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Perception on untreated wastewater irrigation for vegetable production in Ghana

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Abstract Using household-level survey data, this study investigates farmers' perceptions on untreated wastewater use for irrigation of vegetable farms in urban and peri-urban Kumasi of Ghana. Empirical results from an ordered probit model show that there is some relationship between personal characteristics of farmers such as age, education and gender, and perceptions of farmers on health-related risks of untreated wastewater use for irrigation. Policy efforts should be geared toward updating the knowledge, skills and attitudes of producers through frequent training and workshops so that wastewater irrigation farmers in Ghana would better appreciate health-related risks of waster irrigation and how to adopt risk mitigating strategies. Further research for a more in-depth analysis on those relationships in the short-term with immediate emphasis on improving adoption of safer irrigation technologies among wastewater irrigation farmers is recommended.

Keywords Ghana · Farmer's perception · Vegetable production · Wastewater irrigation

1 Introduction

Untreated wastewater is becoming an indispensable source of irrigation water for urban and peri-urban vegetable agriculture in most African countries where urban poverty is on ascendancy. Urban vegetable farming provides income generation and serves as one of the

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useful pathways of solving the urban food insecurity problems in sub-Saharan Africa. One of the Millennium Development Goals (MDGs) of ensuring environmental sustainability and eliminating poverty and hunger as noted by WHO (2006), has seen a growing recognition of the resource value of wastewater and its nutrient contents for agricultural production. The major driving force of the increased use of untreated wastewater for vegetable production in the urban areas of Africa are increasing water scarcity and stress, and degradation of fresh water resources resulting from improper disposal of waste (both human and industrial waste), increasing population growth and its resultant demand for food (WHO 2006). It has further being argued that as the demand for fresh water intensifies, wastewater would frequently be seen as a valuable resource (Hamilton et al. 2007). The global priority of vital importance requiring urgent and immediate solutions is the sustainable use of water for irrigation (FAO 2002).

Irrigated vegetable production in most major cities of Ghana has been intensified (Obuobie et al. 2006) and because the demand for exotic and some traditional vegetables is not seasonal, farmers tend to cultivate vegetable all year round wherever irrigation water is available (Amoah et al. 2006). The importance of wastewater's high nutrient content and its year round availability in sub-Saharan Africa has been well documented (Ouedraogo 2002; Kilelu 2004; Keraita et al. 2003; Amoah et al. 2006). It is however reported that the untreated wastewater used in irrigation of vegetables contains faecal coliforms and other pathogens which are dangerous to human health (Keraita et al. 2003; Amoah et al. 2006). This contamination is traced to the polluted irrigation water from domestic and industrial solid and liquid waste. The World Health Organization (WHO) sensing danger on untreated wastewater use for urban agriculture, recommended a health-based target of 6–7 log units to reduce the risk associated with untreated wastewater. Blumenthal et al. (2000) note that the log unit reduction for faecal coliforms of geometric mean number per 100 ml for crops likely to be eaten uncooked, sports field and public park during irrigation should be less than three.

In many developing countries, most wastewater is seldom treated, and correspondingly contains high levels of pathogenic organisms such as bacteria, viruses, protozoa and helminth which can potentially cause enteric diseases (Kilelu 2004). With Ghanaian data, Armar-Klemesu (2000) reported high levels of contamination of waste water irrigated vegetables, which has increasing health-related risks to both farmers and consumers. Kilelu (2004) and Abdulai et al. (2011) for instance, argue that health risks of wastewater use for agricultural production are closely linked to the type of irrigation practices adopted by the farmers. Notably, some irrigation farmers walk through or step into dug-out wells which are normally contaminated with poultry manure, sewage and other fecal contaminates. Moreover, irrigated wastewater which has high levels of trace elements and heavy metals could pose potential risks to human health and even be toxic to plants (Cornish et al. 1999; Kilelu 2004). Most pathogens in untreated wastewater irrigated farms which cause enteric diseases as noted by Keraita et al. (2002) could survive on crops for about 15 days and hence could be carried to the markets. Kilelu (2004) argues that the microbiological contaminants could cause diseases to consumers if untreated wastewater is used to irrigate food crops. Evidence provided by Faruqui et al. (2004) indicates that farmers who predominantly used untreated wastewater in Dakar were found to have a higher rate of infection with intestinal parasites compared to farmers who mixed wastewater and groundwater. Findings from a study by Hussain et al. (2002) show higher incidences of diarrheal diseases among wastewater irrigation farmers in Pakistan. Feenstra et al. (2000) also found high prevalence of hookworms and roundworms among farmers who irrigated their farms with untreated wastewater. Further evidence provided by Blumenthal and Peasey (2002) and WHO (2006) suggests that agri and aqua-cultural producers, as well as consumers of wastewater irrigated vegetables contract helminth infections, such as round worm (*Ascaris*), whipworm (*Trichuris*), and hookworm. In Cambodia, exposure to urban wastewater has been reported to be associated with skin diseases, especially dermatitis, on the hands and legs of aquacultural producers (van der Hoek et al. 2005). Scot et al. (2004) report that a range of viruses and protozoa in wastewater has been found to be associated with health risks such as chronic low-grade gastrointestinal disease as well as outbreaks of more acute diseases including cholera in Jerusalem and Dakar, and Typhoid in Santiago.

Although WHO recommends the use of treated wastewater for irrigation of vegetables, treatment costs appear to be too high for the predominant smallholder vegetable farmers in developing countries (WHO 2006). The ongoing crusade by FAO/WHO/IDRC to meet the target of reducing the health-related risks of untreated wastewater use for urban agriculture include the introduction of improved irrigation options which comprise of a package of irrigation systems and practices that involve the application of hygienic handling procedures in irrigation vegetable production (WHO 2007). The safer irrigation options are safer technologies for fetching, transporting and applying irrigation water so that health and environmental risks associated with the use of untreated wastewater to producers and consumers are reduced to the barest minimum (WHO 2006; Keraita et al. 2007; Abdulai et al. 2011). Improving farmers' capacity to monitor irrigation water quality especially on safer and efficient irrigation practices as pointed out by Kinane et al. (2008), cannot be overemphasized.

A number of studies have addressed the health and environmental implications of wastewater use for vegetable farming in Africa (Sonou 2001; Keraita et al. 2002; Ouedraogo 2002; Keraita et al. 2003; Kilelu 2004; Amoah et al. 2006; Amoah 2008; Amoah et al. 2009, Abdulai et al. 2011), but rigorous empirical studies have not been undertaken on the socioeconomic factors which influence vegetable farmer's perception on the use of untreated wastewater for vegetable production. Other studies have however been undertaken on public perceptions of water reuse and other sectors (Ajzen 2001; Dishman et al. 1989; Po et al. 2003). A study by Dishman et al. (1989) for instance focused on finding ways to persuade people to accept recycled water. Ajzen (2001) posits that the different factors that would influence people's willingness to use recycled water for horticultural purposes are based on planned behavior such as attitudes toward using the water, their perception of what others think about using recycled water, and their perceived ease or difficulty in using recycled water. Notably, such studies have been limited in their scope which often aimed at using incentives to increase public acceptance but as noted by Po et al. (2003), no research has investigated rigorously the different factors that influence public perceptions of water reuse and how these factors inform people's decision-making processes. Po et al. (2003) have emphasized that an examination of the different ways and situations where factors such as health, environment, treatment, distribution and conservation issues can impact on people's willingness to use recycled water must be given greater attention by researchers, policy makers and other stakeholders. The theme of this present study is therefore relevant.

The main hypothesis tested in this paper is that household and farm characteristics tend to influence farmers' perception on the use of untreated water for vegetable production. Perception of health risk by farmers is a critical factor in any effort to introduce changes to irrigation practices that may reduce risk to both farmers and consumers. Kilelu (2004) revealed that farmers' perception on untreated wastewater irrigation encourages them to adopt risk mitigating strategies such as the use of furrow and flooding irrigation that allow less contact between water and the edible parts of the plants. Knudsen et al. (2008) point out that the need for further insights into farmers' perceptions of risk and health risk awareness when using human excreta and wastewater for agricultural production is very paramount in informing stalkeholders on how to tailor promotional health programmes and activities toward the education of farmers and consumers on untreated wastewater irrigation. Also understanding the perception of farmers on vegetables produced from untreated wastewater for income generation is crucial for improving current irrigation practices especially in the framework of the recommended guidelines for safer vegetable production (WHO 2006) and also for recommending policies targeted at urban poverty alleviation and food security (Raschid-Sally et al. 2004).

Section 2 presents a brief overview on vegetable production and wastewater irrigation in Ghana. Section 3 discusses the materials and methods employed in the paper. Section 4 presents the descriptive and empirical results. Conclusion and policy recommendations are provided in Sect. 5.

2 Vegetable production and wastewater irrigation in Ghana

Urban vegetable production is gaining prominence in Ghana due to its economic potential of reducing urban poverty. Keraita et al. (2007) point out that an important channel for ensuring urban food security and providing balanced diets for many of the urban dwellers in Ghana may lie in urban vegetable farming. Cornish and Lawrence (2001) report that in dry seasons, more than 12,000 hectares of vegetable farms under untreated wastewater irrigation could be found in urban and peri-urban Kumasi of Ghana, a period when vegetable prices are high (Obuobie et al. 2006). Evidence provided by Keraita et al. (2003) show that about an estimated 200 bottomland vegetable farmers as well as about 60,000 households with backyards exist in urban Kumasi. Cornish et al. (2001) also note that as many as 12,800 farmers in the peri-urban areas of Kumasi have been recorded as growing dry season vegetables. In Accra, over 1,000 farmers are involved in market-oriented urban vegetable production where fresh vegetables are eaten by over 200,000 residents daily (Keraita et al. 2007). The commonly grown vegetables in most urban farms in Ghana include lettuce, cabbage, green pepper and spring onions which are often eaten raw as salads in urban fast food restaurants in the cities (Keraita et al. 2007). Urban vegetable producers are predominantly from rural areas of Ghana and with some experience in farming. Obuobie et al. (2006) have observed that although about 90% of urban vegetable producers appear to be men, retail and marketing of vegetables are predominantly women-dominated activities.

Treated water would have been the best option for safer vegetable production but as Amoah et al. (2006) point out, the use of treated water for vegetable production in Ghana is constrained because more than 40% of city dwellers even lack good drinking water. The sanitation infrastructure of Ghana as in most sub-Saharan African countries is not properly developed (Keraita et al. 2002). Moreover, increasing population growth and lack of investment in water treatment plants in Kumasi have overstretched the few available sanitation facilities, triggering pollution of nearby streams by large volumes of untreated or partially treated wastewater. It is estimated that about 280 million m^3 of grey and black wastewater is produced annually in Ghana (Agodzo et al. 2003). Since only 4.5% of households in Ghana have access to wastewater treatment plants (Ghana Statistical Services 2002), it is imperative that the rest of the domestic wastewater discharge ends up in streams, rivers, drains and other water bodies. For instance in Kumasi, a total of about 20,000 m^3 of wastewater is generated each day, but less than 10% is collected for treatment (Keraita et al. 2003). This situation as rightly pointed out by WHO (2006) is alarming because in the absence of treated water, urban wastewater which is mostly a liquid discharge from homes, commercial premises and individual disposal systems or municipal sewer pipes is the main irrigation water source for urban vegetable production in most peri urban and urban locations of Africa (Keraita et al. 2002; Keraita et al. 2007; Amoah 2008).

3 Materials and methods

The section discusses the farmer's perception model and the data employed in the study.

3.1 Farmers' perception model

Farmers are assumed to irrigate their vegetable farms with untreated wastewater and that they apply the available irrigation practices for fetching, sieving, transporting and applying irrigation water on the farm. Following Greene (2008), an ordered probit model could be specified as in Eq. 1 to examine the factors which tend to influence farmers' health-related perceptions on using untreated wastewater for irrigating vegetable farms:

$$T_i^* = \beta' X_i + \varepsilon_i \tag{1}$$

where T_i^* is a latent and continuous measure on health-related perception of farmer i who uses untreated wastewater for vegetable production, X_i is a vector of explanatory variables influencing farmers' perception, β' is a vector of parameters to be estimated, and ε_i is a random error term assumed to be standard normal distributed. Since T_i^* is latent, we observe coded discrete responses of the variable T_i as follows:

$$T = \begin{cases} 0 & \text{if} \quad -\infty \le T_i^* \le \mu_1 (\text{strongly disagree}) \\ 1 & \text{if} \quad \mu_1 \le T_i^* \le \mu_2 (\text{disagree}) \\ 2 & \text{if} \quad \mu_2 \le T_i^* \le \mu_3 (\text{neutral}) \\ 3 & \text{if} \quad \mu_3 \le T_i^* \le \mu_4 (\text{agree}) \\ 4 & \text{if} \quad \mu_4 \le T_i^* \le \infty (\text{strongly agree}) \end{cases} \tag{2}$$

Greene (2008) points out that the vector of parameters β' and the thresholds $\mu's$ can be jointly estimated using the maximum likelihood procedure which yields consistent and asymptotic estimators. The marginal effects of the independent variables are estimated using the estimated coefficient of the model. The associated probabilities with the coded responses of the ordered probit model are:

$$\begin{aligned} P_1(0) =& \Pr(T_i = 0) = \Pr(T_i^* \le \mu_1) = \Pr(\beta' X_i + \varepsilon_i \le \mu_1) = \Pr(\varepsilon_i \le \mu_1 - \beta' X_i) \\ =& \phi(\mu_1 - \beta' X_i) \\ P_i(1) =& \Pr(T_i = 1) = \Pr(\mu_1 < T_i^* \le \mu_2) = \Pr(\varepsilon_i \le \mu_2 - \beta' X_i) - \Pr(\varepsilon_i \le \mu_1 - \beta' X_i) \\ =& \phi(\mu_2 - \beta' X_i) - \phi(\mu_1 - \beta' X_i) \\ & \vdots \\ P_i(k) =& \Pr(T_i = k) = \Pr(\mu_k < T_i^* \le \mu_{k+1}) = \Pr(\varepsilon_i \le \mu_{k+1} - \beta' X_i) - \Pr(\varepsilon_i \le \mu_i - \beta' X_n) \\ =& \phi(\mu_{k+1} - \beta' X_i) - \phi(\mu_k - \beta' X_i) \\ & \vdots \\ P_i(K) =& \Pr(T_i = K) = \Pr(\mu_K < T_i^*) = 1 - \phi(\mu_K - \beta' X_i) \end{aligned} \tag{3}$$

where k is an alternative response, $P(T_i = k)$ is the probability that a vegetable farmer i responds in manner k, and $\phi(\cdot)$ is the standard normal cumulative distribution function. The positive signs of the estimated parameters β indicate higher health-related risks associated with the use of untreated wastewater for vegetable irrigation as the value of the associated variables increase, while negative signs suggest the converse (Greene 2008).

3.2 Description of data

The study employs a cross-sectional data collected in 2008 on 202 vegetable farmers in the urban and peri-urban Kumasi who use untreated wastewater for irrigation. The population of Kumasi is about 1.0 million with an annual growth rate of 5.9% (Ghana Statistical Services 2002). The city attracts daytime population of about 1.5 to 2 million people. The total land area is about 225 km^2 of which 40% is an open land. It is located in the middle belt of Ghana; a predominantly tropical forest zone with semi-humid tropical climate of an annual average rainfall of 1,420 mm and mean monthly temperature ranges of 24–27°C. The rainfall pattern is bimodal with the major season falling between March and July and a minor rainy season around September and October. The soil type is the forest Ochrosol, a very rich soil which supports the cultivation of foodstuffs and vegetables. Important streams and rivers which run through Kumasi metropolis are the Owabi River, Subin River, and Wewe River. Improper solid and liquid waste disposal in the city has polluted most of these rivers (Obuobie et al. 2006). The hilly nature of the city's landscape is such that most streams run through inland valleys which serve as production sites for urban vegetable growers.

The study's population comprises of vegetable farmers in the urban and peri-urban Kumasi, a location of about 25 km from the city centre. A stratified random sampling of 202 vegetable farmers constituting 74 project demonstration farmers from 8 farm sites and 128 non-project farmers from 15 farm sites were selected for the study. The project demonstration farmers and farm-sites refer to farmers and farm-sites respectively where implementation trials on non-treatment risk-reduction techniques were carried out in the Kumasi Metropolis in a World Health Organization (WHO)/Food and Agriculture Organization (FAO)/Kwame Nkrumah University of Science and Technology (KNUST) project. The non-treatment risk-reduction techniques comprise of a package of irrigation systems and practices that involve the application of hygienic handling procedures in irrigation vegetable production (WHO 2007). Apart from this stratification, the selection was based on differences in farm-sites such as water availability, source of irrigation water, and farm sizes. The 74 vegetable project demonstration farmers were randomly sampled from farm sites in Gyinyase (39), Emena (19), Kotei (5), Ayeduase New Site (5) and Apemso (6). The 128 non-project demonstration farmers were randomly selected from farm sites in Ayigya (20), Serwaba (20), Danyame (3), Karikari Farm Site (12), Twumduase (9), Kotei (7), Korkoben (6), Nkentinkrono (5), Tech Arable (19), Boadi (6), Asuoyeboah (13), Ahodwo (6) and Kwadaso (2) all in the Kumasi Metropolis of Ghana.

4 Results and discussion

This section present results and discussion on the socioeconomic variables used in the regression models, farmers' perception and empirical results.

Table 1 Variable definition and sample statistics

Variable	Variable definition	Mean	SD
Dependent variables			
PERCDISF	Perception of farmers on health implications for producers of wastewater irrigated vegetables	4.30	1.16
PERCDISC	Perception of farmers on health implications for consumers of wastewater irrigated vegetables	4.34	1.13
Independent variables			
AGE	Age of farmer (years)	35.00	10.60
EDUC	Years of schooling (years)	6.59	4.71
GENDER	1 if male, 0 otherwise	0.96	0.22
HOHSIZE	Household size	1.76	0.58
INCOME	Average monthly income (in GH¢)	194.93	132.08
CREDIT	1 if farmer has access to credit, 0 otherwise	0.12	0.32
FAMORG	1 if farmer is a member of farmer's organization, 0 otherwise	0.20	0.40
INDFARM	1 if farmer is engaged in individual farm enterprise, 0 otherwise	0.95	0.23
CASHCP	1 if farmer cultivates other cash crop, 0 otherwise	0.17	0.38
FMSIZE	Farm size (hectares)	0.23	0.23
DISIRWT	Distance of farm from irrigation water source (km)	8.22	7.31
SAND	1 if farmer cultivates vegetable on sandy soil, 0 otherwise	0.14	0.35
LOAM	1 if farmer cultivates vegetable on loamy soil, 0 otherwise	0.10	0.30
OWNED	1 if farmer cultivates vegetable on own plot, 0 otherwise	0.10	0.31
COMMU	1 if farmer cultivates vegetable on community plot, 0 otherwise	0.49	0.50
OWNIRG	1 if irrigation equipment is owned, 0 otherwise	1.00	0.10
AWNTOP	1 if farmer is aware of safer irrigation options, 0 otherwise	0.34	0.48
MAKTAVL	1 if farmer has available market for vegetable, 0 otherwise	0.97	0.17

Source: Authors' computation

4.1 Socioeconomic characteristics

The descriptive statistics of the variables investigated in the study are presented in Table 1. The average age of 35 years of the sampled vegetable farmers is lower than the national average of 45 years for maize farmers and 50 years for cocoa famers in Ghana. About 96% of the vegetable farmers were males. Predominant activities of urban vegetable production such as watering, weeding and application of manure which require intense manual labor are mostly done by males. The mean year of schooling of the vegetable farmers is 7 years which is below secondary education and the national average of 15 years of universal and compulsory basic education. The mean monthly income for the vegetable farmers was GH¢194 (US$190) which is three time higher than the national average income for food crop farmers.[1] About 83.1% of the farmers cultivated less than half of a hectare which is relatively lower than the national average of 3.0 hectares for small-scale farmers. The vegetables cultivated by the farmers include cabbage, cauliflower, lettuce, spring onions, green pepper, cucumber and carrot.

[1] At the time of the survey, US$ 1 = GH¢1.1693 in 2008. GH¢ denotes Ghana Cedi, the official currency of Ghana.

The sources of irrigation water include streams, shallow wells, ponds, rivers, bore-holes and pipe-borne water. As Keraita et al. (2007) noted, most of these water bodies are contaminated from domestic and industrial solid and liquid waste due to the failure of the local authorities to treat and safely dispose of wastewater generated in the cities of Ghana. The farmers who cultivate vegetables in the low-lying areas prefer shallow dugout wells located about 1–2 m from streams and rivers for irrigating their vegetable farms. One of the potential sources of contamination to the dug wells is from anthropogenic activities uphill and the fact that farmers usually have to walk through or step into the dug wells in order to fetch irrigation water which increases the risks of contamination. Most rivers, drains and shallow wells in Kumasi have loads of bacteria exceeding the standards set by WHO for safer irrigation (IWMI 2002). The bore-holes and pipe-borne water on the other hand have less contamination and associated health risks. The shallow groundwater is also another source of safer irrigation water for vegetable production. Gbewonyo (2007) and Gerstl (2001) found no significant differences in risk perception between farmers using different water qualities in Accra and Ouagadougou respectively. With quantitative microbial risk assessments techniques, Seidu et al. (2008) could not even predict gross differences in irrigation water sources with respect to the degree of health risks, Consistent with what Keraita et al. (2007) found using field trials on vegetable farms in Ghana, the vegetable farmers mostly used watering cans for irrigation which normally contaminate vegetables when the wastewater is applied directly to the leaves. However the contamination could be reduced if the application of the water is done on the soil surface. Keraita et al. (2007) further notes that farmers who use drip irrigation kits had the highest potential to reduce contamination on vegetables whilst those who employ furrow irrigation techniques had little potential of reducing health risks associated with wastewater irrigation.

4.2 Farmers' attitudes and perceptions toward wastewater reuse

The survey data as shown in Fig. 1 indicates that about 66% of the farmers are aware of the improved irrigation options for wastewater irrigation but 28% had actually attended a workshop on how to safely use wastewater for irrigation. About 57% of them also indicated that they are aware of a law which restricts the use of wastewater for irrigation. Majority of the vegetable farmers however have positive attitudes toward the use of wastewater for irrigation probably due to the fact most of them have been exposed to the improved safer options for wastewater irrigation. For instance as indicated in Fig. 2, about 78% were of the view that the irrigation systems they are using are effective in reducing risks on wastewater use while 10% disagreed with this assertion. Related to this, almost 69% strongly agreed that the existing water sources for irrigation are safe. Moreover, almost 95% believe that the vegetables they produce from wastewater irrigation are wholesome for public consumption with only 2% of them disagreeing with this notion. However about 79% was of the view that using wastewater for irrigation could cause infection to farmers with 16% disagreement on this assertion.

Employing perception indices, the farmers' health-related risk perceptions on the use of untreated wastewater for irrigation were also investigated and the findings are presented in Table 2. Each perception indicator was ranked on a 5-point likert scale indicating whether the farmer strongly disagrees (=−1.0), disagrees (=−0.5), is neutral (=0), agrees (=0.5) or strongly agrees (=1.0) with an assertion on health-related risks to producers and consumers of wastewater irrigated vegetables. About 69% of the farmers strongly agreed that untreated wastewater irrigation has health implications (average score = 0.65) and 70% strongly agreed that untreated wastewater irrigated vegetables pose a health danger to

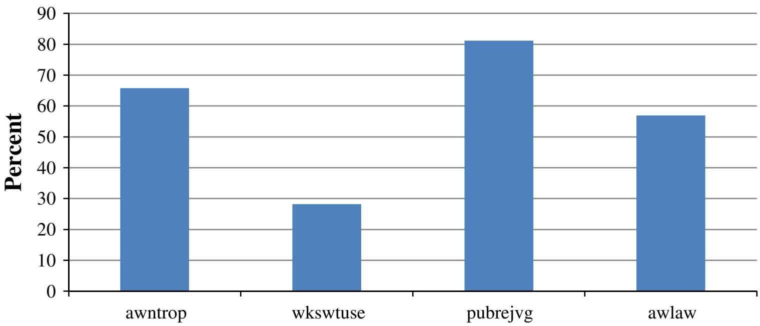

Fig. 1 Awareness on improved irrigation options for wastewater irrigation. *awntrop* denotes awareness of the improved irrigation options of wastewater irrigation. *wkswtuse* denotes attendance of workshop on safe water use. *pubrejvg* denotes public rejection of wastewater irrigated vegetables. *awlaw* denotes awareness of law that restricts the use of wastewater for agriculture purposes. *Source*: Field Survey (2008)

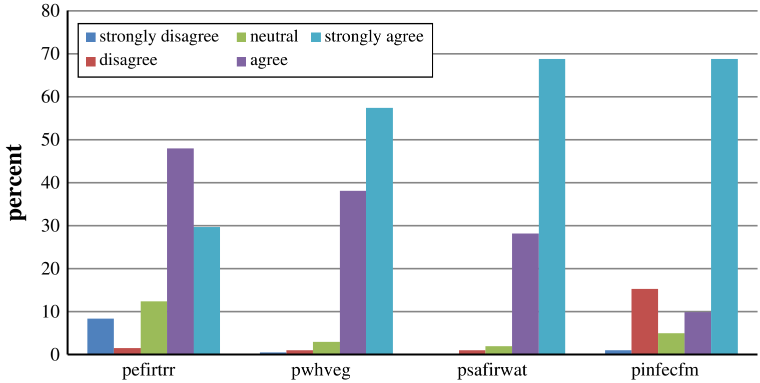

Fig. 2 Attitudes of vegetable farmers on the use of wastewater for irrigation. *pefirtrr* denotes perception on the effectiveness of irrigation system to reduce risk on wastewater. *pwhveg* denotes perception on the wholesomeness of vegetables by the public. *psafirwat* denotes perception on safeness of current irrigation water source. *pinfecfm* denotes perception on infection to farmers from the use of wastewater for irrigation. *Source*: Field Survey (2008)

consumers (average score = 0.67). Averaging the two scores led to a positive health risk perception index, HRPI of 0.66. There is evidence from studies on consumer health risks that support the perceptions of these farmers (Ouedraogo 2002; Kinane et al. 2008). No significant differences in perceptions were found between project and non-project farmers.

4.3 Empirical results

The dependent variable used in the regression model represents each perception indicator ranked into five coded responses. Two ordered probit models were estimated to assess the factors which influence farmer's perceptions on health-related risks to producers (PERCDISF) and to consumers (PERCDISC). The explanatory variables include personal characteristics (age, gender, and education), household characteristics and assets (household size, ownership of irrigation equipment, income and access to credit); farm characteristics (farm size, soil type, land tenure systems and distance of vegetable farm to irrigation water

Table 2 Vegetable farmers' perception on health-related risks of untreated wastewater irrigation

Perception indicators	Percentage of farmers					Mean score		
	Strongly disagree (score = −1)	Disagree (score = −0.5)	Neutral (score = 0)	Agree (score = 0.5)	Strongly Agree (score = 1)	Farmer's aware	Farmer's not aware	Total
Untreated wastewater irrigation has health implications for producers	1	15	5	10	69	0.80	0.45	0.65
Untreated wastewater irrigated vegetables have health implications for consumers	0	17	2	11	70	0.83	0.47	0.67
Health-risk perception index (HRPI)						0.82	0.46	0.66

Source: Authors' computation

source). Other relevant socioeconomic variables included in the ordered probit models to examine their effects on farmers' perception were ownership of vegetable farm plots, membership of farmers' organization, awareness of safer irrigation options, cultivation of other cash crops and market availability for wastewater irrigated vegetables.

The empirical estimates of farmers' perception on health-related risks to producers (PERCDISF) and to consumers (PERCDISC) of wastewater irrigated vegetables are reported in Table 3. The ordered probit models were estimated through the maximum likelihood approach. The marginal effects indicating the likelihood of farmers to "perceive strongly" that using untreated wastewater for irrigation has health implications are presented in Table 4. Other statistics reported include the z-values, McFadden R^2 and the log-likelihood statistics. The coefficients of the variables representing age, education, gender, household size, access to credit, membership of farmer's organization, land quality and cultivation of other crops apart from vegetables are all significant at the conventional levels. Specifically, age and education which indicate the human capital of farmers have positive impacts on "strongly agreeing" perception that wastewater irrigation is associated with health-related risks to producers and consumers. The empirical findings agree with a proposition by Robinson et al. (2005) that highly experienced and educated individuals are more enlightened and knowledgeable on the use of wastewater for agricultural purposes. The marginal effects presented in Table 4 indicate that each additional year of schooling increases the "strongly agreeing" perception of farmers on health implications of wastewater use for producers by 1.4% and for consumers by 1.5%. The significant difference in the health risk perceptions of the farmers may stem from the fact that farmers who are aware of the potential health risks from using polluted water sources appear to perceive such risks to be low and seem willing to accept these risks because of the economic benefits they derive from using polluted water and the unavailability of other water sources (Gbewonyo 2007). Moreover, Knudsen et al. (2008) argue that farmers know the associated health risks of excreta and wastewater use for agriculture but they view these as unavoidable risks related to their agricultural production. Compared to consumers, the lower health risk perception for farmers concur with the findings by Amoah et al. (2006) that educated urban vegetable farmers in Ghana are becoming aware of the health implications of stepping into low quality streams and rivers which are mostly polluted with domestic and industrial wastes, as they take the necessary precautions in reducing direct contact with the untreated wastewater during fetching. Similarly, each additional year increase in the age of the farmer increases the probability of "strongly agreeing" perception that wastewater could cause infection to farmers by 4.4% and to consumers by 3%. Age as a human capital variable is used to proxy experience of the farmer and the empirical finding is consistent with the hypothesis by Keraita et al. (2010) that experience of the farmer could influence farmers' perception on health risks of wastewater use. Notably, Keraita et al. (2008) report that highly experienced wastewater irrigated farmers usually rate health-related risks lower than those who are less experienced in wastewater irrigation farming. Peres et al. (2006) emphasize that knowledge and awareness of risks strongly influence how risks are perceived and managed by farmers. Keraita et al. (2010) further note that although awareness could be based on practical experience, farmers normally incorporate new information and concepts from colleague farmers, agricultural extension officers, field schools, input suppliers, the media and development workers.

The empirical results also show that male farmers tend to have "strongly agreeing" perception that wastewater has health implications for producers of wastewater irrigated vegetables probably due to fact they are more involved in the drudgery of irrigation such as manually transporting the wastewater in cans to the vegetable farms. Specifically,

Table 3 Ordered probit estimates of farmers' perception on health risks of wastewater irrigation

Variables	PERCDISF		PERCDISC	
	Coefficients	*z*-Value	Coefficient	*z*-Value
AGE	0.1381***	2.50	0.0900*	1.65
AGE SQUARED	−0.1569**	−2.28	−0.1028*	−1.76
EDUC	0.0450*	1.89	0.0450*	1.86
GENDER	0.9488**	2.01	1.0240**	2.13
HOHSIZE	0.5392***	3.91	0.3955***	2.90
CREDIT	1.1671***	4.59	0.7966***	2.95
FAMORG	0.8576***	2.92	1.1898***	4.52
INDFARM	0.5721	1.20	0.1057	0.20
CASHCP	1.1173***	4.81	1.1535***	5.11
INCOME	0.0003	0.71	0.0005	0.80
FMSIZE	−0.3202	−0.69	−0.1052	−0.21
DISIRWT	0.0083	0.61	0.0018	0.13
SAND	−0.2784	−0.93	−0.4769*	−1.69
LOAM	−1.0042***	−3.13	−1.3967***	−4.81
OWNED	0.9650***	3.54	0.8014***	2.86
COMMU	−0.1012	−0.41	−0.3508	−1.38
OWNIRG	0.3965	0.29	0.2100	0.15
AWNTOP	−0.0702	−0.23	−0.4937*	−1.68
MAKTAVL	−0.3239	−0.60	−0.2908	−0.53
Pseudo-R^2	0.1899		0.1912	
Log-likelihood	−158.459		−152.443	
Observations	202		202	

PERCDISF denotes perception of farmers on health implications for producers of wastewater irrigated vegetables

PERCDISC denotes perception of farmers on health implications for consumers of wastewater irrigated vegetables

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

households with more males are 30.2% more likely to have strong agreeing perception on health implications for producers and 34.6% more likely for consumers. As already noted, the sampled vegetable farmers were predominantly males (96%). A similar study by Robinson et al. (2005) however indicates that women are especially concerned about pumping wastewater into groundwater for subsequent use whilst both genders were of the view that in order to reduce the health risks to producers, wastewater reuse for agricultural purposes should not involve personal contact. The propensity of farmers to agree strongly with the perception that wastewater has health implications for producers and consumers is higher for farmers with larger household sizes probably due to the manual labor involved in sieving and transporting the irrigation water (Abdulai et al. 2011). The variable representing credit is positive and significantly different from zero in all the regression models. Households with access to credit are 25.2% more likely to agree strongly with the perception that untreated wastewater for irrigation has health implications for producers and 21.4% more likely for consumers. Kilelu (2004) indicates that farmers rely on services such as access to credit and farm inputs to enable them gain access to better quality water and land.

Being a member of a farmer's organization increases the probability of farmers to agree strongly with the perception that untreated wastewater use for irrigation has health-related risks. As indicated already, about 28% had attended workshops on safe wastewater use for

Table 4 Marginal effects of farmers' perception on health-related risks of wastewater irrigation

Variables	PERDISF	PERDISC
AGE	0.0439***	0.0304*
AGE SQUARED	−0.0499**	−0.0347*
EDUC	0.0143*	0.0152*
GENDER	0.3015**	0.3455**
HOHSIZE	0.1714***	0.1334***
CREDIT	0.2518***	0.2140***
FAMORG	0.2204***	0.3031***
INDFARM	0.2067	0.0366
CASHCP	0.2603***	0.2896***
INCOME	0.0001	0.0002
FMSIZE	−0.1018	−0.0355
DISIRWT	0.0026	0.0006
SAND	−0.0939	−0.1736*
LOAM	−0.3716***	−0.5150***
OWNED	0.2211***	0.2128***
COMMU	−0.0322	−0.1183
OWNIRG	0.1260	0.0709
AWNTOP	−0.0221	−0.1724*
MAKTAVL	−0.0917	−0.0896

PERCDISF denotes perception of farmers on health implications for producers of wastewater irrigated vegetables

PERCDISC denotes perception of farmers on health implications for consumers of wastewater irrigated vegetables

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

irrigation. Information on workshops, training and credit packages for farmers is usually transmitted through farmer-based organizations to members. Notably, social networks facilitate the flow of information which tends to influence farmers' perception and decisions on the mode of agricultural production (Kilelu, 2004; Bouma et al. 2008). The negative influence of the land quality variable suggests that farmers with good quality land for vegetable production have lower health-related risk perception on wastewater use for irrigation of vegetables. The implication here is that the economic benefits to the farmers from cultivating on quality land tend to over ride their perception on health-related risks of wastewater reuse for agriculture. Knudsen et al. (2008) even argue that although Vietnamese farmers perceive wastewater as dirty and harmful for people, it has positive long-term effect on the soil and thus nutritious for plants and fish. Moreover, Amoah et al. (2006) and empirical evidence provided by Abdulai et al. (2011) suggest that most of the safer irrigation techniques for fetching and sieving untreated wastewater for irrigation are not all that sensitive to land quality, hence the lower health-related risk perception of the farmers. The same empirical findings could be said of the farm size variable, *albeit* statistically insignificant even at the 1% level. Self-ownership of plots tend to have strong agreeing perception that wastewater could cause infection to them. Notably, vegetable cultivators who owned their farm plots are 22.1% more likely to perceive strongly that using wastewater for irrigation is associated with health-related risks to producers and 21.3% more likely to consumers. Farmers' awareness on existing safer irrigation options for wastewater irrigation of vegetables decreases their strongly agreeing perception that wastewater irrigated vegetables could cause infection to consumers. This is apparently because of the proven non-risk reduction techniques that farmers have been exposed to in the project. Using data from Kenya, Kilelu (2004) found out that farmers use safer irrigation technologies to achieve less contact between water and the edible parts of the plants, as a way of minimizing risks for crop contamination. As already noted, the non-treatment options introduced by World Health Organization (WHO), Food and Agriculture Organization(FAO) and International Development Research Center (IDRC) have the potential of reducing the health risks associated with untreated wastewater irrigation to the barest minimum (WHO 2007).

5 Conclusion

This study has examined farmers' perception on untreated wastewater use for irrigation of vegetables. The household survey data employed was collected in 2008 on 202 vegetable farmers in urban and peri-urban Kumasi of Ghana. The socioeconomic factors which could influence farmers' perception on health-related risks of untreated wastewater use for irrigation of vegetables were explored with the ordered probit model. Understanding farmers' perception on untreated irrigation water use for income generation is critical for the promotion of safer vegetable production and also crucial for recommending policies for food security and poverty alleviation in Ghana and other sub-Saharan African countries. The main sources of irrigation water in the Kumasi metropolis of Ghana include streams, shallow wells and rivers but these water bodies are polluted due to contamination from industrial and domestic liquid and solid waste within the city. In the absence of treated water for irrigation, urban vegetable farmers resort to the use of untreated wastewater for irrigation. Using perception indices, farmer's perception on health-related risks to both producers and consumers were positive. The empirical estimates from the ordered probit models also show that age, gender, education, household size, credit, membership of farmer's organization, land quality, cultivation of other crops apart from vegetables and ownership of vegetable plots may influence farmer's perception on health-related risks to producers and consumers. Notably, human capital and gender tend to positively influence farmers perception that untreated wastewater use for irrigation has health implications for producers and consumers.

Due to the increasing demand for raw and leafy vegetables by the ever-growing urban population in Ghana, sound policy initiatives are needed to ensure reduction of health-related risks associated with untreated wastewater by vegetable farmers. As the study has revealed, health-related risks of untreated wastewater use for irrigation is of paramount concern to vegetable farmers. It is therefore relevant that farmers' perceptions are built upon to encourage them to implement risk reduction strategies. In the short-term, these include improving the human capital of producers through frequent education, training and local workshops on safer use of wastewater for irrigation. Farmers should also be encouraged to use protective clothing and adopt better ways for fetching, transporting and applying wastewater. Other policy options toward risk reduction include involvement of relevant government institutions and local media in promoting safer techniques by providing farmers with safer irrigation water like shallow groundwater, protection of water sources, filtration of irrigation water, using boots when stepping in water sources and treating soils against pathogens (Keraita et al. 2010). The opinions of non-farmers were not investigated in this current study. It is therefore recommended that future health-related risk perception studies should explore this possibility.

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