Wastewater reuse in urban and peri-urban irrigation: an economic assessment of improved wastewater treatment, low-risk adaptations and risk awareness in Nairobi, Kenya

By

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DEDICATION

To my mum and dad

DECLARATION

I, Ezekiel Ndunda declare that the thesis, which I here submit for the degree of PhD at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at another university.

Several sections of this thesis have been published in journals.

Any inaccuracies in exclusions or reasoning are exclusively my responsibility.

Signed:.. Date: 03.01.2014

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ABSTRACT

The overall goal of this study was to analyse the welfare effect of improved wastewater treatment with the view of making policy recommendations for sustainable urban and peri-urban irrigation agriculture in Kenya. This goal was achieved by investigating three specific objectives. The first objective was to assess the farmers' awareness of health risks in urban and peri-urban wastewater irrigation. Second objective was to analyse the factors that affect the choice of low-risk adaptations in reuse of untreated wastewater for irrigation. The third objective was to estimate the value that urban and peri-urban farmers who practice wastewater irrigation impute to improvements in specific characteristics of the wastewater input in agriculture.

In order to achieve the first objective, an ordered probit model was used to identify the factors that influence farmers' awareness of health risks in untreated wastewater irrigation. The model was

fitted to data collected from a cross-sectional survey of 317 urban farm households in the Kibera informal settlement of Kenya. Results of this study show that gender of household head, household size, education level of household head, farm size, ownership of the farm, membership to farmers' group, and market access for the fresh produce significantly affect awareness of farmers about health risks in wastewater irrigation. Therefore, there is need for awareness programs to promote public education through regular training and local workshops on wastewater reuse in order to improve the human capital of the urban and peri-urban farmers.

To achieve the second objective, the study used a multinomial logit model to analyse the farmers' choice of low-risk adaptations in untreated wastewater irrigation. A survey of 317 urban and peri-urban farmers was conducted and measures for risk-reduction in wastewater reuse were analysed. The urban and peri-urban farmers were found to have adopted low-risk wastewater irrigation techniques such as cessation of irrigation before harvesting, crop restriction and safer application methods. Results of the study show that adoption of risk-reduction measures is significantly influenced by the following factors: household size, age of the household head, education of household head, access to extension, access to media, access to credit, farmers' group membership, and risk awareness. Also, marginal analysis of the coefficients confirmed the socio-economic characteristics are key determinants in adoption of low-risk measures in wastewater reuse. The study recommends that policies in support of low-risk urban and peri-urban irrigation agriculture should disaggregate farmers according to their socio-economic and institutional characteristics in order to achieve their intended objectives.

To achieve the third objective, the study employed the discrete choice experiment approach to estimate the benefits farmers impute to improvements in attributes of the wastewater irrigation input, whose aim is to reduce the health risks associated with untreated wastewater irrigation. Urban and peri-urban farmers who practice wastewater irrigation drawn from Motoine-Ngong River in Nairobi were randomly selected for the study. A total of 241 farmers completed the presented

choice cards for the choice model estimation. A random parameter logit model was used to estimate the individual level willingness to pay for wastewater treatment. The results show that urban and peri-urban farmers are willing to pay significant monthly municipality taxes for treatment of wastewater. Conclusion of this study was that, quality of treated wastewater, quantity of treated wastewater and the riverine ecosystem restoration are significant factors of preference over policy alternative designs in wastewater treatment and reuse.

Keywords: discrete choice experiment; low-risk measures; multinomial logit; ordered probit model; random parameter logit model; health-risk awareness; wastewater irrigation.

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ACRONYMS AND ABBREVIATIONS

ADB	*African Development Bank*
AEO	*African Economic Outlook*
ASC	*African Studies Centre*
BOD_5	*Biochemical Oxygen Demand*
CDF	*Cumulative Density Function*
CE	*Choice Experiment*
CS	*Compensating Surplus*
ECFA	*Engineering and Consulting Firms Association*
FAO	*Food and Agricultural Organization*
FWSI	*Falkenmark Water Stress Index*
GOK	*Government of Kenya*
IIA	*Independence of Irrelevant Alternatives*
IID	*Identically and Independently Distributed*
IWMI	*International Water Management Institute*
KNBS	*Kenya National Bureau of Statistics*
NCAPD	*National Coordinating Agency for Population and Development*
NEMA	*National Environmental Management Authority*
RPL	*Random Parameter Logit Model*
UNEP	*United Nations Environment Programme*
UN-Habitat	*United Nations Human Settlements Programme*
WHO	*World Health Organization*
WTP	*Willingness-to-Pay*

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The health and environmental risks associated with untreated wastewater irrigation are of growing concern to policy makers in cities of many developing countries (Raschid-Sally & Jayakody, 2008; Scott *et al*., 2004; WHO, 2006a). This is because millions of households in developing world cities depend on untreated or partially treated wastewater for livelihoods through agricultural activities in urban and peri-urban areas. It is estimated that wastewater irrigation supports about 10 percent of the food consumers worldwide (Hamilton *et al*., 2007; Scott *et al*., 2004; WHO, 2006a). According to Jiménez and Asano (2004) untreated or partially treated wastewater is used to irrigate about 20 million hectares of agricultural land worldwide. Some of the key drivers of urban and peri-urban wastewater irrigation in many developing countries are: growing demand of freshwater; increasing demand of fresh vegetables; strong market incentives; and lack of reliable freshwater sources (Raschid-Sally & Jayakody, 2008). The generation of urban wastewater by domestic, industrial and commercial sectors is expected to continue increasing due population growth, rapid urbanization, improved living conditions and economic development (Asano *et al*., 2007; Lazarova & Bahri, 2005; Qadir *et al*., 2010).

Agriculture is the largest global user of untreated and treated wastewater due to high food demand (Jiménez & Asano, 2008). However, wastewater irrigation has potential benefits and negative consequences on ecosystems, public health, crop production, and soil resources (Blumenthal *et al*., 2000; WHO, 2006b; Scott et al., 2004). Wastewater is a reliable source of water, since it is available throughout the year, unlike seasonal streams and precipitation. This ensures crop production throughout the year, numerous cultivation cycles, improved crop yields, and increased range of crops that can be produced (Keraita *et al*., 2008; Raschid-Sally *et al*., 2005). The improved agricultural productivity and associated income gains allow farmers a better livelihood and additional benefits of utilizing the income to improve health conditions. In addition, wastewater reuse for irrigation constitutes an affordable disposal method and a treatment system that utilizes the soil to abate pollutants while recharging the aquifers through infiltration (Jiménez, 2006). Also, wastewater irrigation adds valuable plant nutrients and organic matter to soils and crops (Qadir *et al*., 2007; Rosemarin, 2004; van der Hoek *et al*., 2002). Therefore, the demand for chemical fertilizers can be reduced if untreated wastewater, which is rich with crop nutrients, is made accessible to many urban and peri-urban farmers in the developing world.

In many developing countries, wastewater flows from large urban areas are untreated and loaded with excreted helminthic, protozoan, viral, bacterial, and pathogens endemic in the community, hence presenting a severe health risk once in the irrigation-water sources (WHO, 2006b). The reuse of untreated or partially treated wastewater for irrigation presents a major challenge since polluted water has environmental consequences and is also linked directly to the food chain. Also, untreated wastewater irrigation poses health risks since it may contain chemical pollutants or micro-organisms that can affect the health of those working on wastewater farms and consumers of vegetables produced using the wastewater, often leading to gastrointestinal disease (Drechsel *et al*., 2010). Untreated wastewater reuse may facilitate transmission of diseases from excreta-related vectors and pathogens, skin irritants and toxic chemicals like pesticides and heavy metals. The major concerns are excreta-related pathogens and skin irritants (Blumenthal *et al*., 2000; van der Hoek *et al*., 2005). Although, some cases of pathogen uptake by crops have been documented, they mainly contaminate crops through direct contact (Hamilton *et al*., 2007). When nitrogen concentration in wastewater used for irrigation is extremely high, the produced crops have excessive vegetative growth which delays maturing while reducing the quality of produce (Qadir *et al*., 2007). Also, some trace elements may lead to plant toxicity thus posing health risk to crop consumers if they exist in excessive concentrations (Jiménez, 2006).

Policy makers in many cities of the developing world recommend sufficient treatment before discharge to the environment (Drechsel, 2002). However, achieving the globally recommended wastewater treatment standards is difficult in many developing countries due to limited financial resources and institutional capacity (UN Millennium Project, 2005). Despite considerable investment in wastewater treatment, 95 percent of the produced wastewater is discharged without adequate treatment into waterways used downstream by farmers (Ujang & Henze, 2006). Thus, there is persistent surface water pollution close to many cities, which has impacts spreading to downstream agricultural areas (Raschid-Sally & Jayakody, 2008; Scott *et al*., 2004). This problem is expected to worsen due to expansion of many cities in the developing world, which is attributed to rapid economic growth, increasing urban population and urbanization (Davis, 2006). The discharge of untreated or partially treated wastewater into the environment is likely to persist into the future and may grow to new areas that are undergoing urban growth in the developing countries.

The growing urban population, rising demand for food, improving quality of life and rapid urbanization has led to increased demand for water in many cities of the developing countries (Jiménez, 2006; Raschid-Sally & Jayakody, 2008). Also, climate change is expected to reduce the availability of water in many countries while increasing responsiveness of ecological water requirements. These circumstances necessitate wastewater recycling and reuse in order to supplement the existing water sources in many water-scarce countries. Agriculture is the most suitable alternative for wastewater reuse since it accounts for about 80 per cent of total water consumption in developing countries. Also, water of lower quality can be used for agriculture unlike in other alternative sectors. There is extensive but unplanned wastewater irrigation in many urban and peri-urban areas, which is driven by the prevailing economic and physical water scarcity (Ensink *et al*., 2004; Mekala *et al*., 2007). In order to address the potential health hazards in wastewater irrigation, there is need for a policy that accommodates needs of the farmers while realizing the public and environmental health prerequisites. The policy should be based on local needs and options so as to be effective and sustainable.

Kenya is a water-scarce country where many municipal councils are unable to supply adequate water for domestic, industrial, and agricultural utilization. The current water availability is 548 cubic metres per capita per year and is expected to shrink to 250 cubic metres per capita per year by 2025 (NCAPD, 2010; NEMA, 2011a). Water scarcity in the country is projected to worsen over time based on the current population of about 38.6 million and the prevailing annual birth rate of about 4 per cent (KNBS, 2010). In Nairobi city, the portable water supply for domestic use is less than 100 litres per capita per day (GOK, 2007). However, portable water is not supplied for irrigation in Nairobi although Kenya has a policy on urban and peri-urban agriculture (GOK, 2010). This has increased the significance of wastewater in the water balance, which has turned untreated and partially treated wastewater into a critical source of water for urban and peri-urban irrigation agriculture. Wastewater irrigation has flourished as a spontaneous and unplanned practice in Nairobi city due to lack of policy on wastewater reuse in the country. This has marginalized many poor urban and peri-urban farmers who rely on wastewater for crop production.

Many urban and peri-urban farmers in Nairobi city rely on untreated wastewater for irrigation agriculture although the practice is generally informal. Most of the raw sewage and domestic wastes from informal settlements drain directly into the rivers in the city, which are used downstream for irrigation. Over 50 per cent of wastewater generated in the city is discharged into the environment without treatment (ADB, 2010; Githuku, 2009; UNEP 2003). Thus, most rivers flowing through the city are the primary sources of polluted water that is utilized for irrigation agriculture. Moreover, many urban and peri-urban farmers in the city divert untreated wastewater flowing through the sewerage system to their farming plots for irrigation (Cornish & Kielen, 2004; Dulo, 2008; NEMA, 2011b). This unplanned wastewater irrigation raises concern over public health of the farm workers and consumers of fresh vegetables produced using the polluted water. The potential health risks in wastewater irrigation are a major constraint in the current wastewater use practices and can possibly limit its long-term sustainability (Jiménez *et al.*, 2010; WHO, 2006b). Therefore, there is need for a compromise between the risks and benefits of untreated wastewater irrigation, since the practice supports livelihoods of many poor farmers.

1.2 Statement of the problem

While several studies have been done on the consequences of wastewater irrigation on livelihoods (e.g. Blumenthal *et al*., 2000; Ensink *et al*., 2003; Fattal *et al*., 2004; Feenstra *et al*., 2000; Hamilton *et al*., 2006; Tiongco *et al*., 2009; van der Hoek *et al*., 2002) they are still inadequate in many perspectives. Three major limitations to sustainable wastewater irrigation in developing countries have been identified in the literature.

The first limitation is the lack of information on the socioeconomic factors that influence the health-risk awareness among wastewater users involved in urban and peri-urban agriculture. According to Jiménez (2006), understanding the influence of socioeconomic characteristics on awareness for health risks across households is critical in wastewater irrigation since farmers are able to make appropriate choices. The responses made by wastewater users to minimize health hazards are partly dependent on the existing information they have and also their level of awareness about the risks involved in wastewater irrigation. Thus, identifying the socioeconomic factors that influence risk awareness can greatly contribute towards safe and sustainable practices in urban and peri-urban agriculture.

The second limitation is the lack of understanding of the institutional factors that determine the choice of risk-reducing measures in wastewater irrigation the in urban and peri-urban areas. This aspect is important because, while untreated wastewater irrigation is common in many developing nations, the extent to which farmers incorporate risk-reduction measures varies considerably due to institutional factors (SuSanA, 2008). Therefore, understanding how institutional characteristics influence the adoption of risk-reducing measures in wastewater irrigation is critical for supporting safe wastewater reuse to ensure sustainability in urban and peri-urban agriculture.

The third limitation is that there is insufficient understanding of the value that urban and peri-urban farmers who practice wastewater irrigation attribute to improved wastewater treatment. Since there are many poor farmers involved in wastewater irrigation in cities of the developing countries, there is a need to understand their willingness to pay for improved wastewater treatment as a cost-effective risk-reducing strategy for welfare improvement (WHO, 2006a).

There is limited research on the three constraints articulated above, particularly in sub-Saharan Africa. To the best knowledge of the author, there is limited use of empirical information on the factors that influence the risk-awareness of farmers who use untreated or partially treated wastewater for crop production. Also, the use of empirical knowledge on the determinants of farmers' decisions on the use of low-risk irrigation methods in untreated wastewater irrigation is lacking in the literature. Lastly, there is very little empirical information on the value of improved wastewater treatment that is currently available in the literature. This is the case with the use of choice experiment in modelling of multiple attributes of treated wastewater to enable the estimation of willingness to pay for improved wastewater treatment.

Based on this background, this study seeks to make three important academic contributions. The first contribution sought in this study is an analysis of the factors that influence the health-risk awareness of farmers involved in untreated wastewater irrigation using an ordered-choice model framework. The model takes into consideration the fact that farmers' health-risk awareness in wastewater reuse is ordinal nature. The second contribution that the study attempts to make is an analysis of the factors that determine the decision to adopt risk reduction measures in wastewater irrigation using unordered-choice model. The framework takes into consideration the fact that the risk-reducing measure chosen by a farmer from various available alternatives in wastewater irrigation is the one with the highest utility. The third is an estimation of farmers' willingness to pay for improved wastewater treatment using a stated preference method known as choice experiment. In the choice experiment, wastewater users are considered to be utility maximizing respondents and hence select the choice options that maximize their utility. The results of this study would produce valuable insights in order to formulate a national policy that supports safe reuse of wastewater for irrigation agriculture in Nairobi. The informal settlements (Kibera and Mailisaba slums), which are located near the Motoine-Ngong River in the Nairobi River Basin (in Nairobi city) have been selected as the case study area.

1.3 General objective

The general objective of this study is to: evaluate the awareness of health risks in untreated wastewater reuse in agriculture; investigate the choice of low-risk adaptations in wastewater irrigation; and assess the farmers' economic value of improved wastewater treatment in Nairobi, Kenya.

1.3.1 Research objectives

The specific objectives of this study are:

1. To evaluate the health-risk awareness of farmers involved in untreated wastewater irrigation in urban and peri-urban areas.
2. To analyse the determinants of farmers' choice of low-risk irrigation measures in wastewater reuse for agriculture in urban and peri-urban areas.
3. To estimate the value that urban and peri-urban farmers who practice wastewater irrigation attribute to improved wastewater treatment.
4. To draw relevant policy recommendations for sustainable management of wastewater in urban and peri-urban regions based on the findings of the study.

1.4 Research hypotheses

Based on the literature on wastewater treatment and non-treatment risk interventions and also the health risks to wastewater users in developing countries, the following hypotheses were formulated:

1. The health-risk awareness of farmers involved in urban and peri-urban wastewater irrigation is significantly influenced by socio-economic characteristics.

2. The adoption of low-risk non-treatment measures by farmers in untreated wastewater irrigation is influenced by institutional characteristics.
3. The farmers' willingness to pay for improved wastewater treatment before reuse in irrigation is significantly affected by wastewater quality, wastewater quantity and ecosystem restoration attributes.

1.5 Approaches and methods of the study

The study employed three main analytical approaches to achieve the aforesaid objectives. The ordered probit model was used to achieve the first objective of this study. This is because the model was considered to be more suitable than unordered multinomial or nested logit or probit models. Unordered models do not account for the ordinal nature of health-risk awareness in wastewater reuse. The dependent variable in the model was individual's certainty of severe health risks in wastewater irrigation, which was measured on a five point scale (1: strongly disagree… 5: strongly agree). Explanatory variables in the analysis included both the demographic and socioeconomic characteristics. Once the model was estimated, the marginal effects were calculated to show the likelihood of the direct and indirect wastewater users to "strongly believe" that wastewater irrigation has health risks.

To achieve the second objective, a multinomial logit model, which is based on random utility theory, was applied. This model allows for an analysis of decisions across more than two categories in the dependent variable unlike the binary models. In the study, alternative low-risk non-treatment interventions for wastewater irrigation in the urban and peri-urban areas were identified and used in the model. The considered low-risk irrigation measures included: irrigation cessation before harvesting, restriction of crops grown using wastewater and safe wastewater application procedures.

Marginal effects were used to evaluate the expected variation in probability of a particular intervention in utilization untreated wastewater for agricultural production.

To pursue the third objective the stated preference environmental valuation technique, namely the choice experiment method was employed. In this model, individuals are asked to select an alternative option from many choices, which are defined according to their characteristics and the levels they take. The utility maximising respondents select an option that maximizes their respective utilities. When the price of an alternative is included as an attribute, marginal rate of substitution is used to yield an estimate of the implicit price. The implicit price provides marginal willingness-to-pay for a discrete change in an attribute level.

1.6 Organisation of the thesis

The following chapter presents an assessment of farmers' awareness of health risks in urban and peri-urban wastewater irrigation is presented[1]. The section presents a discussion of the ordered probit model together with results of the marginal analysis. Chapter three provides an analysis of the factors that determine farmers' choice of low-risk adaptations in untreated wastewater irrigation[2]. A description of the multinomial logit model and results of the marginal estimations are also presented in this chapter. In chapter four, an estimation of the value that urban and peri-urban farmers who practice wastewater irrigation impute to improvements in specific characteristics of the wastewater input in agriculture[3]. In the chapter, a discussion of the choice experiment design together with the conditional logit and random parameter models considered in the study is provided. Results of the model analyses include estimations of implicit prices and also compensation surpluses of distinct scenarios. Finally, chapter five presents a general summary and conclusion of the thesis. In addition, the section derives policy implications which are based on the findings of this study.

[1]Published in the Journal of Natural Resources and Conservation

[2]Published in the African Journal of Agricultural Research

[3]Published in the Journal of Environmental Management

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CHAPTER TWO

FARMERS' AWARENESS OF HEALTH RISKS IN URBAN AND PERI-URBAN WASTEWATER IRRIGATION

ABSTRACT

Most urban and peri-urban farmers in developing countries rely on untreated wastewater for irrigation. The use of poor quality water poses health-related risks to direct and indirect wastewater users. Since the risk-awareness related to wastewater reuse is not well documented in many developing countries, this paper contributes to knowledge by evaluating the factors that determine health-risk awareness among wastewater users in Nairobi, Kenya. The study uses cross-sectional survey data to evaluate the awareness of health-related risks in wastewater irrigation. An ordered probit model was used identify the determinants of farmers' health-risk awareness for indirect and direct wastewater users in urban and peri-urban agriculture. The results show that gender of household head, household size, education level of household head, farm size, ownership of the farm, membership to farmers' group, and market access for the produce were found to significantly ($p < 0.05$) affect awareness of farmers about health risks in wastewater irrigation. There is need for awareness programs to promote public education through regular training and local workshops on wastewater reuse in order to improve the human capital of the urban and peri-urban farmers.

Keywords: Ordered probit model; peri-urban farmers; risk awareness; untreated wastewater; and wastewater irrigation

2.1 Introduction

The significance of urban and peri-urban agriculture for livelihoods of many poor people has received a growing recognition over the last decade. The practice contributes immensely towards food security among the urban poor, mainly in slums. However, the global fresh-water scarcity is estimated to be 60 percent by 2025 due to current demographic trends (Qadir *et al*., 2007). This necessitates the water-scarce countries to rely increasingly on the unconventional resources to meet the growing water demand. Wastewater is an alternative source of water that can be utilized to complement other conventional sources of water. In many developing countries, untreated or partially treated urban wastewater is commonly used for irrigation agriculture. Previous studies show that wastewater resource is increasingly emerging as a viable alternative to conventional water sources in water-scarce countries (Buechler & Devi, 2006; Drechsel *et al*., 2006; Ensink *et al*., 2003; Menegaki *et al.*, 2007; Mojida *et al.*, 2010; Qadir *et al*., 2010; Rutkowski *et al*., 2007; Srinivasan & Reddy, 2009; van der Hoek, 2004). Although the wastewater irrigation is a reliable source of water and crop nutrients, the practice poses various health and environmental hazards (Keraita & Drechsel, 2004; Qadir *et al*., 2010; Rutkowski *et al*. 2007).

Kenya is faced with severe scarcity of freshwater resources, as a result of growing water consumption, heavy pollution of the available water resources, degradation of the environment, extreme exploitation of natural resources, and climate change (NEMA, 2011a; GoK, 2010). Also, rapid urbanization, industrialization and population growth have significantly contributed to the decline of available water resources. Sewage infrastructure in the urban and peri-urban regions of Nairobi, like in most cities in sub-Saharan Africa, is largely inadequate. Wastewater generated in the city is treated in Kariobangi and Dandora sewage treatment plants, which have daily treatment capacities of 32,000 and 80,000 cubic metres respectively (ECFA, 2008). This constitutes less than half of the total amount of wastewater produced in the city per day. Since the untreated wastewater is discharged into the environment, most of the freshwater resources in Nairobi are heavily polluted (Cornish & Kielen, 2004; Dulo, 2008; NEMA, 2011b). Also, the raw municipal and industrial effluents are conveyed into rivers through natural drainage channels thus contributing considerably towards pollution of freshwater sources. Urban and peri-urban farmers in Nairobi use the untreated wastewater for irrigation of vegetable crops. Therefore, Nairobi City offers an important case study to evaluate how urban and peri-urban irrigation agriculture has been practiced to combat food insecurity among the urban poor.

The recognition of wastewater as a sustainable alternative to freshwater for irrigation is generally low among decision-makers in many less developed countries (LCDs) (Hamilton *et al*., 2007; Qadir & Scott, 2010). This may be partly described by lack of adequate and dependable information about wastewater reuse for agriculture in developing countries since the practice is considered obnoxious. In Kenya, the reuse of either treated or untreated wastewater for irrigation agriculture is not recognised by the National Environmental Management Authority (NEMA). This is regardless of the fact that wastewater can greatly contribute in ameliorating the availability of irrigation water for urban farming in the country. Although wastewater reuse in Kenya is illegal, over 50 percent of wastewater generated in Nairobi City is used for crop production without any form of treatment (ADB, 2010; UNEP 2003). It is estimated that about 30 percent of the city dwellers are engaged in urban and peri-urban agriculture (Canada, 2011). This has made it difficult for the decision-makers to control the health and environmental risks attributed to the practice since it is a source of livelihood for thousands of poor urban dwellers. An integrated management approach that would include all stakeholders is likely to help in reduction of health and environmental hazards while sustaining productivity of many crops in many urban areas.

The reuse of untreated and partially treated wastewater for irrigation in Kibera and Maili Saba slums in Nairobi poses serious health risks to farmers and consumers of their produce (Hide *et al*, 2001). Unplanned direct and indirect wastewater reuse makes many poor urban and peri-urban farmers susceptible to enteric diseases and helminth infections due to direct contact with the polluted water. While some wastewater users may be aware of the potential health risks, many others are unable to link their health status to the unregulated irrigation practices. The reuse of untreated wastewater for irrigation agriculture in the context of many farmers in Kibera and Maili Saba slums goes beyond the limited knowledge of the risks. Many small-scale farmers have adopted strategies to enhance livelihoods regardless of the associated health risks due to the growing poverty and food insecurity in the informal settlements (Karanja et al., 2010). According to Jiménez (2006), the reuse of untreated wastewater in many developing countries can be attributed to the influence of socioeconomic factors at household level where there is limited awareness for health risks. Additional drivers of wastewater use in irrigated agriculture are: lack of alternative water sources; limited ability of cities to treat their wastewater; increasing urban demand for fresh vegetables and market incentives supporting production of fresh vegetables in the cities (Raschid-Sally & Jayakody, 2008). Therefore, evaluating the health-risk awareness in a wider socio-economic framework is vital in identification of risk mitigation strategies.

In order for policy makers to support behaviour-change towards safer wastewater irrigation practices in Nairobi, there is need for high level of risk awareness among the urban and peri-urban farmers. This is because awareness of risks can substantially influence how risks are perceived and managed in wastewater irrigation (Peres *et al*., 2006). There have been a several risk assessment studies on wastewater irrigation (e.g. Fattal *et al*., 2004; Malcolm *et al*., 2004; Petterson *et al*., 2001; Hamilton *et al*., 2006). However, there is limited health-related risk awareness literature in wastewater irrigation agriculture (Faruqui *et al*., 2004). An understanding of the farmers' awareness towards health risk is an important determinant in making choices as to which risk-reducing measures to adopt in wastewater irrigation (Tiongco *et al*., 2010). To the authors' knowledge there has not a study on the risk awareness of wastewater reuse among urban and peri-urban farmers. Since there are many poor and small-scale farmers involved in wastewater irrigation, there is need to understand the factors that influence the risk awareness among farmers in Nairobi. This study hypothesises that household and farm characteristics influence farmers' health-risk awareness in wastewater irrigation.

This rest of this paper is organized as follows. The next section describes the materials and methods used in the research. Section 3 presents results and discussions from the econometric model used to identify the determinants of health-risk awareness in wastewater reuse. The conclusion and policy recommendations are presented in section 4.

2.2 Materials and methods

2.2.1 Research area

The study was carried out in the Kibera informal settlement in Nairobi, Kenya. Nairobi, the Capital City of Kenya, has an urban population of about 3.4 million people (Brinkhoff, 2010; KNBS, 2010a). Majority of these people live in densely populated informal settlements such as Kibera, Mathare, Korogocho, Mukuru Kwa Njenga, and Maili Saba Slums. Kibera slum was selected for this study because it is one of the major areas in the city where thousands of poor farmers rely on wastewater for irrigation agriculture. The slum is one of the most populated informal settlements in sub-Saharan Africa with a mean population of about 700,000 people (Umande Trust, 2012). Kibera slum has 11 villages and has a population density of approximately 1,250 persons per hectare. Most of the leafy vegetables produced with the untreated wastewater (about 75 percent) are marketed locally. Also, some of the urban and peri-urban farmers keep livestock for economic purposes.

The slum dwellers in Kibera have encroached on the riparian areas of the river system hence posing serious environmental challenges. In addition, the water quality in Motoine-Ngong River has been extensively degraded by rampant disposal of solid waste, human waste and wastewater from the slum (UN-Habitat, 2009). Poor sanitation in Kibera slum has contributed immensely to a vicious cycle of water pollution, water-borne diseases, poverty, and environmental degradation (Jiménez & Asano, 2008; Raschid-Sally & Jayakody, 2008).

2.2.2 Sampling procedure

This study used the stratified random sampling method to collect survey data from farmers involved in wastewater irrigation in Nairobi City from December 2011 to March 2012. Focus group discussions preceded the formal interviews whereby a group of carefully selected members of the farming community were involved. This provided an opportunity for farmers and interviewers to develop a trustworthy relationship for dialogues about the sensitive topic on wastewater irrigation. The study purposively selected Kibera and maili-Saba slums due to high population of farmers who rely on untreated wastewater either directly or indirectly for irrigation. A representative sample of 325 respondents was randomly selected using a systematic random sampling method. In the systematic sampling procedure, every fourth household involved in urban agriculture in the study area was selected for interview. The sample size was identified using equation 1 (Bartlett *et al*., 2001; Kothari, 2004; Saunders *et al*., 2009):

$$n = \frac{z^2 * p(1-p)}{e^2} \qquad (1)$$

where parameter *n* represents the sample size, *z* is the confidence level at 99% (standard value of 2.576), *p* denotes the estimated extent of wastewater irrigation in this study area (98%), and e refers to the margin of error at 2%.

However, a total of 317 responses were used in the analysis since 8 questionnaires were rejected due to incomplete information. The questionnaires were used to obtain demographic and socioeconomic information of farmers with respect to wastewater reuse in irrigated-agriculture. The study evaluated farmers' awareness of health risks in urban and peri-urban wastewater irrigation in Nairobi City. In order to quantify the awareness for water pollution, a likert scale was applied in this study. The dependent variable was individual's certainty of severe health risks in wastewater irrigation, which was measured in a five point scale (1: strongly disagree … 5: strongly agree). Independent variables in the analysis included both the demographic and socioeconomic characteristics.

2.2.3 Data analysis

2.2.3.1 Econometric model for farmers' awareness

For risk awareness scale, the ordered probit model is taken to be more suitable than unordered multinomial or nested logit or probit models. This is because unordered models do not account for the ordinal nature of risk awareness in wastewater reuse. Ordered probit models yield similar results to ordered logit model (Greene, 2012). In this study, the ordered probit model was used whereby the error term is assumed to be normally distributed as shown in Equation (2):

$$y_i^* = \beta' x_i + \varepsilon_i \tag{2}$$

where $\boldsymbol{y_i^*}$ is a latent measure of health risk awareness of direct and indirect wastewater users; $\boldsymbol{x_i}$ is a vector of factors that influence the users' awareness; $\boldsymbol{\beta^1}$ is a vector of parameters to be estimated; and $\boldsymbol{\varepsilon_i}$ is the error term and is assumed to be standard normal distributed.

Since we cannot observe $\boldsymbol{y_i^*}$, we can only observe the categories of responses as shown in equation (3):

$$y = \begin{cases} 1 \quad if \quad -\infty < y_i^* < \mu_1 & (strongly\ disagree) \\ 2 \quad if \quad \mu_1 < y_i^* < \mu_2 & (disagree) \\ 3 \quad if \quad \mu_2 < y_i^* < \mu_3 & (unsure) \\ 4 \quad if \quad \mu_3 < y_i^* < \mu_4 & (agree) \\ 5 \quad if \quad \mu_4 < y_i^* < \infty & (strongly\ agree) \end{cases} \tag{3}$$

The maximum likelihood technique that provides consistent and asymptotic estimators can be used to jointly estimate the vector of parameters $\boldsymbol{\beta}$ and thresholds $\boldsymbol{\mu}$. The thresholds $\boldsymbol{\mu}$ indicate an array of the normal distribution related to definite values of the explanatory variables. Parameters $\boldsymbol{\beta}$ denote the influence of variation in response variables on the principal scale. The positive sign of parameter $\boldsymbol{\beta}$ implies greater health threats associated with wastewater irrigation as the value of related variable increases.

To address the multicollinearity limitation, the explanatory variables were eliminated based on Variance Inflation Factors (VIFs). The VIFs were calculated by running "artificial" ordinary least squares (OLS) regressions between each explanatory variable as a "dependent" variable and the other explanatory variables. Independent variables for which $VIF_i > 5$ shows strong proof that the estimation of the factors is being influenced by multicollinearity (Maddala, 2000).

The probabilities of ordered probit model estimated in this study are shown in equation (4):

$$\begin{aligned}
\Pr(y_i = 1 \mid x) &= 1 - \Phi[\beta' x_i - \mu_1] \\
\Pr(y_i = 2 \mid x) &= \Phi[\beta' x_i - \mu_1] - \Phi[\beta' x_i - \mu_2] \\
\Pr(y_i = 3 \mid x) &= \Phi[\beta' x_i - \mu_2] - \Phi[\beta' x_i - \mu_3] \\
\Pr(y_i = 4 \mid x) &= \Phi[\beta' x_i - \mu_3] - \Phi[\beta' x_i - \mu_4] \\
\Pr(y_i = 5 \mid x) &= \Phi[\beta' x_i - \mu_4]
\end{aligned} \tag{4}$$

The marginal effects of changes in response variables were obtained once coefficients of the ordered probit model are estimated as shown in equation 5:

$$\begin{aligned}
\frac{\partial \Pr(y = 1 \mid x)}{\partial x} &= -\Phi(\beta' x_i - \mu_1)\beta \\
\frac{\partial \Pr(y = 2 \mid x)}{\partial x} &= [\Phi(\beta' x_i - \mu_1) - \Phi(\beta' x_i - \mu_2)]\beta \\
\frac{\partial \Pr(y = 3 \mid x)}{\partial x} &= [\Phi(\beta' x_i - \mu_2) - \Phi(\beta' x_i - \mu_3)]\beta \\
\frac{\partial \Pr(y = 4 \mid x)}{\partial x} &= [\Phi(\beta' x_i - \mu_3) - \Phi(\beta' x_i - \mu_4)]\beta \\
\frac{\partial \Pr(y = 5 \mid x)}{\partial x} &= \Phi(\beta' x_i - \mu_4)\beta
\end{aligned} \tag{5}$$

where Φ is the cumulative density function (CDF) of a standard normal random variable.

2.3 Results and discussions

2.3.1 Socioeconomic characteristics of farmers

Table 1 provides a summary of the socioeconomic characteristics of the wastewater users in the Motoine-Ngong River basin. Farmers who practice wastewater irrigation have a mean age of 40.22 years. This implies that the urban and peri-urban wastewater users are middle-aged. Also, the results of this study show that about 79 percent of the urban and peri-urban farmers in the study area are male. This may be attributed to intensive labour requirements in wastewater irrigation. The households of farmers who practice wastewater irrigation have an average size is of 4.61. This compares to the national average, which is 4.1 persons per household (KNBS, 2010b) and also the average size in Kibera slum, which is currently estimated at 5.0 persons per household (Umande Trust, 2012). The interviewed household heads in this study have 7.94 years of formal education. This shows that most of the urban and peri-urban farmers are literate and hence able to read and understand information materials on crop husbandry.

According to the summary results, only 29 percent of the interviewed farmers have some non-farm sources of income. This implies that majority of urban and peri-urban farmers in the study area are dependent on wastewater irrigation for their livelihoods. The results show that about 63 percent of the interviewed farmers reside in Kibera informal settlement. This may be explained by the fact that the slum is close to Motoine-Ngong River is a major source of irrigation water. Many farmers in the study area practice wastewater irrigation on plots of approximately 0.38 acres. These small plots are mostly utilized for vegetable production whereby farmers grow different varieties of crops for domestic consumption and also sale in the local market. Also, the households consume these vegetables surplus produce is sold in the local market. The farmers who had ownership of the farming plots in the sample surveyed are only 17 percent. Therefore, many farmers in Nairobi City rely on public land for urban and peri-urban agriculture. The study results show that 39 percent of the sample of farmers surveyed has membership in farmers groups. These farmers are thus able to access information about wastewater irrigation from their fellow farmers.

The results show that there are about 25 percent of farmers who own livestock in the study area. This implies that urban and peri-urban agriculture is not restricted to crop production in Nairobi City. About 13 percent of the interviewed farmers have no access to credit for investment in urban and peri-urban agriculture. Therefore, most farmers rely on their farm income for investment capital in wastewater irrigation. Also, the results show that only 88 percent of urban and peri-urban farmers have access to market for their produce. This implies that they are able to sell their produce in the existing markets due to high demand for leafy vegetables. However, this has health hazards since most of the crop production depends on polluted water (Karanja *et al*., 2010).

Table 1: Socioeconomic characteristics of farmers using wastewater for irrigation

Variable	Variable Description	Mean	SD
Dependent variable			
AWAREDIR	Awareness of direct wastewater users on health risks of wastewater irrigation	4.07	1.59
AWAREIND	Awareness of indirect wastewater users on health risks of wastewater irrigation	4.14	1.54
Independent variables			
AGE	Age of farmer (years)	40.22	11.22
GENDER	1 if male, 0 otherwise	0.79	0.41
HHSIZE	Household size	4.61	1.74
EDUCLEV	Education level (years)	7.94	2.60
EMPLOYED	I if the farmer is employed, 0 otherwise	0.29	0.50
KIBERA	1 if the farmer is from Kibera slum, 0 otherwise	0.63	0.50
FARMSIZE	Farm size (acres)	0.38	0.28
LANDOWN	1 if farmer grows vegetables in public land, 0 otherwise	0.17	0.38
GROUPM	1 if farmer is a member of a farmers' group, 0 otherwise	0.39	0.48
LVKOWN	1 if the farmers also rears livestock, 0 otherwise	0.25	0.50
CREDACC	1 if the farmer has access to credit, 0 otherwise	0.13	0.21
MKTACC	1 if farmer has access to market, 0 otherwise	0.88	0.38

2.3.2 Incidences of infections related to wastewater irrigation

In this study, the wastewater users were requested to self-report on the incidences of wastewater related enteric infections in their families within a month before the survey. This was mainly because farmers who use untreated of partially treated wastewater for irrigation agriculture are exposed to various types of diseases (Carr *et al*., 2004; Drechsel *et al*., 2010; Scott *et al*., 2004). The infections reported by direct and indirect wastewater users are: diarrhoea, stomach-ache, intestinal worms and skin infections (Table 2). In the sample of farmers surveyed, there were 20.82 percent of direct wastewater users and 25.55 percent of indirect wastewater users who reported diarrhoeal infections on at least one household member within a month prior to the survey. The diarrhoeal infections may be as a result of exposure to pathogenic micro-organisms from the wastewater through direct consumption of foods produced with polluted water (Scott *et al.*, 2004).

There were about 14.51 percent of direct wastewater users and 16.40 percent of indirect wastewater users that reported that at least one member of their households suffered severe stomach-ache within a month prior to the day the questionnaire was administered. These infections can be liked to unsafe reuse of wastewater for irrigation agriculture (Blumenthal and Peasey, 2002). The study reported that 22.40 percent direct wastewater users and 21.77 percent indirect wastewater users had one or more of their household members infected with intestinal worm a month prior to the survey. The exposure to wastewater and polluted soils may contribute to worm infections among farm workers (Ensink, 2006; Nabulo, 2006; Rutkowski *et al*., 2007; Trang *et al*., 2007; van der Hoek *et al*., 2005). Also, 26.81 percent of direct wastewater users and 23.66 percent of indirect wastewater users reported skin infections, such as itching and blistering on the hands and feet, on at least one household member a month prior to the survey. This may be attributed to lack of adequate protection from exposure to polluted water during irrigation (Keraita *et al*., 2008). However, it may be difficult to attribute these infections to wastewater irrigation alone since many other sanitation factors are likely to cause enteric diseases.

Table 2: Reported wastewater related infections in the farmers' households

Infection	Direct wastewater users (*n=150*)		Indirect wastewater users (*n=167*)	
	Frequency	Percentage	Frequency	Percentage
No infection	49	15.46	40	12.62
Diarrhoeal infection	66	20.82	81	25.55
Stomach-ache	46	14.51	52	16.40
Intestinal worms infection	71	22.40	69	21.77
Skin infections	85	26.81	75	23.66

2.3.3 Empirical results

Table 3 provides the empirical computations of farmers' awareness of health risks in both direct and indirect wastewater irrigation obtained using the ordered probit model, which was based on maximum likelihood method. Also, the results present McFadden R^2, standard errors, t-values, and log-likelihood statistics. Once the model was estimated, the marginal effects showing the likelihood of direct and indirect wastewater users to "strongly believe" that wastewater reuse has health risks were calculated.

Table 3: Factors that influence farmers' awareness of health risks in wastewater reuse

	Direct users			Indirect users		
Variables	Coefficient	Std. Error	t-Test	Coefficient	Std. Error	t-Test
AGE	0.024	0.017	1.41	0.024	0.017	1.44
GENDER	1.121***	0.353	3.17	1.217***	0.335	3.64
HHSIZE	0.380***	0.141	2.69	0.410***	0.134	3.07
EDUCLEV	0.356***	0.091	3.93	0.367***	0.086	4.26
EMPLOYED	0.492	0.335	1.47	0.450	0.326	1.38
KIBERA	0.602	0.490	1.23	0.320	0.452	0.71
FARMSIZE	1.333***	0.412	3.24	1.372***	0.463	2.96
LANDOWN	1.212***	0.448	2.71	1.048**	0.430	2.44
GROUPM	1.047***	0.390	2.68	0.907**	0.378	2.40
LVSKOWN	0.751	0.481	1.56	0.470	0.433	1.09
MKTACC	1.420***	0.469	3.03	1.478***	0.473	3.13
Pseudo-R^2	0.3701			0.3856		
Log-likelihood	-154.3587			-162.7762		
Observations	150			167		

Note: * Significant at 10%, ** Significant at 5%, *** Significant at 1%

Table 4 presents the marginal effects of farmers' awareness of health risks in wastewater irrigation. The marginal effects results show that gender of household head, household size, education level of household head, farm size, ownership of the farm, membership to farmers' group, and market access significantly ($p < 0.05$) affect health-risk awareness of the direct and indirect wastewater users.

According to the results, male farmers involved in direct wastewater irrigation are 28.9 percent more likely to report high awareness of health risks than female counterparts. Also, male farmers who practice indirect wastewater irrigation are 30.7 percent more likely to report high awareness of health risks compared to female farmers. This difference in the health-risk awareness between the direct and indirect wastewater users stems from the fact that direct users are more aware of the potential health risks from using the polluted water sources compared to the indirect users (van der Hoek, 2004). The high risk-awareness among the male farmers can be attributed to their dominance in arduous wastewater irrigation tasks that necessitate extensive contact periods for the direct and indirect users (Knudsen *et al*., 2008; Bayrau *et al*., 2009; Obuobie *et al*., 2006).

The results of this study show that an increase in household size among the direct wastewater users raises the chance of farmers' reporting high awareness of health risks by 10.2 percent. Also, the indirect wastewater users are 17.3 percent more likely to report high awareness of health risks if there is an increase in household size. In the direct wastewater reuse, farmers are more aware of the health risks involved since raw wastewater from sewerage outlets is used for vegetable production (van der Hoek, 2004). Since urban and peri-urban wastewater irrigation is a labour intensive practice, large household size may be a source of manual labour for the direct and indirect wastewater irrigation (Abdulai *et al*., 2011). Therefore, this increases the intensity and duration of exposure for many household members to wastewater (Blumenthal & Peasey, 2002; WHO, 2006).

Each year of education increases the chance of reporting high awareness about health risk among direct wastewater users by 9.5 percent. Also, the results show that each additional year of education among indirect wastewater users increases the chance of reporting high risk awareness among the farmers by 16.5 percent. Thus, education has greater impact on risk-awareness among the indirect wastewater users than the direct wastewater users. This is because increased education helps the indirect wastewater users to be more enlightened and knowledgeable on the health risks of using diluted wastewater. Urban and peri-urban farmers with high education level are more aware of the causes of health problems and health-risk factors in wastewater irrigation compared to those with low education (Robinson *et al*., 2005).

According to the results of this study, the direct wastewater users are 27 percent likely to report high awareness of health risks when the farm size increases. Similarly, for each increase in farm size the chance of reporting high risk awareness among indirect wastewater users increases by 47 percent. The increase in farm size translates to improved wealth since possession of land is considered a measure of wealth for the farmers. Thus, an increase in farm size can be directly associated with growth in revenue, which might lead to better health-risk awareness in wastewater irrigation (Carr *et al*., 2004).

The direct wastewater users who produce crops in private land are 15.9 percent more likely to report high awareness of health risks in wastewater irrigation than the farmers using public land. This shows that farmers consistently underrate the severity of specific health-risks in wastewater irrigation when using public land. Also, farmers who use private land for indirect wastewater irrigation are 25.7 percent more likely to report high awareness of health risks than the farmers who utilize public land. Many urban and peri-urban farmers using public land for wastewater irrigation are more concerned about the economic risks than the health risks. The security of tenure can lead wastewater users to invest in development of their farms and also become more awareness of health risks due to water pollution (Marenya & Barrett, 2007; Drechsel *et al*., 2005).

Direct wastewater users who have membership in farmers' groups are 12.3 percent more likely to report high risk awareness than non-members. Likewise, the indirect wastewater users who are members of farmers' groups are 20.8 percent more likely to report high awareness of health risks than the farmers who have no membership in farmers' groups. This is because the direct and indirect wastewater users can obtain information that is transmitted through farmer-based organizations thus influencing their risk-awareness (Bouma *et al*., 2008). Although health-risk awareness of wastewater users can be based on practical experience, incorporating innovative concepts and information from other farmers greatly improves knowledge base. Lack of information exchange has been linked to low health-risk awareness among the direct and indirect wastewater users (Peres *et al*., 2006).

The direct wastewater users who have market access are 23.2 percent more likely to report high health-risk awareness than the ones who do not have market access. Also, the indirect wastewater users are 30.4 percent more likely to report high health-risk awareness compared to the farmers who have no market access. These results show that market access can play a significant role in facilitating awareness about health risks for urban and peri-urban farmers (Biran & Hagard, 2003; Cornish & Lawrence, 2001). Therefore, access to market for fresh vegetables by wastewater users expose them to market pressure, which includes demand for cleaner vegetables hence raising their health-risk awareness.

Table 4: Marginal effects of farmers' awareness of health risks in wastewater irrigation

	Direct Users			Indirect Users		
Variables	Coefficient	Std. Error	t-Test	Coefficient	Std. Error	t-Test
AGE	0.006	0.005	1.33	0.004	0.003	1.28
GENDER	0.289***	0.103	2.82	0.307***	0.114	2.69
HHSIZE	0.102***	0.035	2.87	0.173***	0.036	4.81
EDUCLEV	0.095***	0.034	2.79	0.165***	0.028	5.84
EMPLOYED	0.120	0.081	1.48	0.074	0.056	1.30
KIBERA	0.139	0.090	1.54	0.052	0.067	0.78
FARMSIZE	0.270***	0.069	3.94	0.470***	0.127	3.71
LANDOWN	0.159**	0.069	2.31	0.257***	0.084	3.06
GROUPM	0.123**	0.059	2.10	0.208***	0.077	2.70
LVSKOWN	0.075	0.062	1.21	0.139	0.087	1.59
MKTACC	0.232***	0.071	3.26	0.304***	0.104	2.91

Note: * Significant at 10%, ** Significant at 5%, *** Significant at 1%

2.4 Conclusion and policy recommendations

This study examined farmers' health-risk awareness on wastewater reuse for irrigation. The household survey data employed was collected in 2011 on 317 vegetable farmers in urban and peri-urban Nairobi of Kenya. Socioeconomic characteristics that influence farmers' awareness on health risks of wastewater irrigation were analysed with the ordered probit model. The understanding of farmers' risk-awareness on wastewater irrigation is critical for the promotion of safer urban and peri-urban agriculture. Also, adequate understanding of risk-awareness of wastewater users is crucial for recommending policies for improving livelihoods of many poor urban farmers in Kenya. The key sources of water for irrigation agriculture in Nairobi City are: streams, rivers and shallow wells. However, these water sources have been polluted by industrial and domestic waste due to poor sanitation infrastructure in the informal settlements. Many urban and peri-urban farmers have resorted to direct and indirect reuse of untreated wastewater for irrigation due to absence of fresh water.

Empirical analysis from the ordered probit model shows that gender of household head, household size, education level of household head, farm size, ownership of the farm, membership to farmers' group, and market access may influence farmers' awareness of health risks in wastewater irrigation. This explains that socioeconomic factors have a significant positive influence on awareness on health risks in direct and indirect wastewater irrigation. Also, according to the results of this study, wastewater-related health risks are a major concern to urban and peri-urban farmers. There is need for sound policy initiatives to guarantee minimum health risks in urban wastewater irrigation due to the rising demand for fresh vegetables by the rapidly growing population in Nairobi City.

Therefore, efforts towards improving awareness about health risks among the direct and indirect wastewater users can promote safer production practices. This can be achieved through well-designed awareness programs aimed at realizing significant impact on safeguarding public health where sanitation infrastructure is poor. The awareness programs should promote public education through regular training and local workshops on wastewater reuse in order to improve the human capital of the urban and peri-urban farmers. Also, the wastewater users should be encouraged to join farmers' groups in in order to access information through farmer-to-farmer extension services. Further policy interventions toward risk reduction can include participation of allied government institutions and local media in promoting market access for farmers involved in direct and indirect wastewater irrigation.

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CHAPTER THREE

DETERMINANTS OF FARMERS' CHOICE OF LOW-RISK MEASURES IN WASTEWATER IRRIGATED AGRICULTURE

ABSTRACT

The study aimed at identifying the most preferred risk-reduction techniques in wastewater irrigation and the factors influencing the choice of these techniques. This was based on a study of small-scale farmers using wastewater for crop production in Nairobi County. A simple random sampling method was used to select a sample of 317 farmers from which semi-structured questionnaires were used to collect primary data. The data analysis was for descriptive statistics and a multinomial logit model. The results indicated that household size, age of the household head, education of household head, access to extension, access to media, access to credit, farmers' group membership, and risk awareness significantly influence the choice of different risk-reduction techniques. The study recommends that policies in support of low-risk wastewater irrigation should disaggregate farmers according to their institutional and socio-economic characteristics in order to achieve the intended objectives.

Keywords: Low-risk measures, marginal effects, multinomial logit, urban farmers, wastewater irrigation

3.1 Introduction

Studies show that about 20 million hectares of land in developing countries is irrigated with wastewater and at least 10% of the world's population consumes foods produced by irrigation with wastewater (Hamilton *et al*., 2007; Jiménez and Asano, 2008; Scott, Faruqui & Raschid-Sally, 2004; WHO, 2006). However, many developing countries are confronted with apparent limitations in implementing conventional wastewater treatment systems .This has exposed many poor urban and peri-urban farmers in developing countries to health risks due to exposure to polluted wastewater. Therefore, the utilization of risk-reduction options is a low-cost critical risk-reduction measure in wastewater-irrigated agriculture (Keraita *et al*., 2008). Non-conventional methods commonly used in control of health risks include: crops restriction, safer application techniques, and cessation of irrigation before harvesting (Drechsel *et al*., 2008; Keraita *et al*., 2007).

Agriculture is the mainstay of Kenyan economy and growth of the sector is vital for the overall social and economic development of the country. The sector contributes 24 percent directly and 27 percent indirectly to the national GDP (AEO, 2012; GOK, 2009). Millions of rural and urban farmers in the country rely on the agriculture sector for their livelihoods. The urban and peri-urban farming sub-sector is a source of food security, employment creation, and poverty alleviation to the urban population in Kenya (Addo, 2010; GOK, 2010a). However, the agriculture sector is challenged by water-scarcity, which is currently 548 cubic metres per capita per year (NCAPD, 2010; NEMA, 2011). This is much lower than the Falkenmark water stress index (FWSI) that sets the threshold of severe water deficit at 1000 cubic metres per capita per year (Falkenmark *et al*., 1989). Projections indicate that water endowment in the country will shrink to 250 cubic metres per capita per year by 2025, which is much lower than the bordering countries (GoK, 2010b; NEMA, 2003; World Bank, 2010). The scarcity of freshwater resources has led many urban and peri-urban farmers to rely on untreated or partially treated wastewater for irrigation agriculture. Consequently, knowledge of the low-risk interventions and factors affecting farmers' choice of the risk-reduction interventions is important for informing policy in order to reduce risks facing many urban farmers in Nairobi.

Studies show that wastewater is increasingly being embraced as a feasible substitute to freshwater sources for irrigation, especially as the water scarcity increases and more reliable and economic technologies are developed to treat urban wastewater (Buechler & Devi, 2006; Drechsel *et al*., 2006; Ensink *et al*., 2003; Qadir *et al*., 2010; Rutkowski *et al*., 2007; Srinivasan & Reddy, 2009; van der Hoek, 2004). Since many studies on wastewater reuse concentrate on quality analysis and risk-reduction measures in irrigated agriculture, there is still a knowledge gap on the factors affecting the choice of the suggested low-risk intervention. This poses a serious challenge since farmers' response to wastewater-related health risks and also their choice of risk-reduction interventions is influenced by various socio-economic and institutional factors. The knowledge about these factors can support policy intervention measures aimed at minimizing the risks to public health and environment.

This paper analyses the factors affecting the choice of risk-reduction interventions to reduce the health risks attributed to wastewater-irrigation in peri urban and urban Nairobi. The case study was conducted in Kibera informal settlements, which is the largest slum in sub-Saharan Africa but lacks sewerage infrastructure. Most of the raw sewage from this informal settlement is discharged into Motoine-Ngong River without treatment hence threatening the livelihoods of many urban and peri-urban farmers in Nairobi. The case study includes urban and peri-urban farmers in the Motoine-Ngong River basin to guide policy-makers on the approach to promote utilization of low-risk methods in wastewater irrigation. The rest of this paper is structured as follows. Section 2 provides the econometric model used in this study. The case study area, survey data and the empirical analysis are provided in Section 3. The model results and conclusions are described in Sections 4 and 5 respectively.

3.2 Econometric model

This study employed a multinomial logit model to estimate the significance of the factors that are assumed to influence the farmers' choice of risk-reduction measures in wastewater irrigation in Nairobi. The choice of this model was because it allows the analysis of decisions across more than two categories in the dependent variable unlike the binary models (Maddala, 1983; McFadden, 1974). In the model, a set of mutually exclusive and greatly differentiated risk-reduction choices in wastewater reuse were examined.

The random utility model may be used to motivate this unordered-choice model such that, for the *ith* farmer that is faced with *J* choices of risk-reduction options, the utility of choice *j* is:

$$U_{ij} = \beta_{ij} X_{ij} + \varepsilon_{ij} \qquad (1)$$

Therefore, when the farmer makes choice *j* of risk-reduction intervention, it is usually assumed that U_{ij} is the highest utility among the *J* utilities (McFadden, 1974). Multinomial logit model was chosen for this study instead of its counterpart, the multinomial probit model, due to the ease in computing the multivariate normal probabilities for any dimensionality higher than 2 (Greene, 2011). The multinomial logit model was based on the probability that a risk-reduction choice *j* is made as follows:

$$\Pr(U_{ij} > U_{in}) = \quad \textit{for all other } n \neq j \qquad (2)$$

The multinomial logit model (Greene, 2012) specification is:

$$\Pr ob(y_i = j/x_i) = P_{ij} = \frac{\exp(\beta_j' x_i)}{1 + \sum_{k=1}^{J} \exp(\beta_k' x_i)}, \quad \textit{Where } j = 0,1,2,\ldots,J;\ \beta = 0 \qquad (3)$$

The parameter y_i represents the alternative risk-reduction measures in wastewater irrigation, x_i denotes a vector of all the explanatory variables of the *ith* observations, and β_j is a vector of all coefficients in the *jth* regression.

The independence of irrelevant alternatives (IIA) assumption was considered in order for the multinomial logit model estimates to be consistent (McFadden, 1974). This assumption ensures that, even if the number of choice alternatives is increased the odds of choosing an alternative risk-reduction intervention would remain unaffected. Therefore, the probability of choosing the risk-reduction measure remains the same regardless of whether it is compared to one alternative many. In order to address the multicollinearity limitation, explanatory variables were eliminated based on Variance Inflation Factors (VIFs). The VIFs were calculated by running “artificial” ordinary least squares (OLS) regressions between each explanatory variable as a “dependent” variable and the other explanatory variables. In this study, the explanatory variables for which $VIF_i > 0.5$ shows strong proof that the estimation of the factors is being influenced by multicollinearity (Maddala, 2000).

The depended variable used in the multinomial logit model for this study is the risk-reduction measure (irrigation cessation before harvesting, restriction of crops grown using wastewater, or safe wastewater application procedures) with no intervention as the reference choice. Estimated coefficients quantify the variation in the logit for one-unit change in the explanatory variable while the other independent variables are held constant. When the estimated coefficient is positive, this implies an increase in the likelihood that a farmer will select the alternative risk-reduction measure in wastewater irrigation. In contrast, if the estimated coefficient is negative it implies that there is less likelihood that a farmer will change to alternative risk-reduction intervention. Since the parameter estimates of the multinomial logit model only provide the direction of the effect of the explanatory variables on the dependent variable, they are more difficult to interpret (Greene, 2012). Therefore, marginal effects are used to evaluate the expected variation in probability of a particular intervention being selected with respect to a unit change in an explanatory variable from the mean.

In order to obtain the marginal effects, equation (3) is differentiated with respect to the independent variables as shown in equation (4):

$$\delta_j = \frac{\partial \Pr(y_i = j)}{\partial x_i} = \Pr(y_i = j)\left[\beta_k' - \sum_{k=1}^{J} \Pr(y_i = j)\beta_j'\right] = \Pr(y_i = j)(\beta_k' - \bar{\beta}) \quad (4)$$

3.3 Research methodology

The location of the study is in the Motoine-Ngong River basin of Nairobi in Kenya. The total area of the river basin from the source to the confluence with Nairobi River is approximately 127 km^2. Motoine-Ngong River passes through the sprawling Kibera slum, which has an average population density of 6000 persons per hectare. Due to poor environmental sanitation and lack of sewerage infrastructure in Kibera slum, the informal settlement is a major contributor to pollution of the Motoine-Ngong River (UNEP, 2003). It is estimated that about 280 tonnes of municipal solid waste is generated in the slum per day. Also, the Biochemical Oxygen Demand (BOD_5) from solid waste in Kibera slum is approximately 6,650 kilograms per day. The generated urban waste, which includes human waste dumped into channels, drains into the river. Many urban and peri-urban farmers rely on the untreated wastewater either directly or indirectly for irrigation agriculture.

This study was based on a cross-sectional household survey data collected from urban and peri-urban farmers using wastewater for irrigation agriculture in the Motoine-Ngong River basin. A structured questionnaire was administered to urban and peri-urban farmers between December 2011 and February 2012. The study purposively selected Kibera slum due to high population of farmers who rely on untreated wastewater directly for irrigation. A representative sample of 325 respondents was randomly selected using a systematic random sampling method. In the systematic sampling procedure, every fourth household involved in urban agriculture in the study area was selected for interview. The sample size was identified using equation 5 (Bartlett *et al*., 2001; Kothari, 2004; Saunders *et al*., 2009):

$$n = \frac{z^2 * p(1-p)}{e^2} \qquad (5)$$

where parameter *n* represents the sample size, *z* is the confidence level at 99% (standard value of 2.576), *p* denotes the estimated extent of wastewater irrigation in this study area (98%), and e refers to the margin of error at 2%.

Since 8 questionnaires were rejected due to incomplete information, a total of 317 responses were used in the analysis. In order to analyse the determinants of farmers' choice of risk-reduction interventions to wastewater-irrigated agriculture, the dependent variables are crops restriction, safer application techniques and irrigation cessation. The considered independent variables are: household size, age of the household head, education level of household head, extension on crop and livestock, access to media, access to credit, membership to farmers group, and awareness to wastewater hazards. These variables were selected based on literature and availability of survey data. In order to be interviewed in this study, the respondent had to be either a household head or the spouse. The foremost question of the survey required the respondent to specify the risk-reduction measure the household utilized in irrigation with the polluted water.

3.4 Results and discussion

3.4.1 Descriptive statistics

A summary of the socio-economic and institutional characteristics is presented in Table 1. The descriptive results show that households have an average size of 4.61 members in Kibera slum, which compares well with the current mean household size estimation of 5.0 persons per household in the slum (Umande Trust, 2012). This study hypothesizes that increased household size has a positive relationship with the adoption of risk-reduction measures in wastewater irrigation since large families may promote labour-intensive irrigation activities to increase farm income. The summary results show that household heads have an average age of 40.22 years. Since the age of household head may be related to farming experience, its relationship with adoption behaviour may be positive or negative.

The education of household head in the study area was 7.94 years. This study hypothesizes that increase in education of the household head is positively related to adoption of risk-reduction intervention in wastewater reuse for agriculture. This is because more years of education may be linked to an increased access to information and hence technology adoption. Access to agricultural extension services is 26.5 percent for the sample of selected farmers. This study hypothesizes that increased extension contact is positively related to adoption of low-risk irrigation techniques in wastewater reuse due to the transfer of information. About 39.4 percent of urban and peri-urban farmers have membership in farmers' groups. These farmers' groups provide an important platform for exchange of important information for urban and peri-urban agriculture. Therefore, this study hypothesizes that increased membership in farmers' groups is positively related to adoption of risk-reduction intervention in wastewater irrigation.

Results show that access to media in the sample studied was 44.8%. Media may serve as reliable source of information about the methods to minimize infections among communities in polluted environment. This study hypothesizes that increased media access has a positive impact on adoption of low-risk measures in wastewater irrigation among the urban and peri-urban farmers. The descriptive results show that 35.3 percent of farmers have access to credit facilities. In this study it is hypothesized that increase access to credit is positively related to adoption of risk-reduction techniques in wastewater reuse for agriculture. The increased access to credit facilities may enable farmers to acquire efficient risk-reduction technologies and also purchase farm inputs and hence increase farm productivity. Therefore, increased access to credit facilities has a positive relationship with the adoption behaviour of farmers (Buah *et al*., 2011; Pattanayak *et al*., 2003). Also, awareness to wastewater hazards was 52.7 percent in the study sample. This study hypothesizes that increased awareness to wastewater hazards is positively related to adoption behaviour.

Table 1: Description of explanatory variables

Independent Variable	Mean	S.D.	Description
Household size	4.612	1.744	Continuous
Age of the household head (years)	40.215	11.223	Continuous
Education level of household head (years)	7.935	2.601	Continuous
		Percentage	
Access to extension services		26.5	Dummy, 1 if contacted and 0 otherwise
Access to credit media		44.8	Dummy, 1 if has access and 0 otherwise
Access to credit facilities		35.3	Dummy, 1 if has access and 0 otherwise
Membership to farmers group		39.4	Dummy, 1 if a member and 0 otherwise
Awareness to wastewater hazards		52.7	Dummy, 1 if aware and 0 otherwise

Note: S.D. is standard deviation

The strategies adopted by urban and peri-urban farmers in order to reduce health risks in wastewater irrigation are presented in Table 2. About 49.8 percent of the interviewed farmers have not adopted any risk-reduction measures in wastewater-irrigated agriculture. However, they are actively involved in urban crop production by utilizing wastewater either directly or indirectly. The urban and peri-urban farmers who practice crop restrictions to reduce wastewater-related risks were approximately 21.1 percent. This involves the cultivation of varieties of crops that have lower health risk when grown with untreated or partially treated wastewater.

There are on average 21.4 percent of the farmers in this study sample who have adopted safer collection and application techniques in wastewater irrigation. This risk-reduction strategy ensures a reduction in splashing of wastewater during irrigation and also diminishes the uptake of helminth eggs from sediments. About 7.6 percent of farmers in the study area cease to irrigate their crops some days before harvesting in order to reduce the health hazard of wastewater reuse in agriculture. The irrigation cessation strategy involves imposing a minimum period of no irrigation immediately prior to harvest in order to promote pathogen die-off. These risk-reduction measures employed by wastewater users in Nairobi are similar to others practiced by many small-scale farmers in developing countries (Keraita *et al*., 2007; Keraita, 2008; Keraita *et al*., 2008; Knudsen *et al*., 2008; Marenya & Barrett, 2007; AEO *et al*., 2012; Weldesilassie *et al*., 2011).

Table 2: Farmers' choice of adaptation measures in wastewater irrigation

Variable	Percent of respondents
No intervention	49.8
Safer application	21.4
Crops restriction	21.1
Irrigation cessation	7.6
Total number of respondents	317

3.4.2 Multinomial Logistic Regression Results

The regression results support most hypotheses on relationships between the explanatory variables and three risk-reduction measures in wastewater irrigation. Model fit likelihood ratio test produced significant ($p < 0.001$) chi-square statistics, which indicates that the model effectively fits the data. The pseudo R-Square measure, which is analogous R-Squared in multiple linear regression (Tabachnick & Fidell, 2007), is 0.365, showing that the model explains 37% of the variance in the dependent variables.

The results of multinomial logit model estimated for this study are presented in Table 3. In this model, the base category was no intervention variable while the other dependent variables included the following low-risk irrigation methods: crop restrictions, safer application and irrigation cessation. A restriction of crops grown using wastewater can be used as a risk-management approach in which the grown crops that carefully selected (WHO, 2006). This is because the crops whose edible parts are more exposed, low-growing leafy vegetables or root crops are much susceptible to contamination from pathogens in the wastewater than others. The safer application techniques are localised procedures (e.g. surface and subsurface drip irrigation) that are meant to lower the crop contamination through minimization of contact between polluted irrigation water and the edible parts of the crop (Pescod, 1992; Solomon *et al*., 2002; WHO, 2006). Irrigation cessation is a non-treatment method whereby farmers cease to irrigate their crops some days before harvesting in order to reduce pathogens on the crops (Keraita *et al*., 2008).

Under the independence of irrelevant alternatives (IIA) assumption, it is expected that there would not be any systematic change in the coefficients if one of the outcomes from the model is excluded. This study used the Hausman test (Hausman & McFadden, 1984) to confirm the IIA assumption in the model. The Hausman test failed to reject the null hypothesis on the IIA assumption at 95 percent confident level. This suggests that the multinomial logit model is appropriate to identify the determinants of farmers' choice of risk-reduction interventions to wastewater-irrigated agriculture in Nairobi. The likelihood ratio statistics for this study were statistically significant ($\chi^2 = 430.26; p = 0.000$), which implies that the model has a robust explanatory ability.

Multinomial logit model estimation coefficients provide only the direction of the impacts of explanatory variables on response variable. Although the coefficients' signs are important in interpretation of adoption likelihoods, marginal effects have additional implication regarding the probability of making a choice. Marginal effects in multinomial logit models integrate sub-vectors of the estimated coefficients in each marginal effect (Greene, 2012). This comprises the effects of adopting or not adopting other risk-reduction measures. Therefore, marginal effects provide the expected change in probability of a particular risk-reduction intervention selected by farmers with respect to a unit change in explanatory variable. The marginal effects of the multinomial logit model in this study are presented in Table 4.

Table 3: Parameter estimates of the multinomial logistic low-risk wastewater irrigation model

Explanatory variable	**Irrigation cessation**			**Crop restriction**			**Safe application**		
	Coeff.	Std. error	Odds ratio	Coeff.	Std. error	Odds ratio	Coeff.	Std. error	Odds ratio
Constant	-1.237***	0.360	-	-0.064***	0.021	-	-1.873***	0.539	-
Household size	0.618***	0.229	1.855	0.622***	0.191	1.863	0.733***	0.196	2.081
Age of the household head	-0.162***	0.047	0.850	-0.126***	0.042	0.882	-0.125***	0.042	0.883
Education of household head	0.668***	0.252	1.950	0.513**	0.208	1.670	0.569***	0.214	1.767
Access to extension	0.940***	0.280	2.560	0.274	0.212	1.315	0.156**	0.064	1.169
Access to media	0.427***	0.112	1.533	0.859***	0.239	2.361	0.535***	0.139	1.708
Access to credit	0.458***	0.111	1.581	0.582***	0.153	1.790	0.886***	0.219	2.425
Farmers’ group membership	0.993***	0.259	2.699	0.361***	0.094	1.435	0.078***	0.022	1.081
Risk awareness	0.233***	0.069	1.262	0.760***	0.215	2.138	0.802***	0.226	2.230
Model diagnostics									
Base category	No intervention								
LR chi-square	430.26***								
Log likelihood	-165.549								
Pseudo - R^2	0.365								
Number of observations	317								

Note: ***, **, * denotes significance at 1%, 5% and 10% level respectively.

Marginal effects in Table 4 show that household size, age of the household head, education of household head, access to extension, access to media, access to credit, farmers' group membership, and risk awareness are statistically significant ($p < 0.005$) determinants in adoption of low-risk wastewater irrigation measures.

3.4.2.1 Household size

The results of this study show that an increase in household size increases the likelihood of a farmer adopting irrigation cessation as a risk-reduction measure by 1.2 percent. Household size can serve as an important asset in wastewater irrigation since it is a form of human capital (Jansen *et al*., 2005). Also, an increase in household size increases the probability of adopting crop restriction as a measure in risk reduction by 8.1 percent. The increase in household size increases the likelihood of adopting safer application techniques in wastewater irrigation by about 8.0 percent. The results of this study imply that large family labour is an incentive for adoption of labour intensive low-risk technologies in wastewater irrigation. Low-risk irrigation technologies that are labour-intensive can be adopted by households with members with members able to participate in farm activities. Also, the household members can generate income for investment in farm inputs in the case of capital-intensive technologies aimed at risk-reduction in wastewater reuse.

3.4.2.2 Age of the household head

According to results of this study, an increase in age of the household head leads to a decrease in the likelihood of adopting irrigation cessation as a risk-reduction measure by 1.7 percent. This implies that many young urban and peri-urban farmers are keen to embrace low-risk technologies to reduce health hazards in wastewater irrigation compared to the old farmers. Also, an increase in age of the household head lowers the probability of adopting crop restriction as a measure in risk reduction by 1.8 percent. An increase in age of the household head decreases the likelihood of adopting safer application techniques in wastewater irrigation by about 1.2 percent. The results imply that old farmers are more reluctant to adopt new risk-reduction measures in wastewater reuse because they favour their own methods of farming resulting from many years of experience (Huong & Eiji, 2012).

3.4.2.3 Education level of household head

An increase in education of household head increases the likelihood of a farmer adopting irrigation cessation as a risk-reduction measure by 1.4 percent. This implies that low-education is major challenge in application of low-risk wastewater irrigation measures among urban and peri-urban farmers (Biran & Hagard, 2003). The increase in education of household head increases the probability of adopting crop restriction as a measure in risk reduction by 6.8 percent. This shows that farmers' ability to comprehend and react to information concerning new low-risk irrigation technologies can improve with an increase in formal education. Also, an increase in education of household head increases the likelihood of adopting safer application techniques in wastewater irrigation by about 5.9 percent. These results are not unexpected because farmers' education level as a human capital can encourage behaviour-change towards utilization of health inputs in wastewater irrigation (Jiménez, 2006; Weldesilassie *et al*., 2011).

3.4.2.4 Access to extension services

Farmers who have access to extension services are 35.8 percent more likely to adopt irrigation cessation as a risk-reduction measure. When the social linkage between farmers and the agricultural extension officers are weak the transfer of information is negatively affected hence preventing the farmers from acquiring vital innovations in wastewater reuse. Also, the farmers with access to extension services are 9.4 percent more likely to adopt crop restriction as a risk-reduction measure. Access to extension services increases the likelihood of adopting safer application techniques in wastewater irrigation by about 42.4 percent. Knowledge and consciousness of health risks linked to wastewater reuse in agriculture greatly influence how the hazards are managed (Peres *et al*., 2006). This can be achieved through the agricultural extension agents through dissemination of best practices to farmers involved in wastewater irrigation.

3.4.2.5 Membership in farmers' group

The farmers who are members of farmers' group are 8.3 percent more likely to adopt irrigation cessation as a risk-reduction measure. This may attributed to access to sufficient knowledge about the low-risk technology which enables farmers to improve their decision-making processes. Similarly, farmers who are members of farmers' groups are 40.0 percent more likely to adopt crop restriction as a risk-reduction measure. The results are expected since linkages among farmers involved in wastewater irrigation have a high potential in promoting information sharing and uptake of low-risk techniques (Huong & Eiji, 2012). Membership in a farmers' group increases the probability of adopting safer application techniques in wastewater irrigation by about 21.7 percent. Membership in farmers' groups can also facilitate behaviour-change among wastewater users towards adoption of low-risk irrigation technologies (Jeffrey & Seaton, 2004).

3.4.2.6 Access to credit

Farmers who have access to credit are 9.9 percent more likely to adopt safer application methods in order to reduce hazards in wastewater irrigation. In urban and peri-urban irrigation, credit access is vital for adoption of low-risk technologies in wastewater irrigation (Cornish & Lawrence, 2001). Also, access to credit increases the likelihood of adopting crop restriction as a risk-reduction measure by 39.3 percent. The farmers who have access to credit facilities are 36.3 percent more likely to adopt safer application techniques in wastewater irrigation. Therefore, the results are expected since credit access can incentivise wastewater users to invest in low-risk technologies through acquisition of irrigation systems, small pumps, and protective gear (Scott *et al*. 2004).

3.4.2.7 Access to media

Communication media is a source of information which can influence behaviour of wastewater users by presenting facts about contaminants and risks posed by untreated wastewater to human health and the environment. Media can influence farmers to change their behaviour in wastewater irrigation through adoption of low-risk technologies once they learn that their current practices pose health hazards (Obuobie *et al*., 2006). Farmers who have access to media are 21.6 percent more likely to adopt irrigation cessation as a risk-reduction measure. Similarly, the farmers with access to extension services are 3.5 percent more likely to adopt crop restriction as a risk-reduction measure. In addition, access to media increases the likelihood of adopting safer application measures in wastewater irrigation by about 42.5 percent. Therefore, the results are not unexpected since farmers who have access to media are more conscious of the health hazards in wastewater irrigation and hence have higher likelihood of adopting low-risk technologies. Access to media information affects farmers' perceptions of risk and consequently influencing then in choice of low-risk irrigation technologies.

3.4.2.8 Awareness to wastewater hazards

The farmers who are aware of wastewater hazards are 9.8 percent more likely to adopt irrigation cessation as a measure to reduce health risks in wastewater irrigation. This implies that, without adequate risk awareness among urban wastewater users, it may be difficult to promote a behaviour-change towards adoption of low-risk irrigation practices. Also, farmers who are aware of risks in wastewater irrigation are 39.9 percent more likely to adopt crop restriction as a risk-reduction measure. Lastly, farmers who are aware of health hazards in wastewater irrigation are 29.7 percent more likely to adopt safer application procedures. These results are expected since farmers' awareness of health risks in wastewater irrigation influences their behaviour in using health inputs to minimize incidences of illness (Stenekes *et al*., 2006; Weldesilassie *et al*., 2011).

Table 4: Marginal effects from the multinomial logistic low-risk wastewater irrigation model

Explanatory variable	**Irrigation cessation**		**Crop restriction**		**Safe application**		**No intervention**	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Household size	0.012^{***}	0.004	0.081^{***}	0.031	0.079^{***}	0.025	-0.166^{***}	0.046
Age of the household head	-0.017^{***}	0.006	-0.018^{***}	0.007	-0.012^{***}	0.006	0.032^{***}	0.010
Education of household head	0.014^{***}	0.004	0.068^{***}	0.031	0.059^{***}	0.023	-0.135^{***}	0.049
Access to extension	0.358^{***}	0.129	0.094	0.120	0.424^{**}	0.174	-0.568^{***}	0.157
Farmers' group membership	0.083^{***}	0.030	0.400^{***}	0.101	0.217^{***}	0.085	-0.662^{***}	0.117
Access to credit	0.099^{***}	0.034	0.394^{***}	0.108	0.363^{***}	0.098	-0.807^{***}	0.092
Access to media	0.216^{***}	0.069	0.035^{***}	0.012	0.425^{***}	0.107	-0.256^{***}	0.096
Risk awareness	0.098^{***}	0.029	0.399^{***}	0.109	0.297^{***}	0.097	-0.733^{***}	0.114

Note: ***, **, * denotes significance at 1%, 5% and 10% level respectively.

3.5 Conclusions and policy implications

This study used a multinomial logit model to identify the factors influencing a farmer's decision to choose a risk-reduction measure in wastewater irrigation. In the model, the dependent variables comprised four choice alternatives while the independent variables included different social-economic and institutional factors. The urban and peri-urban farmers have adopted low-risk wastewater irrigation techniques such as cessation of irrigation before harvesting, crop restriction and safer application methods. These procedures contained the choice set for the multinomial logit model. A multinomial logit model was used to investigate the effects of socio-economic and institutional characteristics on the choice of risk-reduction techniques as a way of addressing the widespread pollution of irrigation water. Results from the model indicate that the variables used significantly influence the choice of a technique to reduce health risks. These include: household size, age of the household head, education of household head, access to extension, access to media, access to credit, farmers' group membership, and risk awareness.

The study recommends that policies in support of low-risk urban and peri-urban irrigation agriculture should disaggregate farmers according to their socio-economic and institutional characteristics in order to achieve their intended objectives. For instance, to enhance the choice of irrigation cessation method in order to minimize health hazard in wastewater reuse, the relevant stakeholders should enhance access to extension services by farmers. When supporting the use of crop restriction as a risk-reduction measure, the promoters should intensify risk awareness about wastewater reuse. To promote the use safer application techniques, the study recommends that credit facilities be offered to the urban and peri-urban farmers involved in wastewater reuse. In addition, farmers should be encouraged to join farmers' groups in order to encourage farmer-to-farmer exchange of risk-reduction information. Access to media among the urban and peri-urban farmers should be encouraged in order for them to obtain additional information relevant to risk-reduction in wastewater irrigation.

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CHAPTER FOUR

EVALUATING THE WELFARE EFFECTS OF IMPROVED WASTEWATER TREATMENT USING A DISCRETE CHOICE EXPERIMENT

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-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 city 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.

Keywords: Conditional logistic model, constructed wetland technology, discrete choice experiment, random parameter logit model, wastewater treatment, and riverine ecosystem restoration.

4.1 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, 2011a; 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 & 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 & 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 (WHO, 2006). 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 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 & Barbier, 2009; Hanley *et al*., 2001; Hanley *et al.*, 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 & Murty, 2004; Willis *et al*., 2005). However, there are relatively few studies worldwide on the economic costs of wastewater (e.g. Barton, 2002; Birol *et al*., 2010; Cooper *et al*., 2004; Markandya & 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.

4.2 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 City. Kibera slum is situated 5 kilometres from Nairobi City Centre while Maili-Saba is located 10 kilometres from the city centre. The slum 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 City. 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.

Maili-Saba is located 10 kilometres from Nairobi City Centre along the Ngong River, which is a tributary of the Nairobi River Basin. Although land in this slum is publicly owned, it is densely populated and has very poor water and sanitation services. Lack of sanitation infrastructure has severe environmental and public health hazards to many of the slum dwellers. Much of the generated domestic waste from Maili-Saba slum is drained into Ngong River without treatment hence causing serious water pollution. Thus, inadequate sanitation and widespread pollution of surface-water are key drivers of unplanned wastewater irrigation in the informal settlement. Therefore, Maili-Saba is considered a high-risk slum since many small-scale farmers have no other choice than using untreated wastewater for irrigation. Unregulated wastewater irrigation can facilitate transmission of diseases from effluent-related pathogens and vectors, skin irritants and toxic chemicals like heavy metals and pesticides.

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. It is estimated that about 280 tonnes of municipal solid waste is generated in the slums per day. Additionally, the Biochemical Oxygen Demand (BOD_5) from solid waste in Kibera slum is approximately 6,650 kilograms 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 and Maili Saba slums 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 & Hammer, 2008; Mara, 2004; Patwardhan, 2008; WHO, 2006). Therefore, there is a need for Nairobi City to invest in improved treatment of wastewater generated from Kibera and Maili Saba 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.

4.3 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:

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

where $V(\bullet)$ is the deterministic component and $\varepsilon(\bullet)$ 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:

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

If $V(\bullet)$ 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:

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

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, $V(\bullet)$ and $\varepsilon(\bullet)$ 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:

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

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

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

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 over all 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:

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

When the price of 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:

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

In order to include the household specific characteristics $Z_{1\text{-}6}$ (i.e., age of the household head, gender of the household head, education level of the household head, employment status of the household head, and health-risk awareness of the household head involved in untreated wastewater irrigation) in estimation of implicit prices (part-worth), equation (8) is modified into equation (9) below:

$$WTP = -1 * \left(\frac{\beta_{attribute} + \gamma_{attribute} \times Z_1 + \ldots + \gamma_{attribute} \times Z_5}{\beta_{price} + \gamma_{price} \times Z_1 + \ldots + \gamma_{price} \times Z_5} \right) \tag{9}$$

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 & Adamowicz, 2001; Hanemann, 1984; Small & Rosen, 1981).

This can be evaluated as shown in equation (10) where V_{0n} is the indirect utility functions related to the initial state and V_{1n} is the indirect utility functions related to an improved state contained in the study, while β_{price} is the marginal utility of income[4].

$$CS = -\frac{1}{\beta_{price}}\left(\ln\sum_{n}\exp(V_{0n}) - \ln\sum_{n}\exp(V_{1n})\right) \tag{10}$$

4.4 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. The 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. 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 City. Due to uncertainty over the exact changes in attribute features, the levels of choices were qualitatively presented.

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[4]Compensating surplus represents the average farmer's willingness to pay for a package of changes in improved wastewater treatment.

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. In order to ensure that the obstacles in understanding the questionnaires were identified and corrected before the actual data collection, the research questionnaires were pre-tested prior to actual data collection. 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 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 $(3^2 \times 2 \text{ x } 5)^2$ 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 represented the current environmental situation without any wastewater treatment measures.

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 City 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 City 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.

The use of visual aids is vital for respondents in areas with illiteracy (Abou-Ali & Carlsson, 2004; Corso *et al*., 2001). This is because the use of visual facilitates the respondents to understand the trade-offs involved in making a choice. In this study, 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.

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	☐	☐	☐

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 City 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. In addition, the farmers were reminded of the expected benefits from wastewater irrigation after treatment. The respondents were told that in order to support a secondary wastewater treatment programme they would pay monthly taxes to the city. Due to time and budget constraints, 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. The estimated population of farmers involved in untreated wastewater irrigation in the study area is 1,332 (Ayaga *et al*., 2005). Therefore, the selected sample was considered a representative of the target population of wastewater users that would generate an indication of preferences for improved wastewater treatment.

The survey for this discrete choice experiment was representative of the target population in terms of proximity of the wastewater users to Motoine-Ngong River and also socio-economic status of the urban and peri-urban farmers in Nairobi City. In this study, the sampling frame was the map of Kibera and Maili-Saba informal settlements. Households were the sample units whilst the household heads were the units of inquiry. Using systematic random sampling method, the survey sample was selected by visiting every third household along an "X" transect (Birol & Das, 2010; Scarpa *et al*., 2003). 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.

4.5 Results

4.5.1 Socio-economic characteristics of respondents

The descriptive statistics of socio-economic and demographic data obtained for this study is presented in Table 3 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 waste water 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.

Table 3: Descriptive characteristics of the sampled households

Characteristics	Samples mean (Std. dev.)
Household size	4.26 (1.30)
Age of the household head (years)	42.61 (10.77)
Education level of the household head (years)	8.55 (2.38)
Farm experience of household head (years)	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 other 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

The summary results of this study show that 63.58 percent of the interviewed wastewater users are from Kibera slum. 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.

4.5.2 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 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.

The use of alternate specific constant (ASC) is vital for interpretation of the preferences of respondents (Morrison *et al*., 2002). In this study, the ASC was coded 1 where the respondent chose status quo and 0 in the case of choosing alternative A or B. When the coefficient of ASC is statistically significant and negative, it suggests that respondents do not prefer a move away from status quo. The individual-level variables (age, gender, education, employment 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.

4.5.3 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 order to ensure that standard deviations can change in sign throughout the full range of the model, all the 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 4. 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, employment 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 5).

Table 4: Parameter estimates of conditional logit and random parameter logit models

	CL model		RPL Model	
Attribute	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***	0.001	-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

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. When IIA property is violated, CL model estimations might be biased. This prompts the use of RPL model (Layton, 2000; Revelt & Train 1998). Also, 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 ($\rho^2=0.342$) 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 Domenich and McFadden (1975) equate values of ρ^2 between 0.2-0.4 in discrete choice models to values of R^2 between 0.7-0.9 in equivalent linear regression models. In addition, the RPL model shows heterogeneity in the preference of respondents unlike the CL model which shows homogeneity in the preference of respondents.

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 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 city taxes.

The results reveal some degree of status quo bias since the ASC coefficient is negative and statistically significant. In choice experiments, this is common and may be linked with disutility from moving away from a current situation by the respondents (Adamowicz *et al*., 1998; Hanley *et al*., 2005). The status quo bias in this study may be attributed to farmers' lack of trust in municipal authority to implement wastewater treatment programmes. Although many urban and peri-urban farmers in the study area depend on the untreated wastewater for irrigation, there has been reluctance by policy makers to acknowledge wastewater as a resource. This may also make some wastewater users to be more cautious before they commit to change due to inadequate information.

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 who use untreated wastewater for urban and peri-urban agriculture choose status quo more frequently than young wastewater users. A significant difference across gender was also observed. Male wastewater users are more likely to opt for improved wastewater treatment options than the female farmers. Literacy of urban and peri-urban farmers is a significant factor in choosing improved wastewater treatment programmes. Farmers who have more education choose improvement wastewater treatment options more often than the less educated wastewater users. According to the results of this study, wastewater users who are also employed choose wastewater improvement options more frequently than those without another form of employment. On the other hand, farmers involved in untreated wastewater irrigation choose improved wastewater treatment options more frequently if they are awareness of health risks than if they are not.

Table 5: Parameter estimates of conditional logit and random parameter logit models with interactions

	CL model		RPL Model	
Attribute	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 x Age	-0.022^{***}	0.008	-0.024^{***}	0.010
ASC x Gender	0.374^{*}	0.213	0.516^{**}	0.254
ASC x Education	0.049	0.034	0.082^{**}	0.041
ASC x Employed	0.630^{***}	0.166	0.445^{**}	0.202
ASC x 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

4.5.4 Estimations of Implicit prices

The implicit prices of the sample average for all the considered attributes in this study are presented in Table 7. Also, additional valuations of implicit prices, which included six different household profiles (Table 6), 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.

Table 6: 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.

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 Motoine-Ngong River. This welfare gain shows that the WTP for an average household is Kshs.90.57 as monthly municipal taxes in order to treat wastewater before discharge into the Motoine-Ngong River.

These results are plausible since the mean farm income per household is Kshs. 2086.18. Therefore, urban and peri-urban farmers in Nairobi City have positive WTP for an increase in treated wastewater quality, treated wastewater quantity and ecosystem restoration. The 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). Also, the results reveal that 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.

Table 7: 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	51.0	17.39	22.18
	(95% CI)	(42.39-59.56)	(7.13-27.58)	(15.76-29.35)
	SD	27.74	54.55	31.78
Profile 1:Farmers aged below 40 years (young)	Mean	56.93	16.63	17.54
	(95% CI)	(44.12-70.52)	(1.45-31.72)	(8.43-27.84)
	SD	32.75	59.13	32.11
Profile 2:Farmers aged 40 years and above (old)	Mean	44.39	16.26	21.49
	(95% CI)	(35.85-52.94)	(5.05-27.5)	(14.19-29.64)
	SD	17.22	55.59	32.72
Profile 3:Farmers with primary education	Mean	46.78	16.58	18.6
	(95% CI)	(36.58-57.16)	(3.31-29.94)	(10.64-27.51)
	SD	25.37	59.96	32.42
Profile 4: Farmers with post-primary education	Mean	59.50	19.38	29.51
	(95% CI)	(44.29-75.42)	(2.71-35.97)	(18.19- 42.42)
	SD	33.99	48.38	33.72
Profile 5:Farmers with up to 2 years' experience	Mean	62.4	18.11	24.58
	(95% CI)	(47.64-78.35)	(1.42-35.16)	(13.81-36.94)
	SD	39.12	61.50	38.95
Profile 6: Farmers with over 2 years' experience	Mean	41.02	16.65	20.47
	(95% CI)	(31.28-50.99)	(3.43-29.75)	(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.

4.5.5 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 8. In order to obtain the mean WTP value and their respective 95% confidence intervals using equation (9), this study used 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 wastewater for irrigation in the Motoine-Ngong River Basin: urban farmers located about 5 kilometres from Nairobi City Centre (Kibera) and peri-urban farmers located about 10 kilometres 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.

Table 8: Compensating surplus for three possible scenarios

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

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. When the environmental condition is further enhanced in scenario 2, the mean WTP rises above scenario 1. Scenario 2 provides a higher quality of treated wastewater, a higher quantity of treated wastewater and restored riverine ecosystem compared to scenario 1. Consequently, 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. A further improvement of environmental condition in scenario 3 yields a mean WTP that is greater than scenario 2. When compared to scenario 1, scenario 3 provides improved environmental change through better wastewater treatment. This environmental improvement results in an increase in mean 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 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 City will be collecting 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.

4.6 Discussions, conclusion and policy implication

4.6.1 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 & Mariel, 2010; Bennett & Birol, 2010; Birol & Das, 2010; De Groote & Kimenju, 2008; Do & 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 solely dependent on the environmental attributes but also on socio-economic factors.

The affecting socio-economic characteristics include age of the household head, gender of the household head, education of the household head, employment status of the household head, and risks awareness of the household head involved in untreated wastewater irrigation. 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 & Cox, 2007; Carlsson *et al*., 2003; Colombo *et al*., 2006; Othman *et al*., 2004). Also, the compensating surplus from Kibera sub-sample (5 kilometres from Nairobi's central business district) was found to be higher than that of Maili-Saba sub-sample (10 kilometres from Nairobi's central business district). These differences in WTP values may be the attributed to disparity in risk-awareness among the direct wastewater users in Kibera slum compared to indirect wastewater users in Maili-Saba slum (van der Hoek, 2004).

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. 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.

4.6.2 Conclusion and policy implication

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.

This case study has illustrated the value of wastewater treatment in Nairobi City. 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.

The urban and peri-urban farmers involved in wastewater irrigation are willing to pay for improved wastewater treatment. However, the wastewater users have different marginal WTP for different attributes of the treated wastewater. Although the wastewater users have different values for attributes of treated wastewater, they are also affected by several socioeconomic factors. Therefore, the urban and peri-urban farmers' value for improved wastewater treatment depends not only on wastewater qualities and ecosystem restoration but also on socioeconomic factors. The socioeconomic factors that have positive influence on the WTP for improved wastewater treatment include gender of household head, education of household head, employment status of the household head, and risks awareness of the household head. Therefore, the policy makers should involve urban and peri-urban farmers in the wastewater management practices for sustainable urban agriculture sustainable and adequate sanitation. Also, the government should pursue investment to increase farmers' health-risk awareness and education to increase their willingness to pay for improved wastewater treatment.

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CHAPTER FIVE

SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

5.1 Introduction

This chapter presents a summary of main findings of the study and also draws conclusions as well as policy insights based on the research results. First section of this chapter summarises the key findings and further provides specific policy implications. The last section of this study presents the limitations of the study and suggests possible areas for further research.

5.2 Summary of key findings and policy implications

This study had three key objectives based on aspects that have been largely ignored in the literature on wastewater irrigation in developing countries. The first objective was to evaluate the health-risk awareness of farmers involved in untreated wastewater irrigation in urban and peri-urban areas. This objective was achieved by employing the ordered logit model in evaluation of the health-risk awareness of farmers involved in untreated wastewater irrigation in urban and peri-urban. Second objective was to analyse the determinants of farmers' choice of low-risk irrigation measures in wastewater reuse for agriculture in urban and peri-urban areas. The multinomial logit model was used to analyse the determinants of farmers' choice of low-risk irrigation measures in wastewater reuse for agriculture in the urban and peri-urban areas. The third objective was to estimate the value that urban and peri-urban farmers who practice wastewater irrigation attribute to improved wastewater treatment. In order to achieve this objective, the discrete choice experiment was used in estimating the willingness to pay for improved wastewater treatment by the urban and peri-urban farmers who practice wastewater irrigation.

Most studies on wastewater reuse in sub-Saharan Africa have concentrated on wastewater quality aimed at analysing microbiological and chemical contaminants in the polluted water. Since many waster-scarce countries are moving towards planned direct wastewater reuse, there is need to address the key challenges in urban and peri-urban agriculture which include: analysis of benefits and costs of improved wastewater treatment and non-treatment options; locally implementable low-cost technologies for pathogen removal in wastewater through public-health engineering; institutional capacities and linkages to constructively strengthen links between the sanitation and agricultural sectors; and legislation for the regulation of wastewater reuse and control of water pollution. The results of this study are useful for designing effective policies to develop sustainable management of wastewater resource in many developing countries.

Results show that farmers' awareness of health risks in urban and peri-urban wastewater irrigation is influenced by the gender of household head, household size, education level of household head, farm size, ownership of the farm, membership to farmers' group, and market access. These results support the hypothesis that health-risk awareness in urban and peri-urban wastewater irrigation is influenced by demographic and socioeconomic characteristics. The results suggest that health-risk awareness for the direct and indirect wastewater users is affected by similar socioeconomic factors. Policy implication of these results is that the government should promote access to market for wastewater users through dedicated marketing channels to hotels, restaurants and supermarkets to enhance monitoring of quality standard and also improve risk-awareness. Also, the government needs to increase investments in education for the wastewater users to become more aware of health risks in untreated wastewater reuse. Wastewater users should be supported in establishing associations which can in turn be used by the government as communication channels for dissemination of safe practices. There is also a need for the government to ensure that urban and peri-urban farmers have security of tenure in order to effectively promote health-risk awareness.

Findings of the study indicate that household size, age of the household head, education of household head, access to extension, access to media, access to credit, farmers' group membership, and risk awareness influence the farmers' adoption of low-risk irrigation measures in urban and peri-urban wastewater reuse. These results are consistent with the hypothesis that the adoption of low-risk non-treatment interventions in untreated wastewater irrigation is influenced by institutional characteristics. Thus, policies that support low-risk urban and peri-urban agriculture should disaggregate farmers according to their socio-economic and institutional characteristics in order to achieve their intended objectives. These results imply that the government should pursue policy measures that enhance investment in risk-reduction technologies in wastewater irrigation (e.g. improved access to extension services and credit facilities for wastewater users). The government can also develop incentives to promote formation of farmers' groups which are critical for dissemination of risk-reduction measures in untreated wastewater irrigation.

The results of this study showed that wastewater quality, wastewater quantity and riverine ecosystem restoration enhances the farmers' willingness-to-pay for improved wastewater treatment in urban and peri-urban areas. This confirms the hypothesis that farmers' willingness-to-pay for improved wastewater treatment before reuse in irrigation is affected by wastewater characteristics and the restoration of ecosystem. Moreover, the results revealed that gender of household head, years of education for household head, formal employment of household head, and risk awareness of household head enhances the willingness-to-pay for improved treatment of wastewater. The policy implication of these results is that the government needs to promote involvement of urban and peri-urban farmers when investing in improved wastewater treatment in order to ensure sustainable implementation of better sanitation infrastructure. Also, there is need for the government to support increased access to education and off-farm employment opportunities among the urban and peri-urban wastewater users to increase their willingness-to-support improved wastewater treatment programmes. The government should also ensure increased farmers' support in development of health and sanitation infrastructure by enhancing risk-awareness among the wastewater users. There is need for the government, policy-makers and urban planners to acknowledge that wastewater resources play an important role in urban and peri-urban livelihoods. Therefore, environmental protection policies that limit or ban access and reuse of wastewater are likely to increase urban poverty since many poor farmers derive their livelihoods from wastewater irrigation. Instead of advocating for strict policies on irrigation water, the government should invest in development and promotion of safe wastewater reuse practices in urban and peri-urban agriculture. The regulated wastewater irrigation would allow many poor urban and peri-urban farmers to enhance their economic well-being while minimizing pollution of freshwater resources.

5.3 Limitations of the study and areas for further research

The multinomial logit model used in this study generated useful results and important policy insights for low-risk adaptations in untreated wastewater irrigation. However, this study considered the post-treatment low-risk irrigation measures which were used by farmers in this study. Therefore, there is need to seek additional risk-reduction measures which can be adopted in the developing countries to minimize health risks in wastewater reuse. Possible improvement in the model is an analysis of other on-farm risk-reduction options in wastewater reuse for urban and peri-urban agriculture. These are on-farm treatment systems such sedimentation traps, simple ponds and sand filters. Also, the off-farm measures can be considered in the model as reliable risk-reduction measures. Some off-farm measures that may require consideration for further research include: washing, disinfecting, peeling, and cooking of the produce.

The choice experiment model presented in this study does not consider the "cheap talk" approach, which can be applied in stated preference studies. Cheap talk can also be used to remove hypothetical bias in choice experiment rather than using budget constraints and budgetary substitutes as references in hypothetical referendum. The cheap talk script does the following: it describes the phenomena of hypothetical bias; it discusses possible explanations for the phenomena; and it also requests that subjects vote in the upcoming hypothetical referendum as if it were a real referendum. Therefore, a possible extension of the present study is the development of a stated preference model with a cheap talk script designed to eliminate any hypothetical bias. Also, institutional factors can be included in the choice experiment model to identify other determinants of the farmers' willingness to pay for improved wastewater treatment.

APPENDICES

Appendix A: Survey Questionnaire

Questionnaire Number		**hhid**
Interview Location		**loc**
Interview Sub-Location		**subloc**
Date of Interview		**intdate**

PREAMBLE

Dear Respondent,

You are invited to participate in an academic research study conducted by Ezekiel Ndunda, Doctoral student from the Department Agriculture Economics, Extension and Rural Development at the University of Pretoria, South Africa. The purpose of the study is to undertake a comprehensive assessment of the value urban and peri-urban farmers attach to low-risk use of wastewater for agriculture as a basis for developing government policies for regulating wastewater disposal, treatment, and irrigated agriculture.

Please note the following:

- This study involves an anonymous survey. Your name will not appear on the questionnaire and the answers you give will be treated as strictly confidential. You cannot be identified in person based on the answers you give.
- Your participation in this study is very important to us. You may, however, choose not to participate and you may also stop participating at any time without any negative consequences.
- Please answer the questions in the attached questionnaire as completely and honestly as possible. This should not take more than 150 minutes of your time.
- The results of the study will be used for academic purposes only and may be published in an academic journal. We will provide you with a summary of our findings on request.
- Please contact my supervisor, Dr. Eric Mungatana (eric.mungatana@up.ac.za) if you have any questions or comments regarding the study.

Please sign the form to indicate that:

- You have read and understand the information provided above.
- You give your consent to participate in the study on a voluntary basis.

________________________ **Respondent's signature** ________________________ **Date**

Section A: Socio-Economic Characteristics of Farmers

a) Personal Information

1. Please provide the following information about the household members.
   Demog.sav

	Name	Age (Years)	Gender 1= male 2=female	Relation to head	Marital Status	Period lived in this HH in the past one year (months)	Currently in school 1 = yes 2 = no	Highest education level	Illness period in the past one year (weeks)	Employed 1=yes 2=no
mem	**Name**	**age**	**gender**	**rhead**	**mstatus**	**period**	**school**	**educlev**	**illness**	**employed**
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										

Codes				
Relation to head 1 = head 2 = spouse 3 = child 4 = niece/nephew 5 = parent 6= brother/sister	 7 = other relative 8=son/daughter in-law 9=grand child 10 = worker 11=unrelated	**Marital Status** 1=Monogamous marriage 2=Polygamous Marriage 3 = never married	4= divorced 5 = widow/ widower 6 = separated	**Highest education level** 0=none 1….14 for yrs in school 18=some college 19=Completed college 20=some university 21=completed university 22=post-graduate

b) Farming and Income Information

1. Average size of land owned by the household in acres **landsize__________________**
2. Do you farm on public land? 1=yes 2=no **landown________________**
3. If answer to question (2) above is NO, what land ownership rights do you have?

   1=Title deed, 2=Own but no title 3= Lease 4= Communal 5= Squatter **tenure____________________**
4. Average farm size under irrigation (acres) **irrigate___________________**
5. Farming experience of the household head (years) **farmexp__________________**

6. Please specify the crops that you grow and about how much of each was produced and sold in the last one year (use the table below)

***Enumerator: use unit codes for quantities harvested and sold below the table, crop codes are provided in a separate sheet*.**

cropfile

Crop name	Crop code	Source of water	Quantity harvested	units	Quantity sold	units	Price per unit (Ks)
	crop	**watersor**	**qhvt**	**qunit**	**qsold**	**sunit**	**price**

Unit codes	
1=90 kg bag 2=kgs 4=crates 5=numbers 6=bunches(bananas) 7=25kg bag	8=10kg Bag 9=gorogoro (2kg tin) 10=tonne 11=50 kg bag 12=debe 13=grams

7. Do you own any livestock? 1=yes 2=no **lvstkown________________**

8. If yes to question (6), please specify the types of livestock owned in the table below.

File name: livestock

	Animal	**Number currently owned**	**Unit value (Ks.)**	**Total value (Ks.)**
livecode		**cown**	**unitval**	**totval**
1.	Cows			
2.	Bulls			
3.	calves			
4.	Sheep			
5.	Goats			
6.	Pigs			
7.	chicken			
8.	Other poultry			
9.	rabbits			
10.	Other livestock (specify)			

9. Main occupation of the household head: 1= Subsistence farmer, 2= Informal employment , 3= Formal employment **occupat**__________
10. Average household farm income per month (Ks): **income**__________

    1= Below Ks. 1000 2=Between Ks. 1000- 5000 3=Between Ks. 5001- 10000

    4=Between Ks. 10001- 15000 5=Between Ks. 15001- 20000 6= Between Ks. 20001- 30000

    7=Above Ks. 30000

11. Average household off-farm income per month (Ks):***(enumerator instruction: use codes in question 9 above)*** **offinc**__________

c) Institutional Information

1. Have you benefited from the services of agricultural extension officers in the last one year? 1=yes 2=no **agext______________**

2. If your answer is yes in question (1) above, please list some of the benefits below:

   extbenf1……

   extbenf2……

   extbenf3……

   extbenf4……

3. Do you have membership in any Famers Association that supports the welfare of small-scale urban farmers in Nairobi? 1=yes,2=no

   famember___________

4. If your answer in question (3) above is yes, please provide the name of the Famers Association below:

   assoc1……

   assoc2……

   assoc3……

   assoc4……

5. Are there Non-Governmental Organizations that support you as a small-scale urban farmer? 1=yes 2=no **NGO_____________**

6. If your answer in question (5) above is yes, please provide the list of the NGOs below:

    Ngo1…………………………………...…………………

    Ngo2……………………………………...…………

    Ngo3………………………………………...………

    Ngo4…………………………………………...……

7. Have you been able to gain any relevant information on wastewater reuse for agriculture through interactions with other urban farmers?

    1=yes 2=no **waterinf__________**

8. If your answer in question (7) above is yes, please list the major benefits below:

    wbenef1…………………………………...

    wbenef2………………………………...……………

    wbenef3…………………………..………………………

    wbenef4……………………………………...…

9. You have access to credit facilities? 1=yes 2=no **credit_______________**
10. Do you have access to certified seed? 1=yes 2=no **certseed_____________**
11. Do you have access to media? 1=yes 2=no **media_______________**
12. Do you have access to market for your produce? 1=yes 2=no **market_______________**

13. Which of the following items does your household own: 1=yes 2=no

Cell phone	**phone**_______________
Television set	**television**____________
Radio	**radio**________________

14. Do you have any training on safe use of wastewater for irrigation? 1=yes 2=no **watrain**______________

Section B: Household Consumption Expenditure

1. Please specify how much you have spent on the following items in the last 30 days (1 month).

   File name: Expenditure

Expenditure item	**Amount spend on purchased items (Ks.)**	**Value of own production consumed (Ks.)**
Expitem	**amount**	**value**
1) Cereals and pulses		
2) Maize, wheat, millet, sorghum flour (including other flours)		
3) Protein foods (meat, milk, eggs, fish, etc.)		
4) Fruits and vegetables		
5) Bread, mandazi/cake, sweet potatoes, arrow roots, yams		
6) Cooking oil, salt, sugar and beverages		
7) Cooking and lighting fuel (charcoal, firewood, gas & electricity)		
8) Other household consumables (soap & personal care items)		
9) Domestic water		
10) Irrigation water		
11) Water purification		
12) Transport		
13) House rent		
14) Domestic help		
15) Formal medical care		
16) Informal medical care		
17) Contributions to SACCOs		
18) Mortgage and other loan payments		
19) Other household expenditures (specify): i)		
ii)		
iii)		
iv)		
v)		

2. How much did the household spend on school fees in the past one year? Ks **schfees___________**

Section C: Farmers' Perception on the Reuse of Untreated Wastewater

1. Please select the comments in the table below that best describe your degree of motivation for reuse of untreated wastewater for agriculture

Statement	**Comment** 1=Strongly disagree 4= Agree 3= Undecided 2= Disagree 5= Strongly agree	
1. There are no other available sources of irrigation water		**nosorce**
2. Wastewater is readily available near the farm		**ravail**
3. Wastewater ensures high yields of the grown crops		**hiyield**
4. Wastewater improves the structure of agricultural soils		**soilstrc**
5. Wastewater is a strategic source of nutrients for crop production		**nutrient**

2. Please select the comments in the following table that best describe the problems you face in reuse of untreated wastewater for irrigation

Statement	**Comment** 1=Strongly disagree 4= Agree 2= Disagree 5= Strongly agree 3= Undecided	
1. There are health-related problems in untreated wastewater irrigation		**riskaw**
2. Reuse of untreated wastewater has awful persistent stench		**stench**
3. Wastewater irrigation leads to diarrhoeal diseases		**diarrh**
4. Wastewater irrigation causes worm infections		**worms**
5. Irrigation with untreated wastewater causes skin irritation and blistering		**skin**
6. Untreated wastewater damages the irrigation systems		**irrdamag**
7. Reuse of untreated wastewater for irrigation causes soil degradation		**soildeg**
8. Prevalence of crop pests and diseases is increased by wastewater		**cropest**
9. Wastewater irrigation leads to wild growth of weeds in farms		**weeds**
10. Wastewater irrigation leads to contamination of food		**foodcont**
11. Wastewater irrigation leads to contamination of groundwater		**groundwa**

3. Please select the comments in the following table that best describe the measures that you consider effective in reducing the health and environmental risks in untreated wastewater irrigation

Statement	**Comment** 1=Strongly disagree 4= Agree 3= Undecided 2= Disagree 5= Strongly agree	
1. Application of wastewater to the roots crops and not on leaves		**roots**
2. Cessation of irrigation a few days before crop harvesting		**ceasehvt**
3. Protection of urban water sources used for irrigation		**protect**
4. Provision of clean irrigation water to urban farmers		**clcwater**
5. Filtration of irrigation water before discharge into irrigation channels		**filter**
6. Using protective clothing, boots and gloves while in the urban farms		**pcloth**
7. Application of the appropriate amount of wastewater in irrigation		**amount**
8. Treatment of wastewater-irrigated soils against pathogens		**treate**
9. Minimization of wastewater splashing of soils on vegetables		**minsplas**

Section D: Urban and Peri-Urban Wastewater Irrigation

1. How long (years) have you been practicing wastewater irrigation in this farm? **irriyrs_______**

2. What are the three major crops produced through irrigation with wastewater in your farm? (enumerator, list crop name then code using codesheet provided)

   Crop1……………………………………………….

   Crop2……………………………………………….

   Crop3……………………………………………….

   Crop4……………………………………………….

3. Are you aware of the health risks to your household due to reuse of untreated wastewater for agriculture? 1=yes, 2=no **riskawar_______**

4. Please provide information about the incidences and types of wastewater related infections and the number of health clinic visits in your household over the last one year

	Type of infection	**Incidences**	**Health Clinic Visits**	**Cost of Treatment (ks)**
infect		**incidenc**	**visits**	**tcost**
	Bacterial faeco-oral			
1	*Campylobacteriosis*			
2	*Cholera*			
3	*Pathogenic Escherichia*			
4	*coli infection*			
5	*Salmonellosis*			
6	*Shigellosis*			
	Non-bacterial faeco-oral			
7	Viral: *Hepatitis A*			
8	Viral: *Hepatitis E*			
9	*Rotavirus diarrhoea*			
10	*Norovirus diarrhoea*			
11	Protozoan: *Amoebiasis*			
12	Protozoan: *Crystosporidiasis*			
13	Protozoan: *Giardiasis*			
14	*Cyclosporiasis*			
	Geohelminthiases			
15	*Ascariasis,*			
16	*Hookworm*			
17	*Trichuriasis*			

5. Are you aware of the World Health Organization guidelines for wastewater irrigation? 1=yes 2=no **whoaware________**

6. According to your experience in urban agriculture, which stage in wastewater irrigation requires primary attention in order to minimize health and environmental hazards? **irrstage**__________

   1=Pre-farm wastewater management 2=On-farm wastewater application 3=Post-harvest crop handling

7. In on-farm wastewater handling, have you adopted any risk-reduction measures to minimize the risk of infections in your household? 1=yes 2=no

   riskred__________

8. If your answer to question (7) above is yes, please identify the adaptation strategy that best describes your risk reduction measure from the following options:

   1= Low-cost drip irrigation **riskred1**___________

   2=Crop restrictions **riskred2**___________

   3= Furrow irrigation **riskred3**___________

   4= Imposing a minimum period of no irrigation immediately prior to harvest **riskred4**___________

   5= Protective clothing, including gloves, and footwear **riskred5**___________

   6= Regular anti-helminthic treatment **riskred6**___________

   7=Others (specify):

   i) ……………………………………………...

   ii) ……………………………………………...

   iii) ……………………………………………...

Appendix B: The Contingent Valuation Questionnaire

Eliciting the Willingness-To-Pay for Treated Wastewater

The sewerage infrastructure in Nairobi is dilapidated and even covers a very limited area because of inadequate investment and poor maintenance. Since the current sewerage system, which covers less than 40% of the population in Nairobi, can only treat less than 50% of the generated wastewater, most of the effluent is discharged into drains and rivers degrading the environment. This has led many urban and peri-urban farmers to directly and indirectly use untreated wastewater for irrigation. The Motoine-Ngong River is considered the most polluted channel in Nairobi River Basin due to:

i) Uncontrolled disposal of excreta from the major slum areas
ii) Uncontrolled disposal of solid waste from slum areas along the river channel
iii) Blockages and/or breakages of sewage lines
iv) Untreated industrial wastewater discharged

1. Do you know that the water you draw from Motoine-Ngong River for irrigation is heavily polluted by wastewater that is discharged into the river without any treatment? 1=yes 2=no 3=not sure **pollute_________________**

I would like to describe a plan to protect Motoine-Ngong River from further pollution in order to mitigate the health and environmental risks attributed to untreated wastewater irrigation. First, let me give you a background.

SHOW MAP 1

The following map shows the current pollution status in Nairobi River Water Basin.

As you might be aware, the Motoine-Ngong River system has become a natural receptacle for all the untreated sewage emanating from Kibera slum due to lack of sewage infrastructure. This has led to Eutrophication of the Nairobi Dam thus leading to proliferation of Water Hyacinth.

SHOW PHOTO 1

This photo shows Nairobi Dam when it was being used for recreational activities like sailing and fishing.

SHOW PHOTO 2

As you can see in the next photo Nairobi Dam has been completely colonized by macrophytes due to nutrient loading.

SHOW PHOTO 3

The next photo shows untreated wastewater reuse for agriculture in small-scale farms.

The main risk in using wastewaters is food contamination by pathogenic microorganisms and occurrences of water-borne infections. Great health threats linked to the reuse of untreated or inadequately treated sewage water in irrigation is infection from helminths (worms) such as Ascaris (nematode) and Ancylostoma (hookworm). Also, moderate to slight risk is attributed to enteric bacteria and viruses. The negative health effects are problematic only when raw or poorly treated wastewater is used for agriculture. In order to abate the water pollution in Motoine-Ngong River and thus protect thousands of small-scale farmers who rely on the channel for irrigation, a special treatment program has been proposed. We are conducting this survey to establish whether the proposed program is anything to your household as a farmer.

Here is how the program would work.

A wetland will be constructed to ensure secondary treatment through biological purification of sewage from Kibera slum before being discharged into the Motoine-Ngong River. The proposed wetland will treat sewage water from the slum of about 170,070 people. This will ensure a significant improvement of water quality in Nairobi Dam and the Motoine-Ngong River system thus reducing the risks attributed to wastewater irrigation. The proposed wetland will have several sections.

The wastewater will first flow into the wetland through gravel-bed hydroponics (GBH). This will ensure that the anaerobic bacteria on the surfaces of GBH substrate break down the water impurities. Also, the reeds and rushes that are planted on the substrate will remove about 10% of impurities as nutrients. These macrophyte plants transmit some oxygen downwards from top-growth to the roots hence providing ecological niche for the aerobes, which enables both aerobic and anaerobic processes. The ponds in the wetland will be carefully contoured to guarantee continuous movement of water and turnover along a serpentine conduit between influent and effluent. The wastewater will be gravity-fed from the GBH into the ponds, whereby the long flow-path will ensure complete degradation. The ultraviolet radiation wastewater will disinfect (kill) pathogens due to encounter with air and sunlight in the shallow ponds. Since the contouring of the wetland system will expose the wastewater to aerobic and anaerobic processes, biodiversity will be promoted through the wide variation in habitats and depths. The wastewater will be discharged from the final pond into the river system after sufficient purification and thus ensure regeneration of fauna and flora while promoting sustainable urban agriculture.

The following drawing shows how this would be done.

SHOW FIGURE 1

The use of Gravel Bed Hydroponics (GBH) constructed wetlands for wastewater treatment and recycling has been successfully adopted in United Kingdom, China, India and Egypt.

2. Is there any additional information you would like to know about the effectiveness of Gravel-Bed Hydroponics (GBH) constructed wetland for wastewater treatment?

   1= Yes 2= No 3=Not sure **gbhinfo____________**

If the program is approved, the payments will be as below.

All the Kibera slum dwellers will be required to pay a one-time charge in order to supplement the government expenditure in construction of the wetland. The farm households like yours would also pay a special monthly tax in order to be allowed access to treated wastewater from Motoine-Ngong River channel for irrigation. The money will go to the Kibera Gravel-Bed Hydroponics (GBH) Wetland Fund. In order to ensure sustainability of the program, the collected monthly fund will be used to cover the cost of the wetland maintenance and general management of the river channel. By Law, all small-scale farmers along the Motoine-Ngong River will not be required to pay any additional tax for wastewater reuse.

Since every member of the society who pollutes and/or benefits from the Motoine-Ngong River would bear part of the cost, we are using this survey to ask people how they would vote if they had a chance to do so. So far, we have found out that some people will vote for the program while others will vote against it. Those who vote for it state that the program is worth the money to abate water pollution and thus mitigate health and environmental risks attributed to untreated wastewater irrigation. The ones who vote against it state that it is only protecting one river channel in Nairobi. Others state that the money required is too much for them. At present, the government officials have estimated that this program will cost each small-scale farm household a total of Ks.120 per month. This money will only be used to protect the Motoine-Ngong River from pollution in order to ensure sustainable urban agriculture.

3. If the program costs your household Ks.120 per month, would you vote for it or against it?

1 = For (Go to 5) 2 = Against (Go to 6) 3 = Not sure (Go to 6) **cost120**____________

4. What if the final cost estimates showed that it will cost each farm household a total of Ks.240 per month? Would you vote for it or against it?

1 = For (Go to 9) 2 = Against (Go to 7) 3 = Not sure (Go to 8) **cost240**____________

5. What if the final cost estimates showed that it will cost each farm household a total of Ks.60 per month? Would you vote for it or against it?

1 = For (Go to 9) 2 = Against (Go to 7) 3 = Not sure (Go to 8) **cost60**_____________

6. Why did you vote against the proposed program?

1 = Its not worth that much 2 = Cannot afford it 3 = It will only protect Motoine-Ngong River **voteno**____________
4 = Others (specify)

……

……

7. Briefly explain why you are not sure about how to vote for the proposed program **votenot**____________

……

……

8. What encouraged you to vote for the proposed program? **votefor_____________**

1=It will reduce water pollution in water sources

3=It will regenerate the degraded riverine ecosystem

2=It will ensure improved wastewater irrigation

4=Others (specify)

……

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Appendix C: Choice Experiment for Valuing the Treated Wastewater Reuse for Urban and Peri-Urban Agriculture

The sewerage infrastructure in Nairobi is dilapidated and even covers a very limited area because of inadequate investment and poor maintenance. Since the current sewerage system, which covers less than 40% of the population in Nairobi, can only treat less than 50% of the generated wastewater, most of the effluent is discharged into drains and rivers degrading the environment. This has led many urban and peri-urban farmers to directly and indirectly use untreated wastewater for irrigation. The Motoine-Ngong River is considered the most polluted channel in Nairobi River Basin due to: uncontrolled disposal of excreta from the major slum areas; uncontrolled disposal of solid waste from slum areas along the river channel; blockages and/or breakages of sewage lines; and untreated industrial wastewater discharged.

The main risk in using wastewaters is food contamination by pathogenic microorganisms and occurrences of water-borne infections. Great health threats linked to the reuse of untreated or inadequately treated sewage water in irrigation is infection from helminths (worms) such as Ascaris (nematode) and Ancylostoma (hookworm). Also, moderate to slight risk is attributed to enteric bacteria and viruses. The negative health effects are problematic only when raw or poorly treated wastewater is used for agriculture. We would like to know what you would do if a program to treat wastewater before it is used for irrigation was developed for Motoine-Ngong River channel.

1. Do you know that the water you draw from Motoine-Ngong River for irrigation is heavily polluted by wastewater that is discharged into the river without any treatment? 1=yes 2=no 3=not sure **pollute____________**

I would like to describe a plan to protect Motoine-Ngong River from further pollution in order to mitigate the health and environmental risks attributed to untreated wastewater irrigation. First, let me give you a background.

SHOW MAP 1

The following map shows the current pollution status in Nairobi River Water Basin.

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As you can see in the next photo Nairobi Dam has been completely colonized by macrophytes due to nutrient loading.

SHOW PHOTO 3

The next photo shows untreated wastewater reuse for agriculture in small-scale farms

Here is how the program would work. A wetland will be constructed to ensure secondary treatment through biological purification of sewage from Kibera slum before being discharged into the Motoine-Ngong River. The proposed wetland will treat sewage water from the slum of about 170,070 people. This will ensure a significant improvement of water quality in Nairobi Dam and the Motoine-Ngong River system thus reducing the risks attributed to wastewater irrigation. The proposed wetland will have several sections. The wastewater will first flow into the wetland through gravel-bed hydroponics (GBH). This will ensure that the anaerobic bacteria on the surfaces of GBH substrate break down the water impurities. Also, the reeds and rushes that are planted on the substrate will remove about 10% of impurities as nutrients.

These macrophyte plants transmit some oxygen downwards from top-growth to the roots hence providing ecological niche for the aerobes, which enables both aerobic and anaerobic processes. The ponds in the wetland will be carefully contoured to guarantee continuous movement of water and turnover along a serpentine conduit between influent and effluent. The wastewater will be gravity-fed from the GBH into the ponds, whereby the long flow-path will ensure complete degradation. The ultraviolet radiation wastewater will disinfect (kill) pathogens due to encounter with air and sunlight in the shallow ponds. Since the contouring of the wetland system will expose the wastewater to aerobic and anaerobic processes, biodiversity will be promoted through the wide variation in habitats and depths. The wastewater will be discharged from the final pond into the river system after sufficient purification and thus ensure regeneration of fauna and flora while promoting sustainable urban agriculture.

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1. Is there any additional information you would like to know about the effectiveness of Gravel-Bed Hydroponics (GBH) constructed wetland for wastewater treatment?

   1= Yes   2= No   3=Not sure   **gbhinfo____________**

Explain:

……

……

……

……

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……

……

……

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……

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CHOICE SET BLOCK 1

Choice card 1

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	medium	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	120	160	
I choose the situation	☐	☐	☐

Choice card 2

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	high	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	60	60	
I choose the situation	☐	☐	☐

Choice card 3

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	high	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	60	200	
I choose the situation	☐	☐	☐

Choice card 4

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	high	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	60	60	
I choose the situation	☐	☐	☐

Choice card 5

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	low	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	120	60	
I choose the situation	☐	☐	☐

Choice card 6

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	low	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	60	240	
I choose the situation	☐	☐	☐

Choice card 7

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	medium	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	120	60	
I choose the situation	☐	☐	☐

Choice card 8

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	high	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	120	160	
I choose the situation	☐	☐	☐

CHOICE SET BLOCK 2

Choice card 1

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	medium	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	200	60	
I choose the situation	☐	☐	☐

Choice card 2

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	medium	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	160	120	
I choose the situation	☐	☐	☐

Choice card 3

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	low	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	160	200	
I choose the situation	☐	☐	☐

Choice card 4

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	medium	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	120	200	
I choose the situation	☐	☐	☐

Choice card 5

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	low	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	160	120	
I choose the situation	☐	☐	☐

Choice card 6

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	low	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	240	120	
I choose the situation	☐	☐	☐

Choice card 7

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	low	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	120	120	
I choose the situation	☐	☐	☐

Choice card 8

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	high	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	160	240	
I choose the situation	☐	☐	☐

CHOICE SET BLOCK 3

Choice card 1

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	medium	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	240	240	
I choose the situation	☐	☐	☐

Choice card 2

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	low	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	160	60	
I choose the situation	☐	☐	☐

Choice card 3

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	high	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	120	60	
I choose the situation	☐	☐	☐

Choice card 4

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	low	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	60	160	
I choose the situation	☐	☐	☐

Choice card 5

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	medium	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	160	120	
I choose the situation	☐	☐	☐

Choice card 6

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	medium	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	200	120	
I choose the situation	☐	☐	☐

Choice card 7

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	low	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	120	240	
I choose the situation	☐	☐	☐

Choice card 8

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	medium	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	120	160	
I choose the situation	☐	☐	☐

CHOICE SET BLOCK 4

Choice card 1

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	high	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	200	120	
I choose the situation	☐	☐	☐

Choice card 2

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	low	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	160	120	
I choose the situation	☐	☐	☐

Choice card 3

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	high	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	200	160	
I choose the situation	☐	☐	☐

Choice card 4

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	high	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	160	160	
I choose the situation	☐	☐	☐

Choice card 5

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	high	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	160	160	
I choose the situation	☐	☐	☐

Choice card 6

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	low	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	60	120	
I choose the situation	☐	☐	☐

Choice card 7

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	medium	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	120	200	
I choose the situation	☐	☐	☐

Choice card 8

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	medium	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	60	120	
I choose the situation	☐	☐	☐

CHOICE SET BLOCK 5

Choice card 1

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	medium	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	120	120	
I choose the situation	☐	☐	☐

Choice card 2

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	medium	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	60	120	
I choose the situation	☐	☐	☐

Choice card 3

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	medium	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	160	200	
I choose the situation	☐	☐	☐

Choice card 4

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	medium	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	240	60	
I choose the situation	☐	☐	☐

Choice card 5

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	low	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	200	200	
I choose the situation	☐	☐	☐

Choice card 6

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	low	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	120	160	
I choose the situation	☐	☐	☐

Choice card 7

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	medium	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	160	60	
I choose the situation	☐	☐	☐

Choice card 8

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	low	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	120	240	
I choose the situation	☐	☐	☐

CHOICE SET BLOCK 6

Choice card 1

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	medium	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	200	240	
I choose the situation	☐	☐	☐

Choice card 2

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	high	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	120	120	
I choose the situation	☐	☐	☐

Choice card 3

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	high	Neither situation A nor situation B is worth the proposed tax payment.
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	☐	☐	☐

Choice card 4

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	medium	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	60	60	
I choose the situation	☐	☐	☐

Choice card 5

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	low	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	60	60	
I choose the situation	☐	☐	☐

Choice card 6

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	medium	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	60	240	
I choose the situation	☐	☐	☐

Choice card 7

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	low	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	60	160	
I choose the situation	☐	☐	☐

Choice card 8

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	low	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	160	160	
I choose the situation	☐	☐	☐

CHOICE SET BLOCK 7

Choice card 1

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	medium	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	60	160	
I choose the situation	☐	☐	☐

Choice card 2

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	medium	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	60	160	
I choose the situation	☐	☐	☐

Choice card 3

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	high	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	240	60	
I choose the situation	☐	☐	☐

Choice card 4

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	high	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	120	120	
I choose the situation	☐	☐	☐

Choice card 5

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	low	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	160	60	
I choose the situation	☐	☐	☐

Choice card 6

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	high	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	240	120	
I choose the situation	☐	☐	☐

Choice card 7

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	medium	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	160	60	
I choose the situation	☐	☐	☐

Choice card 8

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	low	
Ecosystem restoration in Motoine-Ngong River	no	yes	
Monthly municipal tax (Kshs.)	200	60	
I choose the situation	☐	☐	☐

CHOICE SET BLOCK 8

Choice card 1

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	high	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	60	200	
I choose the situation	☐	☐	☐

Choice card 2

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	medium	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	low	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	240	160	
I choose the situation	☐	☐	☐

Choice card 3

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	low	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	240	200	
I choose the situation	☐	☐	☐

Choice card 4

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	high	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	low	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	200	160	
I choose the situation	☐	☐	☐

Choice card 5

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	high	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	low	low	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	120	60	
I choose the situation	☐	☐	☐

Choice card 6

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	high	
Ecosystem restoration in Motoine-Ngong River	no	no	
Monthly municipal tax (Kshs.)	160	240	
I choose the situation	☐	☐	☐

Choice card 7

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	poor	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	high	medium	
Ecosystem restoration in Motoine-Ngong River	yes	yes	
Monthly municipal tax (Kshs.)	240	160	
I choose the situation	☐	☐	☐

Choice card 8

Attributes	Situation A	Situation B	Situation C (status quo)
Quality of treated wastewater for irrigation	medium	poor	Neither situation A nor situation B is worth the proposed tax payment.
Quantity of treated wastewater for irrigation	medium	medium	
Ecosystem restoration in Motoine-Ngong River	yes	no	
Monthly municipal tax (Kshs.)	160	160	
I choose the situation	☐	☐	☐

Appendix D: Study Area Map and Photographs

Map 1: Pollution Status in Nairobi River Water Basin

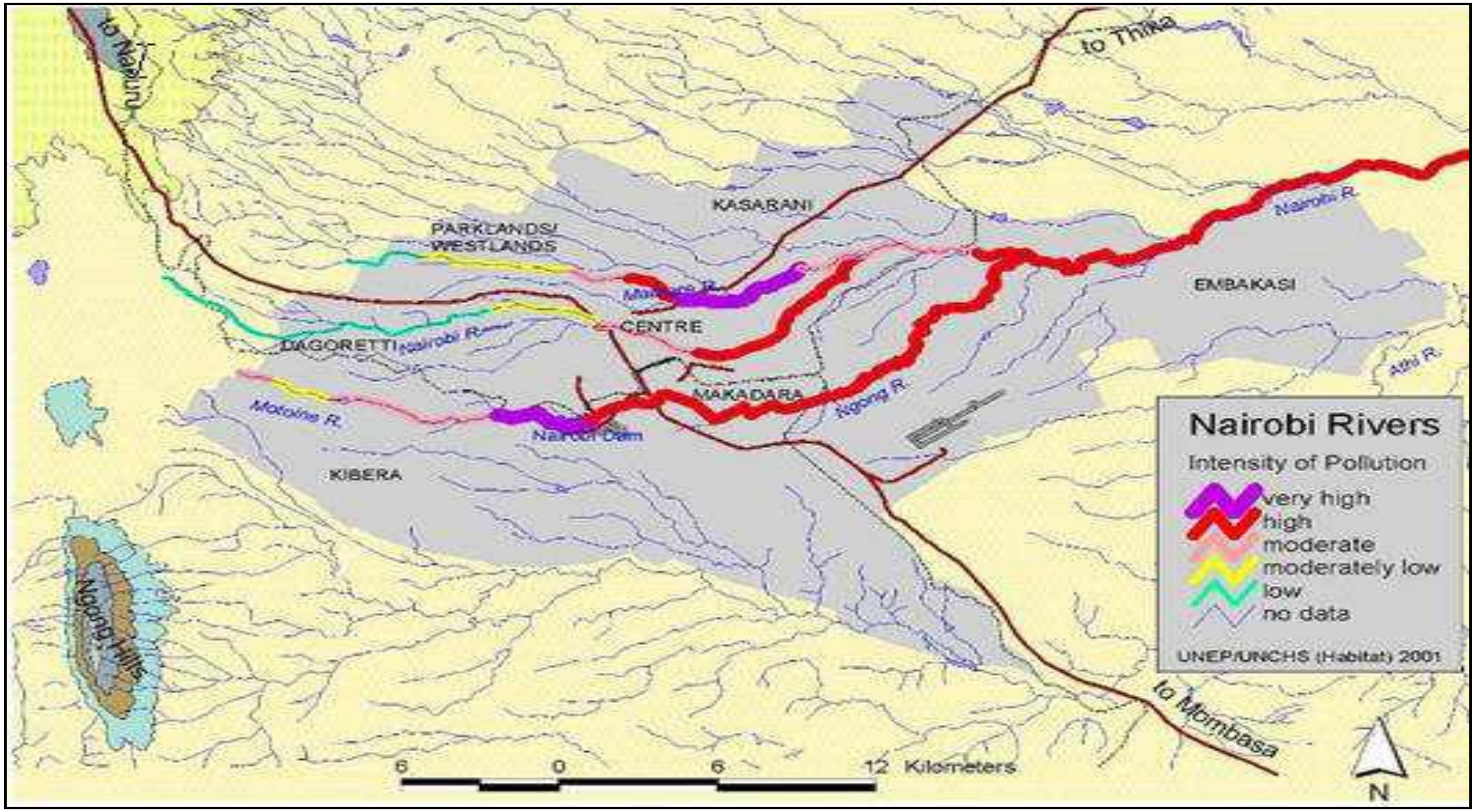
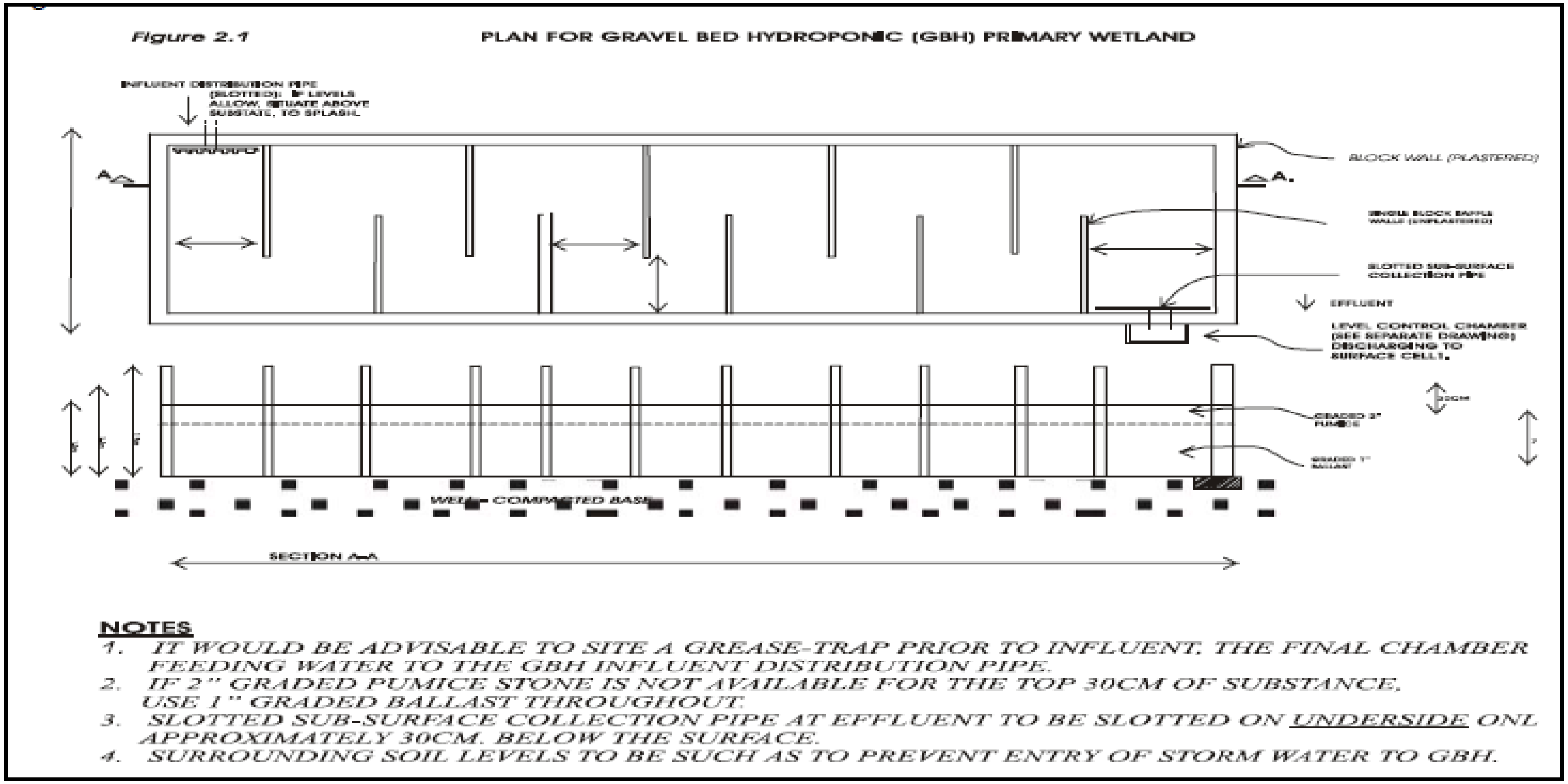


Plate 1: Nairobi Dam before pollution

Plate 2: Nairobi Dam after pollution

Plate 3: Farmers diverting polluted water for irrigation

Figure 1: Plan of a Gravel Bed Hydroponic wetland



In case my supervisor wants to check my work, I would like to ask for your cell number: …………………………..