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Full Length Research Paper

Determinants of farmers' choice of innovative risk-reduction interventions to wastewater-irrigated agriculture

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This paper identifies the innovative methods used by urban farmers to reduce the health and environmental risks linked to wastewater-irrigated agriculture in Nairobi, Kenya. A study involving 317 urban and peri-urban farmers was conducted and innovative methods identified for risk-reduction in wastewater irrigation. According to the results, the farmers' choice of adaptation measures in wastewater irrigation was: No intervention (49.8%), crops restriction (21.1%), protective clothing (12.6%), safer application (8.8%), and irrigation cessation (7.6%). The estimated model had a robust explanatory ability since the likelihood ratio statistics were statistically significant (χ^2=222.13; p=0.000). The marginal analysis results show that the following factors significantly (p=0.005) influence the farmers' choice of low-risk measures in wastewater irrigation: Household size, farming experience, membership to farmers group, access to credit, access to certified seed, access to media, crop income, awareness to World Health Organization irrigation guidelines, and awareness to wastewater hazards. Therefore, it was concluded that education support and creation of awareness about health risks in wastewater irrigation are important for enhanced adoption of risk-reduction technologies among the farmers. There is a need to design policies and programs that support farmers in safe wastewater irrigation, while raising their awareness on the health hazards attributed to untreated wastewater reuse.

Key words: Low-risk measures, marginal effects, multinomial logit, urban farmers, wastewater irrigation.

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 et al., 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, cessation of irrigation before harvesting and using protective clothing (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

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economic development of the country. The sector contributes 24% directly and 27% 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 innovative 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 Kenya.

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 and Devi, 2006; Drechsel et al., 2006; Ensink et al., 2003; Qadir et al., 2010; Rutkowski et al., 2007; Srinivasan and 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 innovative risk-reduction interventions to reduce the health risks attributed to wastewater-irrigated agriculture in peri urban and urban Kenya. 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.

Econometric model

This study employed a multinomial logit model (MNL) to identify the factors that influence the farmers' choice of risk-reduction interventions in reuse of wastewater for agriculture in the Motoine-Ngong river basin in Nairobi. 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:

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

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. The MNL for this study was based on the probability that a risk-reduction choice j is made as follows:

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

The MNL specification is:

$$\Pr ob\left(y_i = n / x_i\right) = \frac{\exp\left(X_i \beta_n\right)}{1 + \sum_{j=1}^{J} \exp\left(X_i \beta_j\right)} \quad Where \ j = 0,1,2,...,J; n = 1,2,...,J \quad (3)$$

The parameter y_i represents the alternative risk-reduction interventions to wastewater irrigation, X_i denotes a vector of all the explanatory variables of the *ith* observations, and β_i is a vector of all coefficients in the *jth* regression. However, the coefficients obtained from the estimation of equation (3) are challenging to deduce. Therefore, marginal effects of the factors on the probabilities are obtained through differentiation of Equation (4):

$$\delta_j = \frac{\partial \Pr\left(y_i = n\right)}{\partial X_i} = \Pr\left(y_i = n\right)\left[\beta_j - \sum_{j=0}^{J} \Pr\left(y_i = n\right)\beta_n\right] = \Pr\left(y_i = n\right)\left(\beta_j - \overline{\beta}\right) \quad (4)$$

The risk-reduction interventions considered in this study include: Crops restriction, protective clothing, safer application techniques and irrigation cessation. The independence of irrelevant alternatives (IIA) assumption was considered in order for the MNL estimates to be consistent.

RESEARCH METHODOLOGY

The location of this 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 kg 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 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. Whereas the selected sample size was 325 respondents (Equation 5), 8 questionnaires were rejected due to incomplete information and hence 317 were used in the analysis.

The sample size was obtained using the following formula (Kothari, 2004):

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

$$= \frac{2.576^2 * 0.98(1-0.98)}{0.02^2} = 325$$

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%.

A structured questionnaire was administered to urban and peri-urban farmers between December 2011 and February 2012. This study purposively selected Kibera slum due to high population of urban and peri-urban farmers who rely on wastewater- irrigated agriculture for livelihoods and also the lack of sewerage infrastructure. A representative sample of the farmers was randomly selected for interview in this research. In order to analyse the determinants of farmers' choice of innovative risk-reduction interventions to wastewater-irrigated agriculture, the dependent variables are crops restriction, protective clothing, safer application techniques and irrigation cessation. The considered independent variables are: household size, farming experience, age of the household head, education level of household head, extension on crop and livestock, membership to farmers group, support from non-governmental organizations (NGO), access to credit, access to certified seed, access to media, log of crop income, awareness to WHO irrigation guidelines, and awareness to wastewater hazards. These variables were selected based on literature and availability of survey data.

RESULTS AND DISCUSSION

Descriptive statistics

The descriptive results show that households have an average size of 4.61 members in Kibera slum (Table 1), which compares well with the current mean household size estimation of 5.0 persons per household in the slum (Umande Trust, 2012). Household size may not necessarily have a positive relationship with adoption behaviour since large families may be forced to divert some labour into non-farm activities to increase income (Yirga, 2007). Respondents interviewed had an average farming experience of 5.2 years and hence able to make informed decisions in crop and animal husbandry. Several studies show that farming experience promotes the adoption of improved technologies (Maddison, 2006; Nhemachena and Hassan, 2007). The 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 this study area was 7.94 years. More years of education may be linked to an increased access to information and hence technology adoption. The study by Maddison (2006) shows a positive relationship between the education level of the household head and adoption behaviour. Results of this study show that the log of crop income is Kshs.7.06. The increase in crop income may provide an incentive for household head to adopt improved technologies. The results show that the mean access to agricultural extension services is 26.5% for the sample of selected farmers. A study Yirga (2007) shows a positive relationship between access to extension services and adoption behaviour of farmers.

This study shows that about 39.4% 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. The farmers who had some support from the non-governmental organizations were 26.5%. This support may provide essential resources that can promote the adoption behaviour of urban and peri-urban farmers. Descriptive results show that 35.3% of farmers have access to credit facilities. The increased access to credit facilities may enable farmers to purchase essential farm inputs such as irrigation facilities and hence ease the resource constraint. Therefore, increased access to credit facilities has a positive relationship with the adoption behaviour of farmers (Pattanayak et al., 2003). Access to certified seeds in this study area was about 48.6%. This may have a positive relationship with adoption behaviour of farmers (Buah et al., 2011). The results show that the access to media in the sample studied was 44.8%. This study hypothesizes that increased media access has a positive impact on technology adoption among the urban and peri-urban farmers. According to this study, only 23.1% of the sample of farmers was aware of the wastewater irrigation guidelines by the World Health Organization (WHO). The guidelines' awareness is considered to have a positive relationship with the adoption behaviour. Also, awareness to wastewater hazards was 52.7% in this study sample. This study hypothesizes that increased awareness to wastewater hazards is positively related to adoption behaviour.

Table 2 presents the adaptation strategies of urban and peri-urban farmers in wastewater irrigation to reduce health and environmental risks. About 49.8% of the interviewed farmers had not adopted any innovative risk-reduction interventions in wastewater-irrigated agriculture.

The urban and peri-urban farmers who practiced crop restrictions to reduce wastewater-related risks were approximately 21.1%. About 12.6% of the urban and peri-urban farmers relied on protective clothing for reduction

Table 1. Description of explanatory variables.

Independent variable	Mean	S.D.	Description
Household size	4.612	1.744	Continuous
Farming experience (years)	5.195	6.329	Continuous
Age of the household head (years)	40.215	11.223	Continuous
Education level of household head (years)	7.935	2.601	Continuous
Log of crop income (kshs.)	7.063	1.032	Continuous
Percentage			
Access to agricultural extension services		26.5	Dummy, 1 if visited and 0 otherwise
Membership to farmers group		39.4	Dummy, 1 if a member and 0 otherwise
Supported by NGO		26.5	Dummy, 1 if supported and 0 otherwise
Access to credit		35.3	Dummy, 1 if has access and 0 otherwise
Access to certified seed		48.6	Dummy, 1 if has access and 0 otherwise
Access to media		44.8	Dummy, 1 if has access and 0 otherwise
WHO irrigation guidelines' awareness		23.1	Dummy, 1 if aware and 0 otherwise
Awareness to wastewater hazards		52.7	Dummy, 1 if aware and 0 otherwise

S.D. is standard deviation

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

Variable	Percent of respondents
No intervention	49.8
Crops restriction	21.1
Protective clothing	12.6
Safer application	8.8
Irrigation cessation	7.6
Total number of respondents	317

of health risks in wastewater irrigation. There were on average 8.8% of the farmers in this study sample who had adopted safer application techniques in wastewater irrigation.

The cessation of irrigation before harvesting was adopted by about 7.6% of the interviewed farmers involved in wastewater reuse in agriculture. These innovative risk-reduction measures employed by urban and peri-urban farmers in Kenya were similar to other findings in the wastewater irrigation literature in developing countries (Keraita et al., 2007, Keraita, 2008; Knudsen et al., 2008; Marenya and Barrett, 2007; Obuobie et al., 2006; Weldesilassie et al., 2011).

Econometric analysis

The results of multinomial logit (MNL) 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 were crop restrictions, protective clothing, safer application and irrigation cessation.

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 and 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% confident level. This suggests that the MNL model is appropriate to identify the determinants of farmers' choice of innovative risk-reduction interventions to wastewater-irrigated agriculture in Kenya. The likelihood ratio statistics for this study were statistically significant (χ^2=222.13; p=0.000), which implies that the model has a robust explanatory ability. Since the MNL model estimates provide only the direction of the impacts of explanatory variables on response variable, a further analysis to obtain marginal effects was conducted (Table 4). The marginal effects provide the expected change in probability of a particular innovative risk-reduction intervention selected by farmers with respect to a unit change in explanatory variable.

Household size

The results show that the adoption of innovative risk-reduction interventions in wastewater irrigation significantly declines with an increase in household size. A unit increase in household size results in 3.6% (p=0.045) decline in the probability of using crop restrictions and 2.1% (p=0.026) decrease in the probability of using protective clothing. Also, the results show that a unit increase in household size decreases the probability of using safer wastewater application by 1.1% (p=0.048) and irrigation cessation by 0.3% (p=0.097). A

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

Explanatory variable	Crops restriction		Protective clothing		Safer application		Irrigation cessation	
	Coefficient	P level	Coefficient	P level	Coefficient	P level	Coefficient	P level
Household size	-0.305**	0.020	-0.300**	0.040	-0.252	0.156	-0.120	0.483
Farming experience	0.081**	0.040	0.080*	0.060	-0.053**	0.017	-0.098	0.300
Age of the household head	-0.033	0.179	-0.036	0.197	-0.004	0.898	0.007**	0.033
Education level of household head	0.054**	0.047	0.022*	0.080	0.201**	0.024**	0.012	0.310
Access to agricultural extension services	-0.350***	0.010	0.251	0.570	-0.511	0.361	-0.654	0.276
Membership to farmers group	1.184***	0.003	1.432***	0.001	1.488***	0.003	2.085***	0.000
Supported by NGO	0.473**	0.025	1.155**	0.011	1.064**	0.039	1.242**	0.021
Access to credit	2.886***	0.000	2.310***	0.000	2.077***	0.000	1.488***	0.007
Access to certified seed	1.026**	0.012	0.800*	0.082	0.111	0.833	1.205**	0.045
Access to media	1.272***	0.001	0.292	0.495	1.137**	0.020	0.574	0.256
Log of crop income	0.378**	0.041	0.292	0.167	0.638***	0.007	-0.234	0.350
Awareness to WHO irrigation guidelines	0.879*	0.053	1.597***	0.001	0.521	0.375	-0.592	0.489
Awareness to wastewater hazards	0.714*	0.063	1.168***	0.009	0.997**	0.049	0.673**	0.039
Constant	-5.366***	0.001	-4.966***	0.008	-9.457***	0.000	-3.458	0.123
Diagnostics								
Base category					No intervention			
LR chi-square					222.13***			
Log likelihood					-315.774			
Pseudo - R^2					0.2602			
Number of observations					317			

*, ** and ***, Significant at 1, 5 and 10% level respectively.

similar study by Adeoti (2009) found that household size has a negative impact on adoption of irrigation technology in Ghana. Similar results were obtained from .Therefore, it can be inferred that the bigger the household size the lower the chance of adopting risk-reduction measures in wastewater-irrigated agriculture.

Farming experience

Farming experience of the household head significantly influences the choice of risk-reduction measures in wastewater-irrigated agriculture. The results of this study show that a unit increase in farming experience raises the probability of using crops restriction to reduce health risks by 1.3% (p=0.020) and that of using protective clothing by 1.8% (p=0.001). Similarly, the probabilities of using safer application methods and practising irrigation cessation in wastewater reuse increase by 2.6% (p=0.032) and 1.2% (p=0.089) respectively with a unit increase in farming experience. The results from a related study in Nigeria shows that farming experience has positive effect on adoption of improved agricultural technologies (Agwu et al., 2008). Thus, it can be deduced that the greater the farming experience the more likely is the household head likely to adopt risk-reduction measures.

Age of the household head

The age of household head has a negative and non-significant impact on the adoption of risk-reduction measures in wastewater irrigation. A unit increase in the age of household head reduces the adoption of crop restriction method by 3.4%, use of protective clothing by 1.3%, employment of safer application techniques by 1.1 %, and irrigation cessation by 2.6%. A study conducted in Western Kenya to identify the determinants of adopting Imazapyr-resistant maize technologies shows that age is positively related to technology adoption (Mignouna et al., 2011). This shows that the older the household head the less the likelihood of adopting risk-reduction measure in wastewater irrigation.

Education level of household head

As expected, the increase in education of the household head has a significant and positive impact on the adoption of the considered risk-reduction measures in wastewater irrigation. A unit increase in education level of household head increases the probability on using crop restriction by 14.4% (p=0.019) and wearing protective clothing by 15.1% (p=0.000). The probability of using safer

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

Explanatory variable	Crops restriction		Protective clothing		Safer application		Irrigation cessation		No intervention	
	Coefficient	P level	Coefficient	P level	Coefficient	P level	Coefficient	P level	Coefficient	P level
Household size	-0.036**	0.045	-0.021**	0.026	-0.011**	0.048	-0.003*	0.097	-0.067***	0.009
Farming experience	0.013**	0.020	0.018***	0.001	0.026**	0.032	0.012*	0.089	-0.019	0.341
Age of the household head	-0.024	0.210	-0.013	0.258	-0.011	0.816	-0.026	0.553	-0.016	0.236
Education level of household head	0.144**	0.019	0.151***	0.000	0.101**	0.027	0.074**	0.046	-0.019	0.211
Access to agricultural extension services	-0.046	0.401	0.018	0.334	-0.031	0.359	-0.027	0.267	0.057	0.499
Membership to farmers' group	0.093*	0.090	0.051**	0.045	0.068*	0.086	0.090**	0.014	-0.342***	0.000
Supported by NGO	0.034**	0.046	0.101**	0.022	0.159**	0.019	0.053**	0.015	-0.217***	0.009
Access to credit	0.355***	0.000	0.119*	0.079	0.048***	0.003	0.027**	0.041	-0.540***	0.000
Access to certified seed	0.127**	0.026	0.050***	0.004	0.022**	0.043	0.046*	0.059	-0.201**	0.011
Access to media	0.172***	0.000	-0.017	0.672	0.060	0.105	0.008	0.757	-0.223***	0.002
Log of crop income	0.045*	0.086	0.017	0.399	0.041**	0.016	-0.022*	0.087	-0.082**	0.030
Awareness to WHO irrigation guidelines	0.083***	0.000	0.186***	0.007	0.023***	0.004	-0.046**	0.019	-0.226***	0.009
Awareness to wastewater hazards	0.060**	0.023	0.092**	0.028	0.049**	0.014	0.015***	0.002	-0.215***	0.004

*, ** and ***, Significant at 1, 5 and 10% level respectively.

application of wastewater increases by 10.1% (p=0.027) and that of irrigation cessation increase by 7.4% (p=0.046) with a unit increase in education of household head. A study on smallholder agricultural productivity in sub-Saharan Africa shows that low level of education limits technology adoption (Muzari et al., 2012). Therefore, higher education of household head promotes the adoption of innovative risk-reduction measures in wastewater irrigation.

Access to agricultural extension services

Access to agricultural extension services has a non-significant and negative impact on crop restriction, safer application and irrigation cessation. However, the access to extension services has a positive but non-significant effect on protective clothing. The unit increase in the access to agricultural extension services reduces the probability of using crop restriction by 4.6%, the probability of employing safer application by 3.1% and the probability of using irrigation cessation by 2.7%. In contrast, a unit increase in access to agricultural extension services increases the probability of wearing protective clothing by 1.8%. A similar study in Nigeria by Ajayi and Okunlola (2005) shows that agricultural extension services have a positive impact on adoption of root crops technologies. Therefore, it can be inferred that higher access to agricultural extension services may inhibit adoption of risk-reduction technologies in the reuse of untreated wastewater for urban agriculture.

Membership to farmers' group

The results show that membership to farmer's group has a significantly positive effect in adoption of risk-reduction interventions in wastewater irrigation. A unit increase in membership to farmers' group increases the probability of adopting crop restriction by 9.3% (p=0.090), the probability of wearing preventive clothing by 5.1% (p=0.045), the probability of using safer application by 6.8% (p=0.086) and the probability of adopting irrigation cessation by 9.0% (p=0.014). A similar study conducted in Cameroon shows that membership to farmers' group has a positive effect on the adoption intensity of improved yam seed technology (Nchinda et al., 2010). This indicates that higher membership in farmers' groups is an important factor in promotion of risk-reduction measures for urban wastewater users.

Supported by NGO

The farm households which had received support from NGOs were more likely to adopt innovative risk-reduction interventions to minimize health risks linked to wastewater irrigation. An increase in NGOs support by one unit significantly raises the probability of adopting crops restriction by 3.4% (p=0.046), probability of wearing protective clothing by 10.1% (p=0.022), probability of employing safer application methods by 15.9% (p=0.019), the probability of using irrigation cessation method by 5.3% (p=0.015). Another study to determine the diffusion technology in Benin shows that Support by NGO positively influences the adoption of improved technology for rice parboiling (Dandedjrohoun et al., 2009). This implies that the significant involvement of NGOs in urban and peri-urban agriculture in Nairobi played a vital role in enhancing the adoption of risk-reduction technologies in wastewater irrigation. Thus, the higher the NGOs support for wastewater users, the greater the adoption of innovative risk-reduction intervention in wastewater-irrigated agriculture.

Access to credit

Access to credit for the farmers has a positive and significant effect on the possibility of adopting crops restriction, protective clothing, safer application and irrigation cessation in wastewater irrigation. A unit growth in access to credit facilities increases the probability of adopting crops restriction by 35.5% (p=0.000) and also raises the probability of using protective clothing by 11.9% (p=0.079). Similarly, a unit increase in access to credit facilities raises the probability of using safer application techniques by 4.8% (p=0.003) and the probability of adopting irrigation cessation by 2.7% (p=0.041). The study by Mohamed and Temu (2008) in Zanzibar shows that the access to credit has a positive effect on the adoption of agricultural technologies. This can be used to infer that the greater the access to credit facilities to wastewater users the more likely is the adoption of risk-reduction measures.

Access to certified seed

Access to certified seed is positively related to the adoption of risk-reduction interventions in wastewater irrigation. The results show that a unit increase in access to certified seeds increases significantly the probability of adopting crops restrictions, protective clothing, safer applications and irrigation cessation by 12.7% (p=0.026), 5.0% (p=0.004), 2.2% (p=0.043), and 4.6% (p=0.059) respectively. Results of a study in Nigeria on sustainable rice productivity and rural farmers' welfare, the access to certified seed positively impacts on the adoption of improved agricultural technology (Awotide et al., 2012). Therefore, it may be deduced that a higher access to certified seed motivates the urban farmers to adopt risk-reduction measures to lower the hazards attributed to wastewater reuse.

Access to media

Access to media has a positive impact on the choice of risk-reduction measures in wastewater irrigation. The results show that the crop income has a positive and significant impact on adoption of innovative risk-reduction measures in wastewater irrigation. A unit increase in the log of crop income increases the use of crops restriction method by 4.5% (p=0.000) and wearing of protective clothing by 1.7%. A study on rice farming technologies in China by Chi (2008) shows that access to media enhances the adoption of technology among rice farmers. This implies that a well organised media access for urban and peri-urban farmers can be used to disseminate important information on wastewater reuse. This can in turn lead to increased adoption of low-risk technologies in wastewater irrigation hence minimizing health hazards.

Log of crop income

As expected, the results show that a unit increase in the log of crop income significantly raises the probability of adopting crop restriction by 4.5% (p=0.086) and safer application techniques by 4.1% (p=0.016). Also, the probability of using protective clothing increased by 1.7% once the log of crop income was raised by a unit. However, a unit increase in the log of crop income results in significant decrease in the probability of using irrigation cessation method by 2.2% (p=0.087). These results is consistent with the findings from a study in Ethiopia which shows that farm income is a key determinant in farmers' decisions to adopt agricultural technologies (Asfaw et al., 2011). Also, another study on sustainable soil conservation technologies in Iran shows that farm income positively effects adoption of sustainable soil conservation practices (Rezvanfar et al., 2009). Hence, it may be inferred that higher crop income encourages adoption of innovative measures to reduce health risks from wastewater reuse.

Awareness to WHO irrigation guidelines

Awareness to WHO irrigation guidelines has a positive and significant impact on the adoption of innovative risk-reduction measures in wastewater irrigation. A unit increase in awareness to WHO irrigation guidelines raises the probability of using crops restriction by 8.3% (p=0.000) and the probability of wearing protective clothing by 18.6% (p=0.007). Similarly, the probability of adopting safer wastewater irrigation technologies increases by 2.3% (p=0.004) as a result of a unit increase in awareness to the irrigation guidelines. However, the probability of using irrigation cessation in order to reduce health risks in wastewater irrigation declines by 4.6% (p=0.019) with a unit increase in awareness to WHO irrigation guidelines. The review of literature focused on agricultural adoption in United States of America shows that environmental awareness has a positive effect on the adoption of best management practices (Prokopy et al., 2008). This shows that the greater the awareness to WHO irrigation guidelines, the greater is the possibility of adoption of risk-reducing innovative technologies.

Awareness to wastewater hazards

Awareness to wastewater hazards has a significantly positive impact on the adoption of innovative risk-reduction interventions in wastewater irrigation. The results show that a unit increase in awareness to wastewater hazards increases the probability of using crops restriction, wearing protective clothing, adoption of safer application, and employment of irrigation cessation by 6.0% (p=0.023), 9.2% (p=0.028), 4.9% (p=0.014), and 1.5% (p=0.002) respectively. A similar study conducted in Ethiopia shows that (Weldesilassie et al., 2011) lack of health risk awareness is a key limitation for individuals' decision to work on irrigation farms. These results may be used to infer that greater awareness to wastewater hazards enhances the adoption of risk-reduction measures in wastewater-irrigated agriculture.

CONCLUSIONS AND POLICY IMPLICATIONS

This study provides an analysis of the factors that affectthe choice of innovative risk-reduction interventions to reduce the risks related to wastewater reuse in agriculture. The urban and peri-urban farmers indicated that they had employed the following risk-reduction innovations: crops restriction, protective clothing, safer application, and irrigation cessation. The MNL model was used in this study to investigate the socio-economic and institutional factors that condition the choice of the risk-reduction measures in wastewater irrigation. In order to ensure efficient estimations under the IIA assumption, the Hausman test was conducted on the MNL model. Marginal effects from the fitted model were used to measure the expected change in probability of the choices made by farmers with respect to unit change in explanatory variables.

The marginal analysis results show that education level and farm income significantly affect the adoption of innovative risk-reduction interventions in wastewater reuse. Therefore, there is need for policy makers to enhance support of education systems and supply of relevant inputs to promote urban agriculture in an effort to reduce the hazards of urban wastewater irrigation. The results also reveal that access to credit facilities, access to certified seed and access to media significantly influence adoption of innovative measures to reduce the health risks due to wastewater irrigation. This paper recommends provision of affordable credit schemes, supply of certified seeds and production of inexpensive media for urban and peri-urban farmers in order to promote the adoption of risk-reduction interventions in wastewater irrigation. The membership to farmers' group and support by NGO also significantly affect the choice of risk-reduction measures in wastewater reuse for agriculture. Thus, future policies that encourage informal community linkages and also incentivise funding of urban agriculture projects by NGOs can greatly enhance the adoption of innovative risk-reduction measures in wastewater irrigation. Lastly, there is a need to design policies and programs that support farmers in safe wastewater irrigation, while raising their awareness on the health hazards attributed to untreated wastewater reuse. This is likely to reduce health risks to the farmers and consumers of wastewater-produced vegetables and also improve livelihoods of many urban people.

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