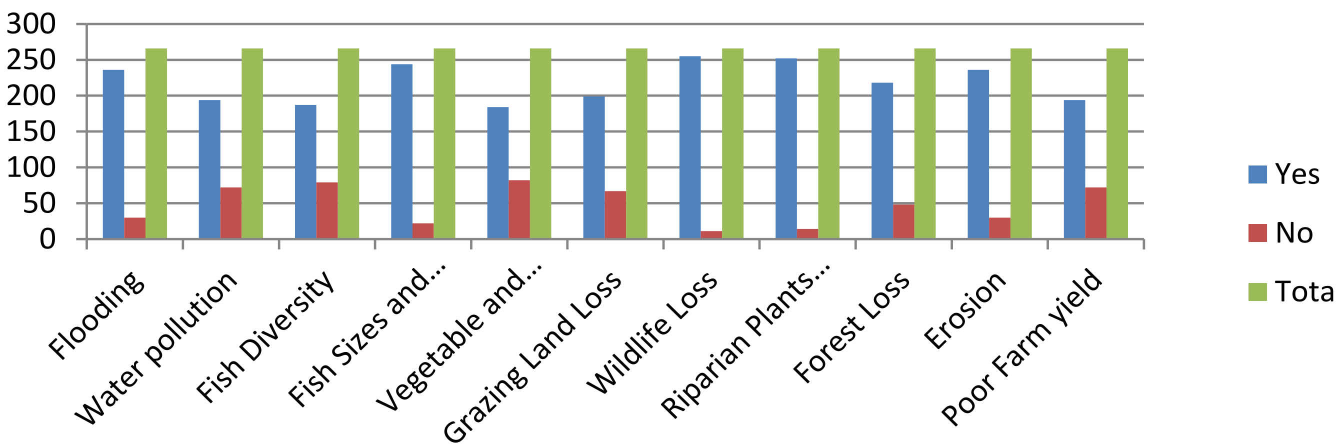


**Figure 2.** Willingness to accept compensation for environmental impacts. Source: Research Survey.

of the LOGIT regression are shown for each of the environmental variable.

**Willingness to Pay (WTP)**

***Constant and free power supply***

The equation line for determining the probability and significance of the WTP for ENG, the outcome variable, z, is the willingness to pay for provision of constant and free power supply. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$\mathrm{In}\frac{P(\mathrm{ENG})}{1-P(\mathrm{ENG})}=\frac{\mathrm{f}(X_1+X_2+X_3+\ldots+X_9)}{f(\mathrm{ENG})}$$

That is =f ($-1.44X_1-0.63X_2+0.36X_3-0.36X_4+1.68X_5-2.07X_6+0.87X_7-1.44X_8+1.44X_9+1.76$).

The P values and odds ratio are given in Appendix Table 1. The combined influence of the nine variables to determine the willingness to pay for constant and free power supply was not significant at P= 0.3510 which is substantially greater than 0.05, or 0.10 significance levels. This is further proved by a mere 8.36% Pseudo $R^2$. The only variables that were significant were $X_6$, that is, Annual Income (at 5%) and $X_5$, that is, Size of Farm (at 10%).

***EMP- Employment***

The equation line for determining the probability and level of significance of the WTP for EMP. The outcome variable, z, is the willingness to pay for Provision of Employment for indigenes. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$\mathrm{In}\frac{P(EMP)}{1-P(EMP)}=\frac{\mathrm{f}(X_1+X_2+X_3+\ldots+X_9)}{f(EMP)}$$

That is = f ($1.99X_1+0.74X_2-0.36X_3-0.45X_4-0.72X_5+0.63X_6-0.19X_7-1.45X_8+0.32X_9+3.01$)

The P values and odds ratio are given in Appendix Table 2. The combined influence of the nine variables to determine the willingness to pay for provision of employment to indigenes was not significant at P= 0.2442 which is substantially greater than 0.05, or 0.10 significance levels. This is further proved by a mere 9.41% Pseudo $R^2$. The only variable that was significant was $X_1$, that is, Gender (at 5% level of significance).

***COL- Collaborations for Development***

The equation line is uused for determining the probability and significance of the WTP for COL. The outcome variable, z, is the willingness to pay for Collaborations for Development. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$In\frac{P(COL)}{1-P(COL)}=\frac{\mathrm{f}(X_1+X_2+X_3+\ldots+X_9)}{f(COL)}$$

That is = f ($-3.55X_1+1.24X_2-0.21X_3-3.71X_4+0.61X_5+1.15X_6-0.35X_7+0.45X_8+4.11X_9+3.01$).

The P values and odds ratio are given in Appendix Table 3. The combined influence of the nine variables to determine the willingness to pay for watershed and prevention of water pollutions was significant at P = 0.0000 which is less than 0.05, or 0.10 significance levels. This is further proved by a 25.2% Pseudo $R^2$. Three variables exerted significant influence in the respondents' choice. These were $X_1$, that is, Gender; $X_4$, Education; and, $X_9$, Distance from Forest Reserve (at 5% level of significance).

***COM- Improved Commerce***

The equation line is used for determining the probability and significance of the WTP for COM. The outcome variable, z, is the willingness to pay for Wildlife Conservation. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$\mathrm{In}\frac{P(COM)}{1-P(COM)}=\frac{\mathrm{f}(X_1+X_2+X_3+\ldots+X_9)}{f(COM)}$$

That is =f ($-2.11X_1+0.35X_2+1.76X_3-0.01X_4+3.09X_5+1.66X_6+0.52X_7-0.06X_8+0.25X_9+1.28$).

The P values and odds ratio are given in Appendix Table 4. The combined influence of the nine variables to determine the willingness to pay for wildlife conservation was significant at P= 0.0002 which is less than 0.05, or 0.10 significance levels. This is further proved by a 17.82% Pseudo $R^2$. Four variables exerted significant influence on the respondents' choice. These were $X_1$, that is, Gender; $X_5$, Size of farm (at 5% level of significance); and, $X_3$, State of origin; and $X_6$, Annual Income (at 10% level of significance).

***IRR- Irrigation***

The equation line is used for determining the probability and significance of the WTP for IRR. The outcome variable, z, is the willingness to pay for Irrigation. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$In\frac{P(IRR)}{1-P(IRR)} = \frac{f(X_1+X_2+X_3+\ldots+X_9)}{f(IRR)}$$

That is = f ($-1.71X_1 + 1.58X_2 - 0.51X_3 - 3.16X_4 + 1.78X_5 + 2.27X_6 - 1.13X_7 - 2.10X_8 + 0.69X_9 + 2.02$)

The P values and odds ratio are given in Appendix Table 5. The combined influence of the nine variables to determine the willingness to pay for maintenance of carbon balance was significant at P= 0.0017 which is less than 0.05, or 0.10 significance levels. This is further proved by a 17.82% Pseudo $R^2$. Five variables exerted significant influence on the respondents choice, namely, $X_4$, that is, Education; $X_6$, Annual Income; $X_8$ , Size of family (at 5% level of significance) and, $X_1$, Gender; and $X_5$, Size of Farm (at 10% level of significance).

***FCM- Flood Control Mechanism***

The equation line is used for determining the probability and significance of the WTP for FCM. The outcome variable, z, is the willingness to pay for Flood Control Mechanism. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$\text{In}\frac{P(FCM)}{1-P(FCM)} = \frac{f(X_1+X_2+X_3+\ldots+X_9)}{f(FCM)}$$

That is = f ($-1.63X_1 + 1.72X_2 + 0.14X_3 - 2.55X_4 + 0.93X_5 + 2.48X_6 - 1.42X_7 - 2.12X_8 + 0.51X_9 + 2.24$).

The P values and odds ratio are given in Appendix Table 6. The combined influence of the nine variables to determine the willingness to pay for biodiversity was significant at P= 0.0017 which is less than 0.05, or 0.10 significance levels. Four variables exerted significant influence on the respondents choice, namely, $X_4$, that is, Education; $X_6$, Annual Income; $X_8$ , Size of family (at 5% level of significance) and, $X_2$, Marital Status.

**Willingness to accept compensation (WTA)**

***FLD- Flooding***

The equation line is used for determining the probability and significance of the WTA for FLD. The outcome variable, z, is the Willingness to Accept Compensation for Flooding. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$\text{In}\frac{P(FLD)}{1-P(FLD)} = \frac{f(X_1+X_2+X_3+\ldots+X_9)}{f(FLD)}$$

That is =f ($0.54X_1 + 1.97X_2 - 0.41X_3 + 0.51X_4 - 0.05X_5 + 0.81X_6 - 1.26X_7 + 0.55X_8 + 1.08X_9 + 0.96$). The P values and odds ratio are given in Appendix Table 7. The combined influence of the nine variables to determine the willingness to accept compensation for flooding was not significant at P = 0.2823 which is less than 0.05, or 0.10 significance levels. This is further proved by a 5.39% Pseudo $R^2$. One variable, $X_2$, Marital Status exerted significant influence on the respondents' choice (at 5% level of significance).

***WPL- Water Pollution***

The equation line is used for determining the probability and significance of the WTP for WPL. The outcome variable, z, is the Willingness to Accept Compensation for Water Pollution. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$In\frac{P(WPL)}{1-P(WPL)} = \frac{f(X_1+X_2+X_3+\ldots+X_9)}{f(WPL)}$$

That is =f ($-0.45X_1 + 2.31X_2 + 1.09X_3 - 2.32X_4 + 0.96X_5 + 2.70X_6 - 2.33X_7 - 2.09X_8 + 0.78X_9 + 1.60$). The P values and odds ratio are given in Appendix Table 8. The combined influence of the nine variables to determine the willingness to Compensation for Water Pollution was significant at P = 0.0001 which is less than 0.05, or 0.10 significance levels. Five variables exerted significant influence on the respondents choice, namely, $X_4$, that is, Education; $X_5$, Size of Farm; $X_6$, Annual Income; and, $X_7$ , Age (at 5% level of significance).

***FSD- Fish Diversity Loss***

The equation line is used for determining the probability and significance of the WTP for FSD. The outcome variable, z, is the willingness to pay for Fish Diversity Loss. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$In\frac{P(\text{FSD})}{1-P(\text{FSD})} = \frac{f(X_1+X_2+X_3+\ldots+X_9)}{f(\text{FSD})}$$

That is =f ($-2.82X_1 + 1.82X_2 + 1.75X_3 - 2.50X_4 + 1.96X_5 + 3.04X_6 - 2.37X_7 - 0.28X_8 + 2.78X_9 + 0.77$).

The P values and odds ratio are given in Appendix Table 9. The combined influence of the nine variables to determine the willingness to Accept Compensation for Fish Diversity Loss loss was significant at P= 0.0000 which is less than 0.05, or 0.10 significance levels. This is further proved by a 21.43% Pseudo $R^2$. Eight variables exerted significant influence on the respondents choice, namely, $X_1$, Gender; $X_4$, Education; $X_6$, Annual Income; $X_7$, *Age:* $X_9$ , Distance from forest reserve (at 5% level of significance) and, $X_2$, Marital Status; and $X_3$, State of

Origin, and $X_5$, Size of Farm (at 10% level of significance).

### *FSQ - Fish Size and Quantity Loss*

The equation line is used for determining the probability and significance of the WTP for FSQ. The outcome variable, z, is the willingness to Accept Compensation for Fish Size and Quantity loss. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$L\frac{P(\mathrm{FSQ})}{1-P(FSQ)} = \frac{f(X_1+X_2+X_3+\ldots+X_9)}{f(FSQ)}$$

That is = f (0.90$X_1$ + 0.08$X_3$ + 0.48$X_4$+0.77$X_5$ - 0.90$X_6$ + 0.51$X_7$ - 0.60$X_8$ + 0.32$X_9$ + 1.08).

The P values and odds ratio are given in Appendix Table 10. The combined influence of the nine variables to determine the willingness to Accept Compensation for Fish Size and Quantity loss willingness to Accept Compensation for Fish Size and Quantity loss was not significant at P= 0.2857 which is much greater than 0.05, or 0.10 significance levels. This is further proved by a 3.65% Pseudo $R^2$. None of the variables exerted significant influence on the respondents choice, at 5 and 10% levels of significance).

### *VFD- Vegetables and Fruits Diversity Loss*

The equation line for determining the probability and level of significance of the WTP for VFD. The outcome variable, z, is the willingness to accept compensation for Vegetables and Fruits Diversity loss. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$\mathrm{In}\frac{P(VFD)}{1-P(VFD)} = \frac{f(X_1+X_2+X_3+\ldots+X_9)}{f(VFD)}$$

That is = f (1.99$X_1$ + 0.74$X_2$ - 0.36$X_3$ - 0.45$X_4$ - 0.72$X_5$ + 0.63$X_6$ - 0.19$X_7$ - 1.45$X_8$ + 0.32$X_9$ + 3.01).

The P values and odds ratio are given in Appendix Table 11. The combined influence of the nine variables to determine the willingness to accept compensation for Vegetables and Fruits Diversity loss was not significant at P = 0.2442 which is substantially greater than 0.05, or 0.10 significance levels. This is further proved by a mere 9.41% Pseudo $R^2$. The only variable that was significant was $X_1$, that is, Gender (at 5% level of significance).

### *GLL- Grazing Land loss*

The equation line is used for determining the probability and significance of the WTA for GLL. The outcome variable, z, is the Willingness to Accept Compensation for Grazing Land Loss. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$\mathrm{In}\frac{P(GLL)}{1-P(GLL)} = \frac{f(X_1+X_2+X_3+\ldots+X_9)}{f(GLL)}$$

That is =f (0.54$X_1$ +1.97$X_2$ -0.41$X_3$ +0.51$X_4$ -0.05$X_5$ +0.81$X_6$ - 1.26$X_7$ +0.55$X_8$ +1.08$X_9$ +0.96).

The P values and odds ratio are given in Appendix Table 12. The combined influence of the nine variables to determine the willingness to Accept Compensation for Grazing Land Loss was not significant at P= 0.2823 which is less than 0.05, or 0.10 significance levels. This is further proved by a 5.39% Pseudo $R^2$. One variable, $X_2$, Marital Status exerted significant influence on the respondents choice (at 5% level of significance).

### *WLD- Wildlife Loss*

The equation line is used for determining the probability and significance of the WTP for WLD. The outcome variable, z, is the willingness to accept compensation for wildlife loss. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$In\frac{P(WLD)}{1-P(WLD)} = \frac{f(X_1+X_2+X_3+\ldots+X_9)}{f(WLD)}$$

That is =f (-1.71$X_1$ +1.58$X_2$ -0.51$X_3$ –3.16$X_4$ +1.78$X_5$ +2.27$X_6$ - 1.13$X_7$ -2.10$X_8$ +0.69$X_9$ +2.02). The P values and odds ratio are given in Appendix Table 13. The combined influence of the nine variables to determine the willingness to accept compensation for wildlife loss was significant at P= 0.0017 which is less than 0.05, or 0.10 significance levels. This is further proved by a 17.82% Pseudo $R^2$. Five variables exerted significant influence on the respondents choice, namely, $X_4$, that is, Education; $X_6$, Annual Income; $X_8$ , Size of family (at 5% level of significance); $X_1$, Gender; and $X_5$, Size of Farm (at 10% level of significance).

### *RCL- Riparian Crops Loss*

The equation line is used for determining the probability and significance of the WTP for RCL. The outcome variable, z, is the willingness to accept compensation for riparian crops loss. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$\mathrm{In}\frac{P(\mathrm{RCL})}{1-P(\mathrm{RCL})} = \frac{f(X_1+X_2+X_3+\ldots+X_9)}{f(\mathrm{RCL})}$$

That is = f ($-2.11X_1 + 0.35X_2 + 1.76X_3 - 0.01X_4 + 3.09X_5 + 1.66X_6 + 0.52X_7 - 0.06X_8 + 0.25X_9 + 1.28$).

The P values and odds ratio are given in Appendix Table 14. The combined influence of the nine variables to determine the willingness to accept compensation for riparian crops loss was significant at P = 0.0002 which is less than 0.05 or 0.10 significance levels. This is further proved by a 17.82% Pseudo $R^2$. Four variables exerted significant influence on the respondents' choice. These were X1, that is, Gender; X5, Size of farm (at 5% level of significance); and, X3, State of origin; and X6, Annual Income (at 10% level of significance).

***FOR- Forest Cover Loss***

The equation line is used for determining the probability and level of significance of the WTP for FOR. The outcome variable, z, is the willingness to accept compensation for forest cover loss. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$\text{In}\frac{P(VFD)}{1-P(VFD)} = \frac{\text{f}(X_1+X_2+X_3+\ldots+X_9)}{f(VFD)}$$

That is =f ($1.99X_1 + 0.74X_2 - 0.36X_3 - 0.45X_4 - 0.72X_5 + 0.63X_6 - 0.19X_7 - 1.45X_8 + 0.32X_9 + 3.01$).

The P values and odds ratio are given in Appendix Table 15. The combined influence of the nine variables to determine the willingness to accept compensation for forest cover loss was not significant at P = 0.2442 which is substantially greater than 0.05 or 0.10 significance levels. This is further proved by a mere 9.41% Pseudo $R^2$. The only variable that was significant was $X_1$, that is, Gender (at 5% level of significance).

***ERS- Erosion***

The equation line is used for determining the probability and significance of the WTP for WPL. The outcome variable, z, is the Willingness to Accept Compensation for Erosion. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$In\frac{P(ERS)}{1-P(ERS)} = \frac{\text{f}(X_1+X_2+X_3+\ldots+X_9)}{f(ERS)}$$

That is =f ($-0.45X_1 + 2.31X_2 + 1.09X_3 - 2.32X_4 + 0.96X_5 + 2.70X_6 - 2.33X_7 - 2.09X_8 + 0.78X_9 + 1.60$).

The P values and odds ratio are given in Appendix Table 16. The combined influence of the nine variables to determine the willingness to accept compensation for erosion was significant at P= 0.0001 which is less than 0.05 or 0.10 significance levels. Five variables exerted significant influence on the respondents choice, namely, $X_4$, that is, Education; $X_5$, Size of Farm; $X_6$, Annual Income; and $X_7$, Age (at 5% level of significance).

***YLD- Lowered Crop Yield***

The equation line is used for determining the probability and significance of the WTA for YLD. The outcome variable, z, is the willingness to pay for Lowered Crop Yield. As stated earlier, the independent variables are $X_1$ to $X_9$. Thus, the expanded equation is given as:

$$In\frac{P(\text{YLD})}{1-P(\text{YLD})} = \frac{\text{f}(X_1+X_2+X_3+\ldots+X_9)}{f(\text{YLD})}$$

That is = f ($0.90X_1 + 0.08X_3 + 0.48X_4 + 0.77X_5 - 0.90X_6 + 0.51X_7 - 0.60X_8 + 0.32X_9 + 1.08$).

The P values and odds ratio are given in Appendix Table 17. The combined influence of the nine variables to determine the willingness to accept compensation for lowered crop yield was not significant at p = 0.2857 which is much greater than 0.05, or 0.10 significance levels. This is further proved by a 3.65% Pseudo $R^2$. None of the variables exerted significant influence on the respondents' choice, at 5 and 10% levels of significance).

**Assigning Values to Environmental impacts of Hydropower Plant on the Watershed of Jebba Lake on Niger River, Jebba- Nigeria**

The data in respect of amounts which the respondents are willing to pay for each of the environmental services were in the intervals of Below ₦1,000; Between ₦1,000 and 10,000; Between ₦10,000 and 20,000; Above ₦20,000. The average WTP for each of the environmental benefits are given in Table 3.

These costs are per capita values of the unit of power produced. To arrive at total environmental costs of hydropower generation, these unit costs need to be extrapolated to reflect production levels from time to time.

## CONCLUSIONS AND RECOMMENDATIONS

It was concluded that the environmental impact of hydropower plants/projects is significant and calls for critical study during its environmental administration process. Thus, the total cost of producing electricity should reflect environmental components in order to serve as adequate basis for pricing units of production.

The issue of environmental measurements transcends mere social responsibility costs but mainstreaming the

**Table 3.** Mean WTP for environmental benefits of power plant and damage costs.

| Mean WTP for environmental benefits of power plant | Amount (₦) |
|---|---|
| Power supply | 4,264.71 |
| Employment opportunities | 3,873.05 |
| Collaborations | 3,622.29 |
| Improved commerce | 3,719.92 |
| Irrigation | 3,682.74 |
| Flood control mechanism | 3,750.00 |
| **Mean WTA for environmental damage costs** | **Amount (₦)** |
| Flooding | 4,264.71 |
| Water pollution | 3,873.05 |
| Fish diversity | 3,622.29 |
| Fish sizes and quantity | 3,719.92 |
| Vegetable and fruits diversity | 3,682.74 |
| Grazing land loss | 3,750.00 |
| Wildlife loss | 3,659.18 |
| Riparian plants decline | 3,573.48 |
| Forest loss | 3,639.42 |
| Erosion | 3,458.82 |
| Poor farm yield | 3,790.64 |

environmental elements into product costing. This requires further research to establish the exact nature of impacts and the remediation required to promote sustainability. The ability to provide for environmental remediation will go a long way to forestall damages and enhance quality of life around the power plants.

Assigning values to environmental elements noted calls for standardisation of metrics and evaluation tools. This is still some way off, hence the dependence on contingent valuation basis. Further multidisciplinary researches are suggested to arrive at globally acceptable measures.

## CONFLICT OF INTERESTS

The author had not declared any conflict of interests.

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## APPENDIX

**Table 1.** WTP for Constant and Free Power Supply.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.150 | 0.532 | 0.721 | 0.716 | 0.094 | 0.038 | 0.382 | 0.151 | 0.149 |
| **Odds ratio** | 0.346 | 0.457 | 1.322 | 0.953 | 2.421 | 0.572 | 1.578 | 0.467 | 4.705 |

**Table 2.** WTP for EMP- Employment.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.047 | 0.460 | 0.718 | 0.650 | 0.469 | 0.526 | 0.850 | 0.147 | 0.747 |
| **Odds ratio** | 4.006 | 2.423 | 0.661 | 0.941 | 0.598 | 1.210 | 0.892 | 0.429 | 1.264 |

**Table 3**. WTP for COL- Collaborations for Development.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.000 | 0.215 | 0.833 | 0.000 | 0.539 | 0.248 | 0.728 | 0.650 | 0.000 |
| **Odds ratio** | 0.147 | 2.225 | 0.914 | 0.763 | 1.204 | 1.212 | 0.887 | 1.146 | 14.390 |

**Table 4.** WTP for COM- Improved Commerce.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.035 | 0.728 | 0.079 | 0.996 | 0.002 | 0.096 | 0.606 | 0.949 | 0.804 |
| **Odds ratio** | 0.328 | 1.728 | 2.689 | 0.999 | 2.733 | 1.629 | 1.296 | 0.981 | 1.150 |

**Table 5.** WTP for IRR- Irrigation.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.088 | 0.115 | 0.613 | 0.002 | 0.076 | 0.023 | 0.258 | 0.036 | 0.487 |
| **Odds ratio** | 0.539 | 2.305 | 0.844 | 0.824 | 1.484 | 1.371 | 0.708 | 0.567 | 1.306 |

**Table 6.** WTP for FCM- Flood Control Mechanism.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.102 | 0.085 | 0.890 | 0.011 | 0.352 | 0.013 | 0.156 | 0.034 | 0.609 |
| **Odds ratio** | 0.554 | 2.385 | 1.046 | 0.859 | 1.215 | 1.390 | 0.665 | 0.564 | 1.207 |

**Table 7.** WTA for FLD- Flooding.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.588 | 0.049 | 0.682 | 0.612 | 0.957 | 0.420 | 0.208 | 0.579 | 0.280 |
| **Odds ratio** | 1.388 | 5.325 | 0.723 | 1.065 | 0.977 | 1.165 | 0.469 | 1.326 | 1.879 |

**Table 8.** WTA for WPL- Water Pollution.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.649 | 0.021 | 0.613 | 0.276 | 0.020 | 0.337 | 0.007 | 0.020 | 0.037 |
| **Odds ratio** | 0.852 | 3.319 | 1.419 | 0.873 | 1.229 | 1.434 | 0.505 | 0.566 | 1.335 |

**Table 9.** WTA for FSD- Fish Diversity Loss.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.005 | 0.069 | 0.081 | 0.012 | 0.051 | 0.002 | 0.018 | 0.782 | 0.005 |
| **Odds ratio** | 0.350 | 2.930 | 1.808 | 0.857 | 1.701 | 1.726 | 0.463 | 0.923 | 3.325 |

**Table 10.** WTA for FSQ - Fish Size and Quantity Loss.

| | $X_1$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|
| **P values** | 0.369 | 0.940 | 0.629 | 0.439 | 0.368 | 0.608 | 0.549 | 0.748 |
| **Odds ratio** | 1.614 | 1.110 | 1.084 | 1.552 | 0.791 | 1.576 | 0.704 | 1.269 |

**Table 11.** WTA for VFD- Vegetables and Fruits Diversity loss.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.047 | 0.460 | 0.718 | 0.650 | 0.469 | 0.526 | 0.850 | 0.147 | 0.747 |
| **Odds ratio** | 4.006 | 2.423 | 0.661 | 0.941 | 0.598 | 1.210 | 0.892 | 0.429 | 1.264 |

**Table 12.** WTA for GLL- Grazing Land loss.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.588 | 0.049 | 0.682 | 0.612 | 0.957 | 0.420 | 0.208 | 0.579 | 0.280 |
| **Odds ratio** | 1.388 | 5.325 | 0.723 | 1.065 | 0.977 | 1.165 | 0.469 | 1.326 | 1.879 |

**Table 13.** WTA for WLD- Wildlife loss.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.088 | 0.115 | 0.613 | 0.002 | 0.076 | 0.023 | 0.258 | 0.036 | 0.487 |
| **Odds ratio** | 0.539 | 2.305 | 0.844 | 0.824 | 1.484 | 1.371 | 0.708 | 0.567 | 1.306 |

**Table 14.** WTA for RCL- Riparian Crops loss.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.035 | 0.728 | 0.079 | 0.996 | 0.002 | 0.096 | 0.606 | 0.949 | 0.804 |
| **Odds ratio** | 0.328 | 1.728 | 2.689 | 0.999 | 2.733 | 1.629 | 1.296 | 0.981 | 1.150 |

**Table 15.** WTA for FOR- Forest Cover loss.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.047 | 0.460 | 0.718 | 0.650 | 0.469 | 0.526 | 0.850 | 0.147 | 0.747 |
| **Odds ratio** | 4.006 | 2.423 | 0.661 | 0.941 | 0.598 | 1.210 | 0.892 | 0.429 | 1.264 |

**Table 16.** WTA for ERS- Erosion.

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|---|
| **P values** | 0.649 | 0.021 | 0.613 | 0.276 | 0.020 | 0.337 | 0.007 | 0.020 | 0.037 |
| **Odds ratio** | 0.852 | 3.319 | 1.419 | 0.873 | 1.229 | 1.434 | 0.505 | 0.566 | 1.335 |

**Table 17.** WTA for YLD- Lowered Crop Yield.

| | $X_1$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|
| **P values** | 0.369 | 0.940 | 0.629 | 0.439 | 0.368 | 0.608 | 0.549 | 0.748 |
| **Odds ratio** | 1.614 | 1.110 | 1.084 | 1.552 | 0.791 | 1.576 | 0.704 | 1.269 |