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Evaluating the welfare effects of improved wastewater treatment using a discrete choice experiment

Ezekiel N. Ndunda*, Eric D. Mungatana[1]

Centre for Environmental Economics and Policy in Africa (CEEPA), Department of Agricultural Economics, Extension and Rural Development, Faculty of Natural and Agricultural Sciences, University of Pretoria, Pretoria 0002, South Africa

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ABSTRACT

This paper employs the discrete choice experiment method to estimate the benefits of improved wastewater treatment programs to mitigate the impacts of water pollution in Nairobi, Kenya. Urban and peri-urban farmers who use wastewater for irrigation from Motoine to Ngong River in Nairobi were randomly selected for the study. A random parameter logit model was used to estimate the individual level willingness to pay for the wastewater treatment before reuse in irrigation. The results show that urban and peri-urban farmers are willing to pay significant monthly municipality taxes for treatment of wastewater. We find that the quality of treated wastewater, the quantity of treated wastewater and the riverine ecosystem restoration are significant factors of preference over alternative policy designs in reduction of water pollution.

1. Introduction

Water is increasingly becoming a scarce natural resource in many arid and semi-arid countries. In Kenya, the current water endowment is 548 cubic metres per capita per year, and this is projected to shrink to 250 cubic metres per capita per year by 2025 (GOK, 2010a; NEMA, 2011; World Bank, 2010). Therefore, policy makers are forced to consider other economically feasible sources of water that might promote sustainable development in the country. The country has a high population growth rate (2.7 percent) and hence a need for higher food production in order to meet the high rate of population growth (KNBS, 2010). Irrigation agriculture has enormous potential to raise agricultural productivity and livelihoods of many poor farmers (FAO, 2009; Lang and Heasman, 2004). Since freshwater resources for irrigation are limited, wastewater will have to be considered for food production in the country. This is because the growth in urban population, rapid urbanization and industrialization result in greater quantities of municipal wastewater, which can be exploited for irrigation in order to conserve freshwater resources for portable use. Correctly planned reuse of municipal wastewater can also ease surface water pollution while providing essential nutrients for crops (Keraita and Drechsel, 2004; Qadir et al., 2010).

Many countries have incorporated wastewater reclamation as a vital aspect of water resources planning. However, Kenya has no national policy to reuse municipal wastewater although there is a national policy on urban and peri-urban agriculture, which is vital for food security, creation of employment, and poverty alleviation (GOK, 2010b). This is despite the fact that wastewater-irrigated agriculture has been practiced for several decades in the country. The lack of progress towards acceptance of wastewater as a viable alternative to freshwater resources may be partly explained by insufficient and unreliable information about the resource. Although wastewater reuse in irrigation agriculture is largely justified on economic and agronomic reasons, there is a need for caution to reduce adverse health and environmental effects. The significant agricultural wastewater quality parameters are the ones related to the crops health and yields, soil productivity maintenance and environmental protection. The main objective of this paper is to estimate the value attached by urban farmers to pollution abatement in Motoine–Ngong River through improved wastewater treatment. The valuation is analysed in terms of

* Corresponding author. Room 2-4, Agricultural Annexe, South Africa. Tel.: +27 725880554.
E-mail addresses: ezndunda@yahoo.com, ezndunda@gmail.com (E.N. Ndunda), eric.mungatana@up.ac.za (E.D. Mungatana).
[1] Room 2-10, Agricultural Annexe, South Africa.

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farmers' willingness-to-pay (WTP) municipal taxes for wastewater treatment in Nairobi.

Policy makers and other authorities responsible for the implementation of environmental policies are increasingly demanding analyses of environmental values (Bateman et al., 2002). The stated preference methods are often preferred for quantification of environmental values, particularly in the evaluation of non-market goods (Adamowicz et al., 1994; Hanley and Barbier, 2009; Hanley et al., 2001, 2003). There has been some research on the economic valuation of improved water quality (e.g. Alvarez-Farizo et al., 2007; Birol et al., 2008, 2009; Colombo et al., 2005; Cooper et al., 2004; Fischhendler, 2007; Hanley et al., 2005, 2006; Kontogianni et al., 2003; Markandya and Murty, 2004; Willis et al., 2005). However, there are relatively few studies worldwide on the economic costs of wastewater (e.g. Barton, 2002; Birol and Das, 2010; Cooper et al., 2004; Markandya and Murty, 2004; Murty et al., 2000; Kontogianni et al., 2003). In Kenya, there is no economic valuation study that has been undertaken on the improvement of water quality using a choice experiment methodology. This paper adds to this literature by employing discrete choice experiment to evaluate farmers' WTP for wastewater treatment before it is discharged into Motoine–Ngong River. This is valuable since it may assist policy makers to redesign wastewater treatment programs to improve social welfare of urban population.

The rest of this paper is structured as follows. Section 2 describes the case study area while choice experiment method is summarized in Section 3. The experimental design and administration are explained in Section 4. The results are provided in Section 5, whilst Section 6 presents some conclusions.

2. Case study

The case study area comprises of Kibera and Maili-Saba informal settlements in Kenya. These are densely populated slums which are located in the Motoine–Ngong River basin, in Nairobi Municipality. Kibera is situated 7 km from Nairobi City Centre while Maili-Saba is located 15 km from the city centre. Although Kibera started as a privileged settlement for ex-African soldiers who aided the British Army during the First and Second World Wars, it has grown to become the largest slum in East and Central Africa. Currently, the slum is home for approximately 55% of all the informal settlers in the Nairobi Municipality. Due to congestion in Kibera slum, there are no spaces for vehicular movement thus making it impossible for exhauster service to access interior parts of the slums to empty toilets. The situation has been worsened by poor environmental sanitation, inadequate water supply, and inappropriate waste management practices. Uncontrolled discharge of untreated wastewater into the environment has resulted into: deterioration of soil structure; eutrophication; phytotoxicity; undesirable growth of algae; communicable diseases; deterioration of water quality; plugging of micro irrigation systems; hypoxic conditions due to depletion of dissolved oxygen in water; and increased mortality in fish and other aquatic species.

Motoine–Ngong River flows through the Kibera and Maili-Saba informal settlements, which are estimated to have an average population density of 6000 persons per hectare. The river is heavily polluted due to poor environmental sanitation and lack of sewerage infrastructure in the slums (Dulo, 2008). It is estimated that about 280 tonnes of municipal solid waste is generated in the slum per day. Additionally, the Biochemical Oxygen Demand (BOD_5) from solid waste in Kibera slum is approximately 6650 kg per day. The generated urban waste, which includes human waste dumped into channels, drains into the river before it is treated. This implies that most of the untreated wastewater from Kibera slum is used for replenishing the Nairobi Dam and Motoine–Ngong River besides urban irrigated-agriculture in the river basin. This extensive water pollution in the Motoine–Ngong River threatens the sustainability of riverine ecosystem functions and also the livelihoods of many urban farm households and consumers of the produced crops. The conventional wastewater treatment methods are significant solutions for health and environmental risks in wastewater-irrigated agriculture (Hammer and Hammer, 2008; Mara, 2004; Patwardhan, 2008; WHO, 2006). Therefore, there is a need for the Nairobi Municipality to invest in improved treatment of wastewater generated from Kibera informal settlements before it is discharged into Motoine–Ngong River. Adequate treatment of enormous quantities of the wastewater generated from the slum will ensure that high quality wastewater is used to replenish the river and also sustain urban and peri-urban agriculture. This is likely to ensure the sustainability of many ecosystem functions in the river basin.

3. The choice experiment method

This study used the Choice Experiment (CE) methodology in the estimation of the value of wastewater treatment. The application of CE has become a widespread means of ecological valuation (Adamowicz et al., 1994). This methodology is some case of the stated preference approach to environmental valuation, which comprises of elicitation of responses from individuals in hypothetical markets. The CE method has its theoretic foundation in Lancaster's model of consumer choice (Lancaster, 1966), and in random utility theory (Luce, 1959; Mansky, 1977; McFadden, 1974). According to Lancaster, satisfaction of consumers is defined over the attributes of goods, rather than over goods themselves. Therefore, in any CE, individuals are asked to select an alternative option from many choices, which are defined according to their characteristics and the levels they take. In this case, the utility maximising respondents select an option that maximizes utility. The conventional utility function comprises of a deterministic and a random component according to the random utility theory. While the deterministic component comprises of factors observable by the researcher, the random component represents the unobserved factors of discrete choice. Thus, the utility U associated with individual n whose choice is alternative i is given by:

$$U_{in} = V(X_{in}) + \varepsilon(X_{in}) \tag{1}$$

where $V(\cdot)$ is the deterministic component and $\varepsilon(\cdot)$ is the error component in the utility function. The probability of individual n choosing alternative i from a set of alternatives J can be estimated using conditional logit model (CL) (Greene, 2002; McFadden, 1973; Maddala, 1999). The estimated probability is:

$$\Pr(Y_i = n) = \frac{\exp[V(X_{in})]}{\sum_{j=1}^{J} \exp[V(X_{jn})]} \tag{2}$$

If $V(\cdot)$ is taken to be a linear function of specific characteristics whose random error term is identically and independently distributed (IID) with a type I extreme value (Gumbel) distribution, the conditional indirect utility function becomes:

$$V_{jn} = \psi_j + \sum \beta_{jk} X_{jk} + \sum \phi_{jn} \left(S_n * \psi_j \right) \tag{3}$$

where ψ_j is an alternative specific constant, X_{jk} is the k characteristic value of the choice j; β_{jk} is the parameter allied to the k characteristic, S_n is the socio-economic characteristics vector of individual n and ϕ_{jn} is the vector of the coefficients related to the individual socio-economic characteristics.

In the presence of preference heterogeneity, the IIA assumption of CL model fails to hold thus leading to biased estimations.

However, random parameters logit (RPL) model does not require the IIA property and hence gives unbiased estimates in the presence of preference heterogeneity among the respondents (Greene, 2002; Train, 1998). Since the RPL model accounts for the unobserved heterogeneity, the utility function is:

$$U_{in} = V(X_n(\gamma + \delta_i)) + \varepsilon(X_n) \tag{4}$$

where, as before, $V(\cdot)$ and $\varepsilon(\cdot)$ are deterministic and error component, while γ is a parameter which varies by random component δ due to preference heterogeneity across households. The probability of individual n choosing alternative i from a set of alternatives J can be estimated using RPL model (Train, 1998). Therefore, from Equation (4) we obtain:

$$\Pr(Y_i = n) = \frac{\exp[V(X_n(\gamma + \delta_i))]}{\sum_{j=1}^{J} \exp[V(X_j(\gamma + \delta_i))]} \tag{5}$$

When the preference deviations with respect to the mean preferences for respondents are considered, the conditional indirect utility function becomes:

$$V_{jn} = \psi_j + \sum \beta_{jk} X_{jk} + \sum \tau_{nk} X_{jk} + \sum \phi_{jn} \left(S_n {*} \psi_j \right) \tag{6}$$

where ψ_j is an alternative specific constant, X_{jk} is the k characteristic value of the choice j; β_{jk} is the parameter allied to the k characteristic, τ represents a vector of deviation parameters, S_n is the socio-economic characteristics vector of individual n and ϕ_{jn} is the vector of the coefficients related to the individual socio-economic characteristics. The estimated coefficients of mean preference values β are assumed to be either log-normally or normally distributed (Train, 1998). Also, the individual tastes τ_{nk} are assumed to be constant overall the choices made but vary from one respondent to the other.

Once the parameters are estimated, the marginal rate of substitution (MRS) between a given pair of attributes i and j can be obtained as follows:

$$\text{MRS} = -1{*}\left(\frac{\beta_{\text{attribute } i}}{\beta_{\text{attribute } j}}\right) \tag{7}$$

When the price of selecting an alternative is included as an attribute, marginal rate of substitution can be used to yield an estimate of the part-worth or implicit price. The part-worth provides marginal willingness-to-pay (WTP) for a discrete change in an attribute level. This enables some understanding of the relative importance that individuals attach to characteristics within the design. Since CE method is consistent with utility maximisation and demand theory (Hanemann, 1984; Bateman et al., 2002), the part-worth of an attribute j can be estimated as follows:

$$\text{WTP}_j = -1{*}\left(\frac{\beta_{\text{attribute } j}}{\beta_{\text{price}}}\right) \tag{8}$$

In order to include the household specific characteristics in estimation of implicit prices (part-worth), Equation (8) is modified into Equation (9) below:

$$\text{WTP}_j = -1{*}\left(\frac{\beta_{\text{attribute } j}}{\beta_{\text{price}}}\right) \tag{9}$$

Lastly, diverse environmental scenarios associated with multiple changes in attributes can be applied in evaluation of the compensating surplus (CS) welfare measures (Bateman et al., 2002; Bennett and Adamowicz, 2001). This can be evaluated as shown in Equation (10) where V_{i0} is the indirect utility functions related to the initial state and V_{i1} is the indirect utility functions related to an improved state contained in the study, while β_{price} is the marginal utility of income.

$$\text{CS} = -\frac{1}{\beta_{\text{price}}}\left(\ln \sum_i \exp(V_{i0}) - \ln \sum_i \exp(V_{i1})\right) \tag{10}$$

4. The choice experiment design

This study aimed at identifying the farmers' preferences towards diverse characteristics of treated wastewater. Therefore, the primary step of the research was to select applicable attributes. A wide review of wastewater treatment and environmental literature was conducted in order to identify the characteristics of treated wastewater and also diverse effects of wastewater reuse for irrigation agriculture. There were two focus group discussions that involved 20 urban and peri-urban farmers in the study area. Similarly, there were extensive consultations with managers and employees of the two wastewater treatment plants (Kariobangi and Dandora) in Nairobi Municipality. Due to uncertainty over the exact changes in attribute features, the levels of choices were qualitatively presented. A pilot contingent valuation study with open-ended questions was conducted for 80 urban and peri-urban farmers in order to identify the price attribute values. The municipal tax per farm household per month was used as a payment vehicle in this research because it was the most preferred alternative by respondents. Table 1 presents

Table 1
Choice experiment attributes and levels for treated irrigation wastewater.

Attributes	Description	Levels	Codes
Quality of treated wastewater for irrigation	Large amount of untreated wastewater is currently discharged into Motoine–Ngong–Nairobi River hence creating environmental and health risks. Improved sewage infrastructures in Nairobi municipality can increase the amount of treated wastewater and hence minimize the environmental and health impacts.	*Poor* Medium High	Dummy
Quantity of treated wastewater for irrigation	Currently the quantity of wastewater treated in Nairobi municipality is below the generated amount. Development of sewage infrastructures can increase the amount of treated wastewater discharged into Motoine–Ngong–Nairobi River. This would consequently lower the quantity of untreated sewage discharged into Motoine–Ngong–Nairobi River.	*Low* Medium High	Dummy
Ecosystem restoration in Motoine–Ngong–Nairobi River	Water pollution in Motoine–Ngong–Nairobi River has resulted into environmental degradation of the riverine ecosystem. Restoration of the ecosystem could result into natural capital regeneration, biodiversity enhancement, and improvement of aesthetic value of the resource.	*No* Yes	Dummy
Monthly municipal tax	A pilot contingent valuation survey will be used to identify five levels of the payment vehicle (Kshs.)	60, 120, 160, 200, 240	Continuous

Note: Levels in italics indicate the status quo level.

a universe of possible combinations. Taking the full factorial design for two alternatives (A & B), each with two attributes with three levels, one attribute with two levels, and one attribute with five levels, we obtain $(3^2 \times 2 \times 5)^2$ different treatment combinations.

A total of 64 pairwise combinations of main effects of different wastewater management options were obtained from an orthogonal fraction of the complete factorial for this study. This was achieved by means of experimental design technique (Louviere et al., 2000) and IBM SPSS 19 software. The pairwise combinations were randomly blocked to eight groups of eight choices using a blocking factor. Therefore, each of the randomly selected farmers was presented with eight tripartite choice cards, as shown in the example of choice set (Table 2). The respondents were required to indicate their preferred choice on each card, which contained alternatives A, B and C (status quo) "no change" option. The alternatives A and B represent the expected environmental situation with different wastewater treatment measures that would allow for water pollution abatement in the Motoine–Ngong River. However, the status quo option (Table 3) represented the current environmental situation without any wastewater treatment measures. The respondents were provided with coloured photographs illustrating how the untreated wastewater from Kibera slum has polluted the Motoine–Ngong River basin. While the farmers were completing the questionnaires, they were also presented with photographs of Nairobi Dam before excessive pollution (when it was being used for recreation activities) and now when it is infested with Water Hyacinth due to eutrophication.

The choice experiment survey for this study was conducted from November 2011 to March 2012. Respondents for this study were randomly sampled from Kibera and Maili-Saba slums since they are located near Motoine–Ngong River. The household heads in the selected sample were provided with various wastewater management options, and the respective attributes were clearly explained to them before any interview. Once the respondents were made aware of health and environmental risks of untreated wastewater reuse in irrigation, it was explained how the Nairobi Municipality was financially constrained to fund for construction of treatment plants near slums without additional support. While the farmers were reminded of their financial limitations, they were also informed that they could voluntarily support efforts to sustainably manage the urban riverine ecosystem. The respondents were told that in order to support a secondary wastewater treatment programme they would pay monthly taxes to the municipality. A sample of 280 urban and peri-urban farmers, who represented the population of farmers that rely on wastewater for irrigation agriculture in terms of age, gender and urban–peri-urban area of residence, was selected. However, from the total sample surveyed, 7 respondents who failed to complete the questionnaire were omitted from the analysis. Similarly, 19 respondents provided a protest response and hence refused to respond to the CE cards, and 13 revealed a zero WTP by constantly selecting the status quo option in all the 8 choice cards presented and hence were also classified as protesting respondents. Therefore, a total of 241 farmers fully completed the survey, which included either option A or option B, and hence provided a total of 1928 (241*8) valid observations for choice model estimation.

Table 2
Example of choice set card presented to urban and peri-urban farmers.

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	Medium	High	No change.
Quantity of treated wastewater for irrigation	High	Low	
Ecosystem restoration in Motoine–Ngong River	No	Yes	
Monthly municipal tax (Kshs.)	60	120	
I choose the situation	☐	☐	☐

Table 3
The attributes and levels of status quo option.

Attributes	Levels
Quality of wastewater for irrigation	Poor
Quantity of wastewater for irrigation	Low
Ecosystem restoration in Motoine–Ngong–Nairobi River	No
Monthly municipal tax	0

5. Results

5.1. Socio-economic characteristics of respondents

The descriptive statistics of socio-economic and demographic data obtained for this study is presented in Table 4 below. According to the statistics, an average household size in Kibera slum is 4.26. This average household size is similar to the general average of 4.1 persons per household in Kenya (KNBS, 2010). The average monthly crop income among the farmers who practice wastewater irrigation is Kshs.2086.18. In the sample surveyed, 80.5% of household heads are male and are aged on average 42.6 years. Majority of farmers who use wastewater for irrigation agriculture in the study area have completed primary level education (8.6 years of education) and have a mean farming experience of 4.93 years. About 34.9% of the interviewed farmers involved in urban agriculture have other non-farm sources of income. The results show that 24.1% of urban farmers sampled for this study actively work together thus enabling exchange of information. According to the results obtained from this study, 45.23% of urban farmers in the study area are aware of health and environmental risks associated with wastewater irrigation. Also, 35.7% of the farmers involved in urban wastewater irrigation have adopted low-cost measures to reduce the health and environmental hazards associated with the practice.

5.2. Data coding

The data for analysis in this CE study were coded as follows. Municipal tax was coded as a continuous variable, which presented five levels. Qualitative attributes, which include, quantity of treated wastewater, quality of treated wastewater, and restoration of the

Table 4
Descriptive characteristics of the sampled households.

Characteristics	Samples mean (Std. dev.)
Household size	4.26 (1.30)
Age of the household head	42.61 (10.77)
Education level of the household head	8.55 (2.38)
Farm experience of household head	4.93 (7.03)
Monthly crop income (Kshs.)	2086.18 (2621.80)
	Percentage
Gender of the household head, 1 if male 0 otherwise	80.49
Employment, 1 if employed and 0 otherwise	34.85
Interaction with urban farmers, 1 if yes 0 otherwise	24.09
Risk awareness on wastewater irrigation, 1 if yes 0 otherwise	45.23
Adoption of risk reduction measure, 1 if adopted, 0 otherwise	35.68

river ecosystem were effects-coded (Hensher et al., 2005; Louviere et al., 2000). The high quality and high quantity levels of treated wastewater were respectively coded as 1. Medium quality and also medium quantity of treated wastewater were correspondingly coded as 0. For ecosystem restoration, code −1 was used to denote no (i.e. no investment in restoration of ecosystem) and code 1 was used to represent yes (i.e. investment in restoration of ecosystem). The status quo attributes for "neither alternative" were coded as −1 for treated wastewater quality and treated wastewater quantity. Alternate specific constant (ASC), which was also coded as a dummy, was equal to 1 if respondents preferred neither management option and zero otherwise. When the coefficient of ASC is statistically significant and negative, it implies that urban and peri-urban farmers have a strong propensity to pay for a programme on better wastewater treatment. The individual-level variables (age, gender, education, employed and awareness) were not directly applied in the econometric models as they are similar across the choices made by a respondent. In order to analyse the average willingness to pay for improved wastewater treatment programme, socio-economic variables were interacted with the ASC variable.

5.3. Conditional logit and random parameter logit models

The choice experiment results from CL and RPL models were estimated with Stata 11. Firstly, basic models were analysed to show how the selected attributes explain the choice of different alternatives in a choice set. The explanatory variables contained in the basic CL and RPL models are the ASC, monthly municipal tax, quality of treated wastewater, quantity of treated wastewater and ecosystem restoration. In the RPL model, the monthly municipal tax was specified as non-random. Also, in order to ensure that standard deviations can change in sign throughout the full range of the model, all the other attributes were estimated as normally distributed random parameters (Carlsson et al., 2003; Hensher et al., 2005; Train, 1998, 2003; Revelt and Train, 1998). The results of the basic CL and RPL models are reported in Table 5. Also, the CL and RPL models were estimated with interactions between ASC and socio-economic characteristics and also the choice attributes. This study used the following socio-economic characteristics in the interactions: age, gender, education, employed and awareness. The CL and RPL models with interactions were found to have higher pseudo-R^2 than the corresponding models without interactions. Therefore, further econometric analysis involved only the CL and RPL models with interactions (Table 6).

Since the failure of IIA assumption in CL model results in misspecification, the Hausman and McFadden (1984) test for the IIA property was carried out in this study. The likelihood ratio test was constructed for three distinct subsets of all the choice alternatives in order to ascertain whether the IIA holds. According to the test results, the IIA property was rejected at 1% significance level for the three CL subset models. In order to assess if the regression parameters of RPL model and CL model are different, this study conducted the Swait–Louviere log likelihood ratio test (Swait and Louviere, 1993). The test results indicate a significant increase to model fit from the CL model to the RPL model at 1% significance level. When the McFadden's ρ^2 value for CL model and RPL model are compared, the results show a higher level of parametric fit for latter ($\rho^2 = 0.314$) compared to the former ($\rho^2 = 0.211$). Therefore, the RPL model is a better fit than CL model for analysis of the survey data for this study. This is because the simulations by Domencich and McFadden (1975) equate values of ρ^2 between 0.2 and 0.4 in discrete choice models to values of R^2 between 0.7 and 0.9 in equivalent linear regression models. Lastly, the RPL model assumption that random coefficients are independent was relaxed in order to assess the model fit with correlated normally distributed coefficients (Hole, 2007). Since correlation coefficients and standard deviations were not statistically significant at 5%, the variance of random effects was considered insignificant in the RPL model estimates.

The RPL model with 1000 random draws shows that urban and peri-urban farmers have heterogeneous preferences over treated wastewater quality, treated wastewater quantity and ecosystem restoration at 1% significance level. Based on the results of this study, all the utility function parameters have theoretically consistent signs. Thus, respondents appreciate enhanced quality of treated wastewater, increased quantity of treated wastewater, and

Table 5
Parameter estimates of conditional logit and random parameter logit models.

Attribute	CL model		RPL model	
	Coefficient	Standard error	Coefficient	Standard error
Mean effects:				
Constant (ASC)	−0.518***	0.103	−0.773***	0.167
Quality of treated wastewater	0.659***	0.047	0.842***	0.073
Quantity of treated wastewater	0.248***	0.046	0.291***	0.088
Restoration of ecosystem	0.219***	0.036	0.377***	0.058
Monthly municipal tax	−0.013***	0.0007	−0.017***	0.001
Standard deviation effects:				
Quality of treated wastewater			0.440***	0.119
Quantity of treated wastewater			0.925***	0.098
Restoration of ecosystem			0.541***	0.073
Model Statistics				
Log-likelihood	−2585.12		−1463.92	
ρ^2 (Pseudo-R^2)	0.205		0.308	
Observations	1928		1928	

Notes: ***, **, * denotes significant at 1%, 5% and 10% level respectively. RPL model was estimated by using 1000 draws and keeping the tax term fixed.

Table 6
Parameter estimates of conditional logit and random parameter logit models with interactions.

Attribute	CL model		RPL model	
	Coefficient	Standard error	Coefficient	Standard error
Mean effects:				
Constant (ASC)	−0.799***	0.053	−0.653***	0.126
Quality of treated wastewater	0.661***	0.047	0.863***	0.076
Quantity of treated wastewater	0.250***	0.046	0.294***	0.089
Restoration of ecosystem	0.210***	0.036	0.375***	0.058
Monthly municipal tax	−0.013***	0.001	−0.017***	0.001
ASC × Age	−0.022	0.008***	−0.024***	0.010
ASC × Gender	0.374	0.213*	0.516**	0.254
ASC × Education	0.049	0.034	0.082**	0.041
ASC × Employed	0.630	0.166***	0.445**	0.202
ASC × Awareness	0.452	0.165***	0.450**	0.199
Standard deviation effects:				
Quality of treated wastewater			0.469***	0.117
Quantity of treated wastewater			0.923***	0.096
Restoration of ecosystem			0.538***	0.073
Model statistics				
Log-likelihood	−2570.002		−1453.154	
ρ^2 (Pseudo-R^2)	0.211		0.314	
Observations	1928		1928	

Notes: ***, **, * denotes significant at 1%, 5% and 10% level respectively. RPL model was estimated by using 1000 draws and keeping the tax term fixed.

ecosystem restoration in the Motoine–Ngong River. The urban and peri-urban farmers who use wastewater for irrigation agriculture value high quality of wastewater through appropriate treatment. Since the utility weight on medium level of treated wastewater quality and medium level of wastewater quantity are inferior to utility weights for high improvements in characteristics, comparative magnitudes between attribute levels are utilitarian. The treated wastewater quality has higher coefficient than the coefficients of the treated wastewater quantity, and ecosystem restoration in the Motoine–Ngong River. This may be attributed to the environmental and health hazards (e.g. diarrhoea, dysentery, typhoid, cholera and intestinal helminth infections) that the urban and peri-urban farmers, attach to wastewater quality for irrigation agriculture. Therefore, the secondary wastewater treatment should produce high quality wastewater for discharge into Motoine–Ngong River. The probability that urban and peri-urban farmers in the study area select a wastewater management option reduces with an increase in the monthly municipality taxes. There is no status quo bias since the ASC coefficient is negative and statistically significant, which shows that a positive utility impact occurs in any move away from the status quo (Adamowicz et al., 1998; Hanley et al., 2005). Therefore, ceteris paribus, urban and peri-urban farmers prefer the payment of monthly municipal tax for improved wastewater treatment before discharge into Motoine–Ngong River in order to move from status quo situation.

Since the socio-economic variables do not change over choice cases, they were interacted with the alternative specific constant. In the RPL model, the coefficients of all estimated socio-economic interactions were statistically significant and plausible. The results show that older farmers involved in wastewater irrigation chose improved wastewater treatment programme more frequently than young farmers involved in wastewater irrigation. This indicates that older farmers are more aware of the health risks in wastewater irrigation to farm workers and consumers of the wastewater grown crops. The coefficient of an interaction with gender variable shows that male farmers in the study sample chose status quo more frequently than the female farmers. On the other hand, respondents chose status quo more often if they had better education. This reveals that urban and peri-urban farmers with better education were more concerned about the payment of monthly municipal tax. The urban and peri-urban farmers chose status quo more often if they had another form of employment. This implies that respondents with an alternative form of employment are more concerned about the introduction of monthly municipal tax. The results show that respondents who are aware of health risks of wastewater irrigation had a higher likelihood of choosing status quo. This could be owing to the fact that, they do not agree to themselves contributing towards improved wastewater treatment programme.

5.4. Estimations of implicit prices

The implicit prices of the sample average for all the considered attributes in this study are presented in Table 8. Also, additional valuations of implicit prices, which included six different household profiles (Table 7), were conducted in the study. In order to obtain the implicit prices and their respective 95% confidence intervals, Equation (9) was used in Krinsky and Robb (1986) bootstrapping procedure.

Generally, average households are willing to pay Kshs.51.0 monthly municipal taxes to ensure that wastewater is treated before it is released into the Motoine–Ngong River. Also, they are willing to pay about half (Kshs.22.18) as much to ensure the riverine ecosystem restoration. The households are willing to pay Kshs.17.39 for improved treatment of wastewater before discharge into

Table 7
Household profiles used to estimate marginal WTP for treated irrigation wastewater.

Profile	Post-primary education (%)	Over 2 years' experience (%)	Mean age of farmers
Average household in the study area	36.51	51.45	42.61 (10.77)
Profile 1: Farmers aged below 40 years (young)	33.61	52.94	34.81 (3.85)
Profile 2: Farmers aged 40 years and above (elderly)	37.23	52.13	45.71 (10.02)
Profile 3: Farmers with primary education	0	49.67	43.18 (11.61)
Profile 4: Farmers with post-primary education	100	54.55	41.61 (9.05)
Profile 5: Farmers with up to 2 years' experience	34.19	0	42.13 (10.43)
Profile 6: Farmers with over 2 years' experience	38.71	100	43.06 (11.07)

Note: Standard deviations are in parentheses.

Motoine–Ngong River. The results from this study show that urban and peri-urban farmers have positive WTP for an increase in treated wastewater quality, treated wastewater quantity and ecosystem restoration. This is an indication that the urban and peri-urban farmers are willing to pay for improvement of wastewater quality and quantity from low level (status quo) to medium or high level, and also for restoration of riverine ecosystem from degradation (status quo). Similarly, the WTP for higher quality of treated wastewater is greater than for high quantity of treated wastewater and ecosystem restoration across all the six household types considered.

The results also show that profile 1 (young farmers) are willing to pay more than profile 2 (elderly farmers) for treated wastewater quality, treated wastewater quantity and ecosystem restoration attributes. Also, profile 4 (farmers with quality education) are willing to pay more than profile 3 (farmers with poor education) for treated wastewater quality and treated wastewater quantity attributes. Lastly, the study shows that profile 5 (farmers with little experience) are willing to pay more than profile 6 (farmers with much experience) for treated wastewater quality, treated wastewater quantity and ecosystem restoration attributes. The estimated implicit prices for environmental attributes are of significant importance to policy makers. Relative importance of the attributes can be derived from the values of their implicit prices, whereby those with higher implicit prices are assigned more resources than the others. In this study, the implicit prices of quality of treated wastewater are consistently bigger than ecosystem restoration and treated wastewater quantity. This reflects the fact that the urban and peri-urban farmers involved in wastewater irrigation value highly the quality of treated wastewater discharged into Motoine–Ngong River.

5.5. Compensating surplus estimates

The compensating surplus estimates for this study were obtained from the choice model parameters of RPL model and Equation (10) for a variety of policy scenarios as shown in Table 9. In order to obtain the mean WTP value and their respective 95% confidence intervals using Equation (9), this study used Wald Procedure (Delta method) for analysis. This was meant to explain the general WTP for upgraded wastewater treatment over the status quo. In order to determine the indirect utilities of respondents for the three scenarios, this study used the coefficients of the significant attributes and the sample means of the socio-economic characteristics. The survey data from this study were divided into two sub-samples of farmers who use untreated

Table 8
Implicit prices and confidence intervals for the average and six household profiles.

Profile		Quality of treated wastewater	Quantity of treated wastewater	Restoration of ecosystem
Average household in the study area	Mean (95% CI)	51.0 (42.39–59.56)	17.39 (7.13–27.58)	22.18 (15.76–29.35)
	SD	27.74	54.55	31.78
Profile 1: Farmers aged below 40 years (young)	Mean (95% CI)	56.93 (44.12–70.52)	16.63 (1.45–31.72)	17.54 (8.43–27.84)
	SD	32.75	59.13	32.11
Profile 2: Farmers aged 40 years and above (old)	Mean (95% CI)	44.39 (35.85–52.94)	16.26 (5.05–27.5)	21.49 (14.19–29.64)
	SD	17.22	55.59	32.72
Profile 3: Farmers with primary education	Mean (95% CI)	46.78 (36.58–57.16)	16.58 (3.31–29.94)	18.6 (10.64–27.51)
	SD	25.37	59.96	32.42
Profile 4: Farmers with post-primary education	Mean (95% CI)	59.50 (44.29–75.42)	19.38 (2.71–35.97)	29.51 (18.19–42.42)
	SD	33.99	48.38	33.72
Profile 5: Farmers with up to 2 years' experience	Mean (95% CI)	62.4 (47.64–78.35)	18.11 (1.42–35.16)	24.58 (13.81–36.94)
	SD	39.12	61.50	38.95
Profile 6: Farmers with over 2 years' experience	Mean (95% CI)	41.02 (31.28–50.99)	16.65 (3.43–29.75)	20.47 (12.53–29.37)
	SD	19.52	52.46	27.86

Note: Mean prices and standard deviations are in Kshs/household/month. Confidence intervals at 95%, calculated using Krinsky and Robb (1986) bootstrapping procedure, are given in parentheses.

wastewater for irrigation in the Motoine–Ngong River basin: urban farmers located about 5 km from Nairobi city centre (Kibera) and peri-urban farmers located about 10 km from Nairobi city centre (Maili-Saba). The following change scenarios were compared to status quo:

- Scenario 1: Quality of wastewater treated for irrigation is medium; quantity of discharged wastewater for irrigation after treatment is medium and there is no ecosystem restoration in Motoine–Ngong–Nairobi River.
- Scenario 2: Quality of wastewater treated for irrigation is medium; quantity of discharged wastewater for irrigation after treatment is high and there is ecosystem restoration in Motoine–Ngong–Nairobi River.
- Scenario 3: Quality of wastewater treated for irrigation is high; quantity of discharged wastewater for irrigation after treatment is high and there is ecosystem restoration in Motoine–Ngong–Nairobi River.

The calculated values of compensating surplus for the change from the status quo to various scenarios are plausible over the selected policy options. This is described by the WTP, which rises as policy options change towards improved environmental status. For instance, scenario 1 is based on medium quality of treated wastewater, moderate quantity of treated wastewater and degraded riverine ecosystem in relation to the status quo. The mean WTP for this development bundle is Kshs.56.56 for Maili-Saba, Kshs.78.73 for Kibera and Kshs.68.39 for the pooled data. When the environmental condition is further enhanced in scenario 2, the mean WTP rises to Kshs.116.62 in the case of Maili-Saba, Kshs.142.10 in the case of Kibera and 130.13 in the case of pooled data. In the case of scenario 3, the mean WTP increases to Kshs.160.08 in Maili-Saba, Kshs.199.47 in Kibera and Kshs.181.14 in the pooled data. Compared to scenario 1, scenario 2 provides a higher quality of treated wastewater, a higher quantity of treated wastewater and restored riverine ecosystem. This results in an increase in average WTP of Kshs.60.06 in the case of Maili-Saba, Kshs.63.37 in the case of Kibera and Kshs.61.74 in the case of pooled data. Also, compared to scenario 1, scenario 3 provides improved environmental change through enhanced wastewater treatment. The environmental improvement results in an increased average WTP of Kshs.103.53 in the case of Maili-Saba, Kshs.120.72 in the case of Kibera and Kshs.112.75 in the case of pooled data. The compensating surplus results reveal a distance-decay function for the estimated mean WTP values for urban and peri-urban farmers.

6. Discussions and conclusion

6.1. Discussions

The importance of wastewater to the livelihoods of many poor urban and peri-urban farmers in developing countries cannot be overemphasized. However, the practice may pose numerous health and environmental risks to farm-workers, consumers and communities near the irrigated farms. Since the health and environmental hazards involved in wastewater irrigation warrant policy action, decision makers require information on public preferences for adequate intervention. However, the literature on choice experiment methods is limited in developing countries (e.g. Abdullah and Mariel, 2010; Bennett and Birol, 2010; Birol and Das, 2010; De Groote and Kimenju, 2008; Do and Bennett, 2009; Hope, 2006). Therefore, this paper contributes to the limited literature by showing the relevance of choice modelling applications in producing policy-relevant estimates of different environmental attributes on improved wastewater treatment. The urban and peri-urban farmers in the Motoine–Ngong River basin were willing to pay for improved wastewater treatment. However, the estimated values for improved wastewater treatment are not

Table 9
Compensating surplus for three possible scenarios.

Policy scenarios		Research sites		
		Urban data	Peri-urban data	Pooled data
Scenario 1	Mean (95% CI)	78.73 (58.25–99.22)	56.56 (38.39–74.74)	68.39 (54.67–82.10)
Scenario 2	Mean (95% CI)	142.10 (102.22–181.99)	116.62 (80.67–152.56)	130.13 (103.12–157.15)
Scenario 3	Mean (95% CI)	199.47 (152.67–236.26)	160.08 (117.98–202.17)	181.14 (149.35–212.93)

Note: Compensating surplus values are in Kshs/household/month. Confidence intervals at 95%, calculated using delta method, are given in parentheses.

solely dependent on the environmental attributes but also on socio-economic factors.

The affecting socio-economic characteristics include age, education, gender, employment status, health and environmental risks awareness of farmers. The study results show that young farmers have a higher mean WTP than elderly farmers. Other choice experiment studies on environmental improvements have shown that elderly respondents have lower WTP for the enhancements than young ones (e.g. Carlsson et al., 2003; Colombo et al., 2006; Othman et al., 2004). The other used socio-economic variables had a positive sign for their coefficients. This reveals similar findings to related studies, which have employed the choice experiment methods (e.g. Birol and Cox, 2007; Carlsson et al., 2003; Colombo et al., 2006; Othman et al., 2004). When the compensating surplus for the sub-sample from Kibera (5 km from Nairobi's central business district) was compared to the sub-sample from Maili-Saba (10 km from Nairobi's central business district), the WTP values reduced as the distance increased indicating the distance-decay effect for the wastewater treatment.

In developing countries like Kenya, choice experiment studies require comprehensible and plausible scenarios for respondents (Whittington, 2002). Since economic valuation research on water quality has not been undertaken in the study area before, this application of stated preference method to value improved wastewater treatment provided unique challenges to respondents. This study used focus group discussions to ensure that respondents clearly comprehended the importance of different attributes presented to them in the choice tasks of improved wastewater treatment. Also, the research questionnaires were pre-tested prior to actual data collection in order to ensure that the obstacles in understanding the questionnaires were identified and corrected before the actual data collection.

The challenges experienced in this study provide valuable information for similar choice modelling studies in developing countries. Urban and peri-urban farmers in Kenya consider the wastewater treatment projects to be a responsibility of the municipal councils. The respondents were informed about the health and environmental risks attributed to the reuse of untreated wastewater for irrigation. After the farmers were made aware of health and environmental effects of their current practice, they were informed that the Nairobi City Council would be presented with their opinion for policy intervention. This was achieved through the support of four enumerators and a field supervisor who were carefully trained prior to the choice experiment survey. The training involved the interpretation of questionnaires to respondents in order to simplify the uniqueness between the provided alternative choices. This was aimed at enabling the respondent to be certain about the trade-offs to make in selecting choice options.

6.2. Conclusion

There are substantial benefits that can be associated with a reduction in the discharge of untreated wastewater in the Motoine–Ngong River. This case study shows that an investment in the treatment of wastewater is justified by resultant benefits. The study shows that urban and peri-urban farmers care about riverine ecosystem restoration, wastewater quality and wastewater quantity. Although the choice experiment design and data analysis are complex, this study reveals how the method can provide relevant data for policy intervention in the developing countries. The choice modelling provides WTP values of individual attributes for wastewater treatment, in addition to the overall policy package. The valuation of individual wastewater treatment attributes enables policy makers to ensure that the meagre resources in developing countries are prioritized for sustainable management. Since the choice modelling includes socio-economic characteristics, the results are more valuable than the comparable contingent valuation method.

The welfare gains reported in this study show that the WTP for an average household is Kshs.90.57 (Kshs.51.0 for high quality of treated wastewater, Kshs.17.39 for high quantity of treated wastewater and Kshs.22.18 for ecosystem restoration) as monthly municipal taxes in order to treat wastewater before discharge into the Motoine–Ngong River. This implies that the Nairobi Municipality will be collecting additional taxes annually estimated at Kshs.1086.84 per household. There are approximately 150,000 farmer households who use raw sewage for irrigation agriculture in Kibera, Maili-Saba and Kariobangi South. Once the annual municipal taxes are aggregated over the overall farmer households, the annual WTP for wastewater treatment is estimated as Kshs.163.026 million. This reveals a strong demand for enormous amount of high quality wastewater and ecosystem restoration in order to minimize health hazards.

This case study has illustrated the value of wastewater treatment in Nairobi Municipality. The attributes of treated wastewater have been quantified and hence can be utilized for justification of wastewater treatment in urban and peri-urban Kenya. This study is also a notable example of how choice experiment method can be applied to estimate non-market values of treated wastewater in sub-Saharan Africa. The use of choice modelling may thus contribute towards policy formulation processes for sustainability in natural resources conservation. However, there is a need for further research to establish the actual costs and benefits of wastewater treatment in the study area. The cost-benefit analysis will provide policy makers with other benefits that may accrue to other stakeholders as a result of pollution abatement in the river. The costs must include the wetland construction and also maintenance costs. Since the investment has welfare effects for future generations, long-run discount rate should be considered in the cost-benefit analysis.

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