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Research Article

Valuing Malaria Morbidity Risk in Bakolori Irrigation Scheme

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ABSTRACT

The incidence of malaria continued to be a recurring issue across the developing countries, in spite of concerted efforts at reduction and eradication by governments, national, regional and international development organizations. The resistance of malaria to chemical control, further compounded issues, suggesting the need for environmentally sustainable prophylactic measures. Thus, the study examined irrigators' willingness to pay for morbidity risk reduction from malaria, arising from irrigation and drainage services, estimated the cost of illness and implicit value of malaria risk reduction and identified the drivers of malaria morbidity risk reduction. We employed the stated preference approach, single-bound dichotomous choice, with open-ended questions in eliciting responses from 600 irrigators under Bakolori Irrigation Scheme (BIS), Zamfara State, Nigeria. The study deployed the risk reduction valuation model, ordered logit regression analysis, chi2 and descriptive statistics for data analysis. We concluded that estimates from the willingness to pay (WTP) and cost of illness (COI) approaches to risk valuation differs considerably, as revealed by values of US$6.0 and US$ 82.86 respectively, while the implicit value of malaria risks reduction for 1 in 1,000 cases of malaria morbidity risk reduction was US$6,599.92 per season. The drivers of morbidity risk reduction from malaria were income, marital status and days absent from farming due to malaria illness. The study recommended intensive sensitization of irrigators/Water Users' Associations (WUAs) by APEX WUAs and BIS on malaria morbidity risk, in addition to effective irrigation and drainage services, to minimize the spread of malaria. It was further recommended that the implicit value of malaria risk reduction obtained can serve as "Benefit Transfer" estimate for economic analysis of irrigation intervention in sub-Saharan Africa and in other developing nations with data challenge, following appropriate adjustments.

Introduction

Malaria incidence continued to be a recurring issue across the developing countries in spite of concerted efforts at reduction and eradication by governments, national, regional and international development organizations. Of the 229 million cases recorded across the globe in 2019, Africa accounted for estimated 215 million infections, representing 93.9% of cases. Expectedly, Nigeria, the largest country by population in the continent was responsible for 27% of this number (World Health Organization, 2020). With respect to Bakolori Irrigation Scheme (BIS), numerous studies (Yahaya, 2002; Yusuf and Yusuf, 2008; Federal Ministry of Water Resources, 2014) affirmed the prevalence of malaria within the scheme, with Yusuf and Yusuf (2008) noting that malaria incidence was most dominant, relative to other diseases, put at 33.9%. The researchers further affirmed that malaria was most prevalent at the start of both the wet and irrigation seasons, attributed to the presence of the irrigation scheme, which served as breeding grounds for mosquitoes. In addition, the key informant interview conducted within the

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framework of the study, confirmed that malaria was the key health risk witnessed by irrigators within the scheme. Even though, the environmental impact assessment on the project put in place mitigation measures, not precluding the several related malaria interventions by national and donor agencies, the incidences of malaria on the scheme and within the host state (Zamfara) are still considerable. Between 2016 and 2017 for instance, confirmed cases of malaria in Zamfara State ranged from 69.3% in January 2016 to 61.9% in March, 2017. Similarly, malaria test positivity rate ranged between 70.9% and 62.1% within same period (Malaria Frontline Project of NSTOP/AFENET and Zamfara State Government, 2017). Severe Malaria Observatory (2020) also established that malaria incidence stood at 34% in the North West, in which Bakolori Irrigation Scheme is located. Although, Kutluay et al. (2019) noted that considerable progress was recorded with respect to malaria mortality reduction between 2000 and 2012 globally, the researchers however affirmed that recent developments may have limited these achievements. Meanwhile, the Federal Ministry of Health et al., 2016; The Global Fund, 2019 noted that the incidence of malaria is prevalent in the rural compared to the urban areas in Nigeria.

Rural livelihoods and agriculture are synonymous, given that agriculture is the preoccupation of majority of the rural populace. Logically, malaria is likely to be dominant among the rural poor resource farmers in Nigeria. In the study on malaria prevalence and farm level productivity, Osuji et al. (2018) established that malaria prevalence rate limited farmers' productivity in Imo State, Nigeria.

Unlike other agriculture related studies, cross cutting research on Value of Health Risk Reduction (VHRR), Value of Statistical Life (VSL) and Value of Statistical Case (VSC) are very rare within the Agriculture sector in Africa and in particular, Nigeria. Thus, this study provided key baseline literature and will likely address the dearth of data with respect to "benefit transfer" on environmental health risk reduction attributable to malaria incidence within the agriculture sector using the VSL and VSC approaches. In addition, the study will contribute to the valuation of health reduction benefits attributable to intervention projects and programmes in the agriculture sector.

Within the realm of literature, combinations of economic theories have been established to define the life-saving valuation approach. These included the novel work of Schelling *"the Life You Save May Be Your Own"*, principle of consumer sovereignty, which recognizes that consumers are the best judge of their utilities, and the von Neumann and Morgenstern's expected utility theory (Hammitt, 2000; Robinson and Hammitt, 2011).

Specifically, the von Neumann and Morgenstern's expected utility theory, which is premised on the neo-classical economic orientation, affirmed among other axioms of rational behaviours, that individuals will always have preference for actions that maximize expected utility. However, critics, particularly, the behavioural economists argued that decision utility in question is only relevant to individual decision preference and does not in any way imply utility in the context of happiness. Notwithstanding, the application of this theory continued to find relevance in the context of health risk reduction, VSL, VSC, willingness to pay (WTP) and benefit-cost analysis; and more also, with respect to the on-going COVID-19 studies (Viscusi et al., 1998; Hammitt, 2000; Robinson et al*.,* 2019; Robinson, 2020).

On the other hand, Campbell and Brown (2016) grouped the utility approach to non-market valuation to comprise revealed and stated preference methods. The authors categorized the former to consist of travel cost methods, random utility methods and Hedonic price method. The latter comprise the Contingent Valuation Method and the Discrete Choice Modelling.

Researchers such as Robinson and Hammitt (2013) have worked on assorted non-fatal risks reduction using the contingent and other approaches. Robinson and Hammitt, (2013); Robinson and Hammitt, (2018) affirmed that the approach to non-fatal health risk valuation under the benefit-cost non-market estimation analytical framework is similar, but broader than those of the mortality risk valuation due to shortage of qualitative research on non-fatal risks. The key parameters in question for which this study focuses attention are the WTP, health risk changes or risk reduction and the VSC. Key recognized approaches to the valuation of the non-fatal risks are WTP, implicit value of injury, proxy measures such as; averted costs, which comes in form of cost of illness (COI) and days of lost productivity, the monetized quality adjusted life years (QALYs) and disability adjusted life years (DALYs).

Robinson and Hammitt (2011) for instance, noted that WTP is applicable to the valuation of beneficial and harmful risk changes. The technique had been established to be the most suitable for the valuation of non-market outcomes (Robinson and Hammitt, 2018). The authors defined WTP as the maximum amount an individual will be willing to forgo in exchange of a service or risk reduction. According to Hammitt (2000), CV-estimated WTP is not sensitive to variation in risk reduction, mainly due to inadequate communication of risk change to respondents and the limited appreciation for numerical differences in magnitude. Even though, numerous approaches have been tried, few studies exist on the effect of these approaches on respondents' comprehension and responses, while in some cases, respondents ignore the targeted risk reduction, but rather depend on prior beliefs to complement information solicited by the questionnaire (Hammitt, 2000). In-spite of these concerns, WTP and risk reduction remain key parameters for the deduction of VSL and VSC. Meanwhile, Robinson and Hammitt (2013) noted that non-fatal risks have received less emphasis compared to the mortality risk reduction which is relatively well studied.

The concept of VSL has wide applications to fields such as environment, health and services, but has however been widely mis-understood (Robinson, 2020). Robinson (2020) defined it as the willingness to exchange one's own money for a small change in one's risk. Hammitt (2000) on the other hand, noted that the concept is premised on individual preferences between safety and other desired goods. Campbell and Brown (2016) defined the concept as the willingness to pay to save the life of a category of person, whether young, old, ill or healthy. The authors affirmed that the VSL can be estimated through the non-market valuation techniques, using specifically the production and utility approaches. The researchers affirmed that early attempts to value cost of illness or death depended largely on the production approach, however, its weakness lies in the fact that considerable number of the populace are unemployed, while cost of pain and suffering are excluded. It is criticized for largely measuring livelihood rather than life.

VSLs are obtained through the revealed and stated preference approaches Hammitt (2000). While the former relies on real behaviour or behavioural clues (King, 2020) and assumes that individuals chose the alternative that most satisfy their self-interests, the latter, for which the contingent valuation is prevalent, rely on surveys to solicit response on hypothetical choice (Hammitt, 2000). In-spite of its longer history and documented shortcomings, King (2020) noted that the revealed preference approaches are yet to be subjected in depth validity and reliability concerns as the stated preference approaches. Generally, VSL relates to expected changes in fatalities, while VSC applies to changes in non-fatal illness.

The COI depicts the actual costs of illness incurred by individuals, as represented by mainly two components, namely; direct medical costs and indirect productivity losses. According to Robinson and Hammitt (2013), these costs include; cost incurred by patients, their household members, third parties such as the National Health Insurance Scheme, employers of labour, doctor's services drugs, hospital admittance, among others. Other inclusion comprises indirect costs related to lost productive during illness and may include decreased productivity at work, idling assets or cost incurred in building the capacity of replaced employee. Hammitt (2013) revealed that the value of lost productivity is based on compensation obtained in similar responsibilities. It is however noted that the utilization of the COI is associated with shortcomings such as, omission of value of pains and sufferings, quality of life associated with health impairment, timing of risk consideration and the belief that the estimates understate the WTP.

With respect to malaria and irrigated agriculture, Namara *et al*. (2008) established the need for environmental and irrigation management as viable alternative or complementary to malaria control. On the other hand, Boelee et al. (2002) noted that engineering and environment-based interventions have played an important role in malaria prevention.

Arising from the aforementioned background, this study: (i) ascertained the willingness of irrigators to contribute to reducing malaria risk incidence and cost of illness from malaria within the Irrigation Scheme; (ii) determined the value of malaria morbidity risk reduction, as expressed by the value of implicit health risk reduction; and (iii) identified the drivers of irrigators' WTP for malaria morbidity risk reduction. The study hypothesized that irrigators' willingness to pay for morbidity risk reduction from malaria is not influenced by their socio-demographic and economic characteristics (age, household size, gender, marital status, income, days absent from farming due to malaria).

Materials and Methods

Study area

Bakolori Irrigation Scheme (BIS) is situated in Zamfara State, Nigeria, spread across three Local Government Areas, namely; Talata Mafara, Maradun and Bakura. The Scheme is under the management of the Sokoto Rima River Basin Development Authority and falls under the Sokoto-Rima sub-Basin and Niger North Basin, with originating water sources from rivers N'Kaba and Tarka within Niger, while joining river Rima enroute Nigeria. BIS, though inaugurated in December 1978 (Yahaya, 2002), commenced operation effectively in 1983, with a storage capacity of 450 million cubic meter of water, covering 8,000 ha. At inception, it was initiated to support 3MW of electricity with its two 1.5MW hydroelectric turbines installed and originally built to irrigate 23,000ha (out of which 8,000ha is for surface irrigation and 15,000ha for sprinkler irrigation system). However, current intervention by Transforming Irrigation Management in Nigeria (TRIMING) Project is an estimated 13,000ha (rehabilitation and conversion from sprinkler) under full irrigation and drainage services (TRIMING Project, 2021).

Sampling and data collection

The study deployed the multi-stage sampling technique to select 600 respondents from a frame of over 24,000 irrigators, covering 540 (90%) formal and 60 (10%) informal irrigators. The first stage entailed the stratification of the scheme into the three LGAs that make up the scheme, namely; Bakura, Talata Mafara and Maradun. This was followed by stratification into sectors, comprising Bakura - 8, Talata Mafara - 2 and Maradun - 1. The third stage involved random selection of 30% of the blocks according to the population of blocks under each sector. Thus, 12, 4 and 3 blocks were selected under Bakura, T/Mafara and Maradun respectively, with proportionate samples of 379, 126 and 95 respondents respectively. This was followed by further stratification according to irrigators' placement for water service-head and tail users at 50% each of the sample size; gender (75% male and 25% female), while samples according to key crop enterprises were in the ratio 65%, 15% 15% and 10% for rice, maize, tomatoes and onions respectively. The sample size was higher than the 393 expected from the Yamane sample determination technique at 5% confidence level given the need to cover the informal irrigators, who are also part of the direct project beneficiaries of the scheme.

Primary data for this study were obtained for the 2019 farming season, through informal Focus group discussions and structured questionnaires administered by trained enumerators and supervisors and from secondary sources. Primary data were collected on the socio-economic and demographic characteristics of irrigators, such as age, gender, household size and irrigators' net returns. Other information collected covered irrigators' willingness to pay for malaria risk reduction, incidence of ill health due to malaria, costs of treatment and medication, days absent from farming, etc. The secondary data were sourced from project documents and from internet outlets.

Statistical analyses

The analytical tools employed in achieving the study objectives were descriptive statistics, analysis of implicit value of risk reduction, chi square, ordered logit regression analysis, Gini Coefficient and Lorenz Curve. Descriptive statistics such as means, standard deviation, coefficient of variation, minimum, maximum, percentages, frequencies and graphs were used to describe the characteristics of the irrigators and present the individual and mean WTP for malaria risk reduction.

Risk reduction valuation

The implicit value of risk reduction was modelled in tandem with the logic for VSL analytics as deployed by Hammitt (2000) in Equation 1.

$$U(p, w) = (1-p)Ua\,(w) + \;PUd(w) \;\;\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (1)$$

Where p represents the likelihood of falling ill as a result of malaria infection during the current period and $Ua\,(w)$ and $Ud(w)$ represent utility as a function of wealth premised on not contacting malaria and falling ill due to malaria respectively. The function $Ud(.)$ takes cognizance of the financial consequences of falling ill such as cost of treatment, medical bills, etc.

Arising from the aforementioned, individual Value of Health Risk Reduction (VHRR) or the marginal rate of substitution between *p* and *w* is obtained by differentiating Equation 1 while leaving utility constant to obtain Equation 2.

$$VHRR = \frac{dw}{dp} = \frac{U\mathbf{a}(w) - Ud(w)}{(1-p)U'a(w) + PU'd(w)} \;\;\ldots\ldots\ldots\ldots \; (2)$$

The numerator in Equation 2 represents utility differentials with respect to if the agent avoids illness or falls ill due to malaria in the current period. The denominator represents the expected marginal utility of wealth, which is the utility associated with additional wealth depending on the likelihood of not contacting malaria and falling ill as a result of malaria, weighted by the probabilities of these events. It is worthy of mention that the VHRR also depends on the baseline risk and wealth like the VSL. As it is with the VSL, WTP for morbidity risk reduction will depend on the ability to pay and may likely increase with wealth.

Drivers of willingness to pay for malaria morbidity risk reduction

The drivers of WTP for malaria incidence were derived using ordered logit regression analysis. The implicit model is presented in Equation 3.

$WTP = a + b_1X_1 \ldots\ldots b_nX_n + e_k \;\ldots\ldots\ldots\ldots\; (3)$

Where WTP represents the amount respondents were willingness to pay for reducing the risk of contracting malaria. The independent variables included in the model were gender (Male or Female), age (Years), marital status (Single, married, divorced or separated), household size (Number of person in the household), education (years spent in school), net returns (in Nigerian Naira), treatment costs (Naira), days absent from farming due to malaria (Number of days).

Results and Discussion

Socio-economic and demographic characteristics of irrigators

This sub-section presents the socio-demographic characteristics of the sampled irrigators by their willingness to pay (WTP) for malaria health risk morbidity reduction.

Gender and WTP for malaria morbidity risk reduction

Table 1 shows the distribution of respondents by gender and WTP for malaria morbidity risk reduction. The results indicated that considerable proportion of the males (65.28%) and females (53.85%) were willing to pay between ₦2,000 and ₦3,000 per season. The mean WTP on gender basis stood at ₦2,747.39 and ₦2,096.15 respectively for the male and female gender respectively, while WTP estimates ranged from ₦500 - ₦4,000. The coefficients of variation (COV) were 0.44 and 0.56 for the males and female gender respectively, indicating a lesser dispersion around the mean for the male gender and a more precise estimate. In addition, the chi2 model was significant, indicating that WTP was not independent of gender within the irrigation scheme. Trapero-Bertran et al. (2012) established statistical significance and positive relationship between being male and having a higher WTP. The researchers affirmed that 14 of the 17 coefficients reviewed were statistically significant.

Table 1. Willingness to pay and gender

WTP	Male	Female	Total
< 2,000	142a	12a	154
2,000 - 4,000	376a	14a	390
> 4,000	56a	0a	56
Total	574	26	600
Std. Dev.	1,198.48	1,166.36	1,203.49
Mean	2,747.39	2,096.15	2719.17
COV	0.44	0.56	0.44
Minimum	500	500	500
Maximum	5,000	4,000	5,000
Chi Square (WTP and Gender)		7.501	
Df		2	
Asymp Sig		0.024	

Source: Field survey, 2019

Age and WTP for malaria risk reduction

Evidence from Table 2 indicated that majority (65%) of respondents were willing to pay between ₦2,000 and ₦3,000 per season for malaria morbidity risk reduction. This is largely made up of 62.56% (244) within the age bracket of 31-50 years. This is not unexpected, given that this age bracket falls under the active working population. Also, few persons under 31 years (1.5%) and over 50 years (1.3%) were WTP above ₦4,000 per season, while, only 9% and 25% were WTP over ₦4,000 and less than ₦2,000 per season respectively. The mean WTP ranged from ₦2,546.60 for respondents under 31 years to ₦2,766.67 for respondents over 50 years. In addition, the COV of 0.42 was lowest under respondents above 50 years, indicating a more consistent trend. Worthy of note however is that WTP was not dependent on the age categories, as indicated by an insignificant chi2 at 5% level of significance. However, Kutlay et al. (2019) established that age had a non-linear impact on mean WTP and that people within the age of 31 and 48 years have increasing WTP with each passing year, given that within this age bracket, most families look after their children who are vulnerable to the effects of malaria than adults. In a related development, Trapero-Bertran et al. (2012) revealed that, of the 28 coefficients from 16 articles reviewed, 11 were statistically significant, indicating that older people are associated with low WTP.

Marital status and WTP for malaria health risk reduction

The results on Table 3 show the distribution of respondents according to marital status and WTP. According to the results, majority of those willing to pay were married, accounting for 60.83% of the total respondents. However, the mean WTP was highest under respondents that were single (₦3,163.27) compared to the ₦2,693.37 and ₦ 1,750.00 obtained under respondents that were married and those divorced/separated. This result is not expected, but could have been due to the fact that respondents under this category have fewer responsibilities, but could also be more aware of the dangers of malaria illness. Trapero-Bertran (2012) revealed that 5 out of the 7 statistical significant coefficients were negative, indicating that marriage was associated with reduced WTP. Meanwhile, the chi2 analysis revealed that WTP for malaria morbidity risk reduction was highly dependent on marital status.

Table 2. Willingness to pay and age

WTP	< 31	31 – 50	>50	Total
< 2,000	33a	94a	27a	154
2,000 - 4,000	61a	244a	85a	390
> 4,000	9a	39a	8a	56
Total	**103**	**377**	**120**	**600**
Std. Dev.	1,260.24	1,203.28	1,150.33	1,203.49
Mean	2,546.60	2,751.19	2,766.67	2,719.17
COV	0.49	0.44	0.42	0.44
Minimum	500	1,000	500	500
Maximum	5,000	5,000	5,000	5,000
Chi Square (WTP and Gender)		4.705		
Df		4		
Asymp Sig		0.319		

Source: Field survey, 2019

Table 3. Willingness to pay and gender marital status

WTP	Single	Married	Others	Total
< 2,000	12a	137a	5b	154
2,000 - 4,000	22a	365b	3a, b	390
> 4,000	15a	41b	0ab	56
Total	**49**	**543**	**8**	**600**
Std. Dev.	1,514.33	1,160.92	1,164.97	1,203.49
Mean	3,163.27	2,693.37	1,750.00	2719.17
COV	0.48	0.43	0.67	0.44
Minimum	1,000	500	1,000	500
Maximum	5,000	5,000	4,000	5,000
Chi Square (WTP and Gender)		35.051		
Df		4		
Asymp Sig		0.000		

Source: Field survey, 2019

Distribution of respondents' net benefits, WTP and mean treatment cost

The quartile distribution of irrigators' net benefits, WTP, cost of treatment and the extent of income inequalities are captured under Table 4 and Figure 1. The Table shows that mean income ranged from ₦484, 835 - ₦4,205, 737 per season representing the 1st and 4th quartile categorization. Also, mean WTP for malaria morbidity risk reduction was observed to increase with the quartile income categorization, rising from ₦2,430 under the fourth 25% categorization to ₦2,960 under the top 25% income categorization. Similarly, mean treatment cost increased with higher quartile categorization, from ₦23,191.89 under the 4th 25% categorization to ₦37,282.71 under the top 25% income categorization. Meanwhile, evidence from the Lorenz curve (Figure 1) indicated considerable inequality in income among irrigators as shown by Gini Coefficient (GC) of 0.60. The GC estimate is unexpected given that considerable number of irrigators cultivate less than one hectare, however, variations in enterprise types undertaken by respondents may be contributory, while the informal irrigators (who are also part of the sample) have also been established to be economically better than the formal irrigators.

Table 4. Distribution of net benefits, willingness to pay and mean cost of treatment

Quartile Disaggregation	Mean Net Benefit (Naira)	Level of Disaggregation (%)	Mean Willingness to Pay (Naira)	Mean Cost of Treatment (Naira)
1	484,835	Fourth 25	2,430	23,191.89
2	980,951	Third 25	2,681	31,321.97
3	1,520,276	Second 25	2,805	34,542.45

4	4,205,737	Top 25	2,960	37,282.71

Source: Field survey, 2019

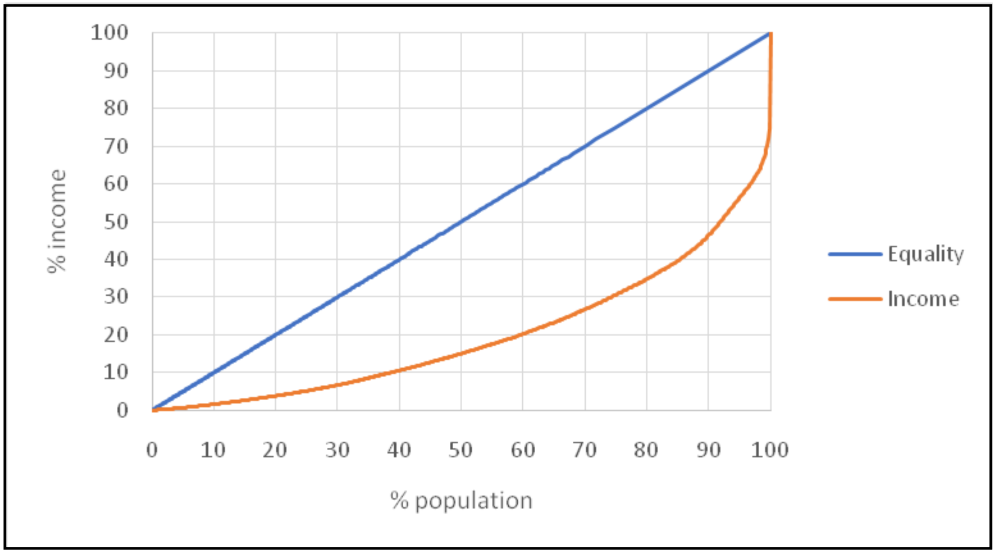

Figure 1. Lorenz Curve for Income inequality among irrigators of Bakolori Irrigation Scheme

Value of risk reduction from malaria results

The derivation of the estimates of the value of morbidity risk reduction from malaria as obtained from the WTP and COI approaches are presented below:

Willingness to pay approach

The willingness to pay for and value of malaria risk reduction under the Bakolori Irrigation Scheme are presented in Table 5. The results indicated that majority of the irrigators (65%) were willing to pay between ₦ 2,001 and ₦ 3,000 4,000, while estimated 25.67% affirmed they would pay less than ₦2,000 Naira per season. The mean WTP stands at ₦2,719.17 (US$ 6.60), ranging from ₦500-₦5,000 Naira per season. The likely causes of variation in the WTP may be due to personal choices, priorities and incomes of the irrigators.

On the other hand, the estimated implicit value of malaria risk reduction was ₦2.7 million (US$6,600); with the assumption of malaria morbidity risk reduction of one percent, from 294-293 cases per every 1,000 persons. This translates to about ₦66.53m ($158,400) for estimated 24,000 irrigators, premised on the aforementioned risk assumption. Though, with focus on insecticide treated nets and drugs for treatment, Bertran et al. (2012) obtained WTP values of US$2.79, US$6.65 and US$2.60 for insecticide treated nets, treatment and for other preventive services respectively. Using the WTP and COI approached, Namara *et al*. (2008) justified the need for irrigation and environmental water management for control of malaria.

Table 5. Distribution of respondents according to maximum amount respondents are willing to pay and value of morbidity risk reduction (VRR) from malaria infection

Maximum Amount willing to pay (Naira)	Frequency	Percentage
Less than 2,000	154	25.67
2,000-4,000	390	65.00
Greater than 4,000	56	9.33
Total	**600**	**100**
Mean WTP	2,719.17 Naira (USD 6.60)	
VRR from malaria	2,719,167 Naira (USD 6,599.92)	

Source: Field survey, 2019
Malaria risk reduction was from 294 to 293 cases per every 1,000 persons.

Cost of illness (COI) approach

The costs of illness estimates per irrigators' households are presented in Table 6. The results indicated that physician and hospital stay by household head and household members accounted for the highest COI of 41.61%, while other treatment related costs, such as patronage of patent medicine store and traditional health service provider by the household head was least with about 13.78% of the total cost. In all, the average total cost of ill health per household stood at ₦ 34,136.21 per season, which translated to about USD 82.86. This estimate represented 13 folds the WTP estimate of USD 6.6 per season. This clearly implies that the results from both approaches to health risk valuation differ, with obvious implications for methodological review.

Table 6. Cost of illness per irrigator's household (Naira per season)

Medical cost incurred	Mean	%
Medical costs incurred with local pharmaceutical shop	4,811.41	14.09
Medication costs	5,061.25	14.83
Physician and hospital stay costs	14,203.10	41.61
Other treatment related costs	4,702.68	13.78
Non-treatment related health costs	5,357.98	15.70
Total Cost	**34,136.42**	**100.00**

Source: Field survey 2019

Relationship between the WTP and COI estimates

The variance between the output of the WTP and COI emanating from this study is not unexpected, given methodological differences. The USDA (undated) argued that there was no theoretical justification for equating WTP and COI, as long as individuals place any value on non-market goods, services or intangibles, income and consumption measures will always diverge from true welfare measures. Aside this, the COI was mainly a communal measure covering the households, while the WTP related largely to the household head. Though, WTP estimate was observed to be higher than COI in developed countries, same may not be applicable in developing countries in Africa, where income per capita is well below the universal standards, aside the low level of health awareness and its implication. To a large extent, the rural poor mainly focus on current survival rather than future sustainability, given their unique circumstance. Thus, this study will not delve into harmonizing the estimates from the two approaches or reaching a middle ground. However, as it stands, the value of the WTP may serve as a lower boundary for future studies on malaria health risk reduction within an irrigation scheme, following necessary adjustment for inflation and time value of money.

Specification error test result

Socioeconomic characteristics of the respondents were chosen as explanatory variables for the ordered logistic regression model to ascertain the drivers of WTP for malaria health risk reduction. Thus, to ensure that the model is free from specification error or problem, link test was undertaken as detailed in Table 7. The test shows that the probability of the t-statistic for the_hatsq is 0.600, which implies that the variable is not statistically significant and hence, it is concluded that the model is free from specification error.

Table 7. Link diagnostic test for logistic regression

WTP	Coefficient	Std. Error	Z	P Greater than Z
-hat	1.039843	0.1341451	7.75***	0.0000
-hatsq	-0.037535	0.071669	-0.52	0.600

Source: Extract from Stata 14 output

Ordered logit regression results

Ordered logit regression model was chosen because the depended variable (WTP) was categorically ordered into three classes. The results of the drivers of irrigators' WTP is presented in Table 8. The model was significant at 1% as indicated by the chi2, with a log likelihood of -464.09283 and pseudo R^2 of 0.0905. In addition, three variables, namely; marital status, income and days absent from farming were significant at 1% probability level. However, the impact of the significant variables cannot be explained using the results, rather, the marginal effect is estimated as indicated in Table 9.

Table 9 shows the results of the marginal effect analysis. For the income, the results indicated that with a unit increase in income, the probability to pay less than ₦2,000 decreases by -6.14e-08, while the probability of paying above ₦2,000 increases among the irrigators. This is not unexpected given that the WTP for malaria health risk reduction is expected to increase in income. Given that a rational human being is expected to take decision that will further maximize his/her utility. The reduction of malaria risk will likely enhance productivity, reduce cost of malaria treatment and prolong life. Numerous researchers (Hammitt 2000; Trapero-Bertran et al. 2012; Wang et al. 2018) established positive relationship between income and WTP. With respect to the days absent from farming activities, the results indicated that an increase in the number of days absent from farming by a day due to malaria sickness, will increase the probability of paying from ₦2,000 and above. This is expected given that having realized the negative effect of malaria, irrigators may be willing to pay higher for risk reduction, in order to sustain their productivity, output and income. With respect to marital status, the results indicated that a change in marital status of irrigators, probably from being single to married status may increase payment of less than ₦2,000 and decrease the willingness to pay higher cost of malaria health risk reduction. This may likely be due to higher responsibilities associated with married life. Trapero-Bertran et al. (2012) established that being married is associated with reduced WTP.

Table 8. Estimated coefficients of ordered logistic model

WTP	Coefficient	Std. Error	Z	P Greater than Z
Gender	0.58435	0.4327865	1.35	0.177
Age	0.006807	30.0097229	0.7	0.484
Marital Status	-0.92735	0.3458225	-2.68***	0.007
Household Size	-0.005291	0.0313568	-0.17	0.866
Education	0.046624	0.0603953	0.77	0.44
Treatment Cost	-4.67E-06	3.49E-06	-1.34	0.18
Income	3.55E-07	4.78E-08	7.43***	0
Days Absent from Farming	0.062552	0.0183648	3.412***	0.001
Log Likelihood	-464.0928			
Prob. Chi^2	0.0000			
Pseudo R^2	0.0905			

Source: Field survey, 2019; *** 1% level of significance

Conclusion and Recommendations

The study concluded that estimates from the WTP and COI approaches to valuation of malaria morbidity risk reduction from irrigation and drainage services varied as indicated by the US$6.0 and US$82.56 obtained respectively, while the implicit value of malaria morbidity risk reduction was US$6,599.92 per season. In addition, the drivers of probability of morbidity risk reduction from malaria were irrigators' marital status, income and days absent from farming due to malaria illness.

Arising from the outcome of the study, there is the need for the Apex WUA, BIS Management, Sokoto Rima River Basin Development Authority and TRIMING Project to embark on intensive sensitization of the Water Users' Associations/irrigations on malaria preventive measures through sustainable and pragmatic strategies, including encouraging payment for malaria health risk reduction through irrigators' remittances to the WUAs. In addition, Project Appraisal Teams, Consultants and the Academia can obviate the stress of primary data collection, by deploying estimate of malaria risk reduction from irrigation management obtained from this study as "Benefit Transfer" in their economic analysis, particularly in sub-Saharan Africa and across Nigeria, following relevant adjustments.

Authors' Contribution

The study established that estimates from the WTP and COI approaches to malaria morbidity risk reduction differs considerably, while the implicit value of malaria morbidity risk reduction obtained, can serve as "Benefit Transfer" estimates for use in future risk valuation and economic analysis related studies in sub-Sahara Africa. However, we encourage studies focusing on identifying single universally acceptable methodology for malaria health risk reduction valuation, particularly in sub-Sahara Africa.

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Competing interests

We declare that no competing interest exists.

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