UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

AGRICULTURAL WASTEWATER USE, INCIDENCE AND COSTS OF ILLNESS AMONG URBAN FARM HOUSEHOLDS IN OUAGADOUGOU, BURKINA FASO

MOHAMMED ABDULAI

(UDS/MEC/0047/15)

2017

UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

AGRICULTURAL WASTEWATER USE, INCIDENCE AND COSTS OF ILLNESS AMONG FARM HOUSEHOLDS IN OUAGADOUGOU, BURKINA FASO

BY

MOHAMMED ABDULAI (M.Phil. in Agricultural Economics)

THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS, FACULTY OF AGRIBUSINESS AND COMMUNICATIONS SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN AGRICULTURAL ECONOMICS

SEPTEMBER, 2017

DECLARATION

Student

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere:

Candidate's signature:…………………………..Date……………………………..

Name:………………………………………………………………………………

Supervisors'

We hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidance on supervision of thesis laid down by the University for Development Studies.

Principal Supervisor's Signature:………………………Date……………………..

Name:………………………………………………………………………………

Co-Supervisor's Signature:……………………………Date……………………...

Name:………………………………………………………………………………

ABSTRACT

Agricultural wastewater irrigation practices increasingly reached problematic levels, thereby raising concerns for higher risks and costs of water-related diseases for farm households. After reviewing the empirical literature, it appears, however, that both micro and macro level studies have not provided clear evidence to show the linkage between wastewater irrigation and incidence and costs of illness. The main objective of this study is to analyze how wastewater use for irrigation influences incidence and financial costs of illness among farm households, and the effect of illness on household farm production. Using a cross-sectional data, results showed that wastewater use was strongly correlated with incidences of malaria, skin infections, and diarrhoea. Also, financial burden of illness was significantly higher for households that used wastewater compared with those that used relatively clean-water. Incidence of malaria, household non-farm income, size of dependants, and number of care-givers were among factors that significantly influenced farm households' financial burden of illness. Adoption of wastewater or clean-water was generally influenced by factors such as household non-farm income, access to extension service, type of farm cultivated, location of farm, and costs of clean-water. Illness reduced family labour supply to household farm, but increased hired labour use, which offset the effect of illness on farm income. It is, however, argued that distributing insecticide mosquito nets and protective clothing, and implementing a broader health insurance scheme will reduce exposure to diseases and mitigate against catastrophic financial burden of illness. Also, increasing extension access, providing wastewater filters, promoting backyard farming and off-farm income-generating activities, among others, will profoundly control wastewater use and increase adoption of relatively clean-water for irrigation.

ACKNOWLEDGEMENT

My greatest gratitude goes to Allah, the Merciful and the Beneficent, for sustaining my life and good health, without which I would not have been able to successfully complete this thesis in particular, and the Mphil programme as a whole.

I am also highly indebted to my supervisors, Dr. Samuel A. Donkoh and Mr. Isaac Gershon Kodwo Ansah for their immense contributions to this work measured in terms of their dedicated time, ideas, guidance, and material support for me before and during the compilation of this thesis work. May Almighty God sufficiently reward both of you!

The grant from GlobE-UrbanFood^{Plus} (UFP) that financed my data collection in Ouagadougou, Burkina Faso, is also gratefully acknowledged.

Significant thanks also go to Dr. Paul Kwame Nkegbe and Mr. Yazeed Abdul Mumin for their insightful comments on my data analysis.

DEDICATION

I conscientiously dedicate this work in its entirety to my Mother, Rahinatu Salifu, for her selfless support incomparable to none throughout the entire work.

LIST OF ACRONYMS

2SLS	**Two-Staged Least Squares**
3SLS	**Three-Staged Least Squares**
BLUE	**Best Linear Unbiased Estimator**
COI	**Cost-of-Illness**
COIs	**Cost-of-Illness Studies**
CSSVD	**Cocoa Swollen Shoots Virus Disease**
EPD	**Environmental Protection Department**
FBOs	**Farmer-Based Organizations**
FCFA	**Franc Communaute Financiere Africaine**
GDP	**Gross Domestic Product**
GLS	**Generalized Least Squares**
GPS	**Global Positioning System**
HCE	**Health Care Expenditure**
HDSS	**Health and Demographic Surveillance System**
HSPC	**Health and Social Promotion Centre**
IMF	**International Monetary Fund**
IMR	**Inverse Mills Ratio**
IWMI	**International Water Management Institute**

LICs	**Lower Income Countries**
MCHIP	**Maternal and Child Health Integrated Programme**
MLM	**Maximum Likelihood Method**
MoH	**Ministry of Health**
NGOs	**Non-Governmental Organizations**
OLS	**Ordinary Least Squares**
OOPP	**Out-of-Pocket Payment**
OS	**Open Space**
Ouaga	**Ouagadougou**
PNDS	**National Programme for Health Development**
SAF	**Smoking Attribution Fraction**
UFP	**Urban Food Plus**
UNDP	**United Nations Development Programme**
VIF	**Variance-Inflation Factor**
WAEMU	**West African Economic and Monetary Union**
WHO	**World Health Organization**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background

The agricultural sector plays a vital role in the growth and economic development of developing countries than the most industrialized economies (Todaro and Smith, 2012). The sector directly or indirectly employs more than half of the economically active population in Africa, and constitutes the largest contributor to GDP, wealth creation and poverty reduction, particularly among rural households (Osei-Akoto *et al*. 2013). It serves as the engine of growth and economic development in developing countries by providing large proportion of their foreign exchange for the importation of capital equipment, raw materials and market for industrial sector, and food for the general population (Todaro and Smith, 2012).

Sustained growth in agricultural productivity is critical for a meaningful structural transformation of any country's economy because it does not only cause growth in farm incomes, but also stimulates both forward and backward linkages between the farm and non-farm economy, resulting in sustained economic growth, broad-based poverty reduction and economic development (Osei-Akoto *et al*. 2013). It is equally essential for ensuring food and nutrition security in countries experiencing rapid urban population growth (Kumar, *et al*. 2008).

However, transient human diseases such as child malnutrition, malaria, diarrhoea, measles, and debilitating parasitic worm infections like guinea worm, have become notorious inhabitants of African countries, which serve as fundamental setbacks on efforts to raise agricultural productivity and economic growth, and to eradicate the vicious cycles of poverty in which they are trapped (Todaro and Smith, 2012; Osei-Akoto *et al*. 2013). Infectious diseases have long been known to suppress the productivity of agricultural workers in Sub-Saharan Africa (SSA) and elsewhere (Larson *et al*. 2005). Among these major diseases, malaria is one of the greatest threats facing development in Africa today (Ajani and Ashagidigbi, 2008).

Nevertheless, many countries in the region have concentrated investments in technical, institutional, and price support mechanisms as well as human capital development programmes designed to enhance growth in technical efficiency of smallholder farmers and ensure accelerated output growth in the agricultural sector, and consequently achieve rapid economic growth and development (Kumar, *et al*. 2008; Todaro and Smith, 2012). Rapid growth in public investments in research, irrigation, training, extension, and physical infrastructure such as roads and electricity are the real tangible efforts African countries are making to raise agricultural productivity (Kumar, *et al*. 2008; Osei-Akoto *et al*. 2013).

Similarly, agriculture serves as the engine of growth of Burkina Faso's economy. The sector is predominated by subsistence smallholder farms of less than 5 hectares (FAO, 2014). Its contribution to GDP grew from 29.4 percent in 2009 to 33.6 percent in 2013 resulting in an increase in the real growth rate of GDP from 5.2 percent to 6.5 percent within the same period (CIA, 2010a, 2016). The sector also employs over 90 percent of the economically active Burkinabes, while the remaining10 percent of the workforce derive their income from both the industry and service sectors, making agriculture the largest sector that provides livelihood for the largest proportion of the population (CIA, 2016a; Simonsson, 2005).

Despite the significant role agriculture plays in employment and wealth generation, and the decade of sustained economic growth, productivity in the sector is low, while poverty is high partly due to poor quality of, and access to, health-care services, thereby making diseases a significant factor that affect the welfare, productivity and income levels of households in the country (Simonsson, 2005). For instance, cereal productivity in Burkina Faso is among the lowest in the world, while growth rates in yields and returns per labour per day are generally low in the country (Reardon, *et al*. 1997).

These can be linked to high incidences of transient diseases such as malaria, diarrhoea, and upper respiratory and skin problems among farm households due to insanitary environments, widespread dependence on wastewaters for irrigation farming, and the misapplication of pesticides, and rearing of livestock (Simonsson, 2005; CIA, 2016b). In addition, from 1990 to 2010, malaria, diarrhoea, and lower respiratory infections were the three leading sicknesses that caused significant number of premature deaths of people in the country (IHME, 2010). The rate of morbidity also precipitated between 2006 and 2008 as a result of increasing incidence of malaria, malnutrition, and diarrhoea in Burkina Faso (Combary, 2016), which may have major implications for household costs of illness, agricultural labour use as well as farm productivity and income. Other factors that are largely responsible for downward movements in agricultural productivity in the country include inadequate access to improved irrigation water systems, high cost of inputs and machinery, and lack of properly defined and enforceable property rights as well as low technological adoption (FAO, 2014).

Growth in disease burden among urban farm households can partly be attributed to high and growing proportion of urban dwellers living in despicable sanitary conditions, as 81.4 per cent of the population lack access to improved sanitation facilities in 2012 (CIA, 2016b). Also, the country's urban population grew from 12 per cent in 1994 to 25 per cent in 2009, causing rate of urban poverty and risks of illnesses to rise within the same period (IMF, 2014), thereby causing further downward changes in urban agricultural productivity. Given these, the chance of a Burkinabe between the ages of 30 and 70 years dying from cardiovascular, cancerous, chronic respiratory, and diabetic diseases is currently over 24 per cent, while mortality rate among male Burkinabe from cardiovascular diseases increased from 230 per 100,000 in 2000 to 400 per 100,000 in 2012 (WHO, 2014).

These have consequentially attracted investments from governments, development partners, and Non-Governmental Organizations (NGOs) in the provision of primary health care since 2000. For instance, government increased budgetary allocation to the health sector from 7.07 per cent of total government expenditure in 2000 to 15.46 in 2009 (Combary, 2016). The country's investments in the health sector in terms of expenditure as a percentage of GDP also outweigh that of West African Economic and Monetary Union (WAEMU) countries and Lower Income Countries (LICs) (IMF, 2014). Also, the on-going implementation of the National Programme for Health Development (PNDS) 2011-2020 and the National Nutrition Programme are both expected to improve access to health-care services, human resource development in terms of education, and quality of health-care services in the country (Africa Progress Panel, 2010; Dayo, 2014).

Nevertheless, whereas these planned policy interventions may produce significant positive impacts, unanticipated health shocks resulting from wastewater use and other sources have the tendency of increasing the economic burden of diseases and affecting agricultural productivity negatively, thereby reversing these anticipated benefits. It is on the basis of this that this study seeks to examine the effect of wastewater use on the incidence and costs of ill-health among urban farm households in Ouagadougou.

1.2 Problem Statement

Urban farming contributes to reliable supply of food and employs about 800 million farmers globally (Ambrose-Oji, 2009). The participation rate in urban farming is estimated to range between 30 and 80 percent of all urban households in sub-Saharan African cities (UNPD, 1996). However, rapid urbanization in SSA cities provides enormous opportunities for urban farmers in terms of growth in demand for food, economies of scale, and numerous social and economic positive externalities such as cheap labour and well-developed transportation system (Ambrose-Oji, 2009; Todaro and Smith, 2012). Nevertheless, it places fundamental environmental and economic constraints on the growth and development of the industry. For example, urban farmers have, as a result of urbanization, faced insurmountable competition for scarce resources such as arable land and clean water for irrigation from industries, massive estate and other infrastructural developments, which have compelled them to rely on hazardous farming practices (Norton *et al*. 2010;Todaro and Smith, 2012).

However, the availability of water determines the growth of urban farming since agriculture consumes about 70 percent of global freshwater (Kanyoka and Eshtawi, 2012). Adequate availability of water fundamentally determines the number of crops that can be grown per land area per year, the types of inputs used, and crop productivity for both rain-fed and irrigated agriculture (JIFSAN, 2010; Norton *et al*. 2010; Kpoda *et al*. 2015). However, due to climate change that affects rainfall patterns and temperature, and over-use of aquifers and major rivers for competitive industrial and domestic purposes, urban farmers currently face freshwater shortages (Norton *et al*. 2010), which has resulted in acceleration in agricultural wastewater use in Africa (Havelaar *et al*. 2001). Besides, inadequate access to cheaper, reliable, and clean water sources and the socio-economic and urbanization conditions altogether have precipitated the condition for uncontrolled and unplanned use of diluted chemically and disease-causing contaminated wastewater for irrigation in growing African cities (FAO, 2007, 2012; JIFSAN, 2010; Havelaar *et al*. 2001; De Neergaard *et al*. 2009; Naré *et al*. 2015).

However, what constitutes wastewater? According to FAO (2012), wastewaters are polluted liquid wastes discharged from farms, institutions, domestic sewages, and commercial and industrial establishments that get mixed with ground, surface, and storm waters, which contain pathogens (bacteria, viruses), inorganic particles (salt, pesticides, toxins), and organic particles such as faeces and plant debris. The major sources of urban raw wastewater include domestic effluents such as blackwater and greywater, effluents from commercial establishments, and stormwater and other run-off (Jiménez *et al*. 2010; JIFSAN, 2010; FAO, 2012). Surface irrigation water sources including rivers, dugouts, streams, and ponds are more susceptible to contamination from domestic, commercial and industrial waste discharges and storm water runoff compared with groundwater sources (Uyttendaele *et al*. 2015). These wastewaters can be used for irrigation directly or indirectly. For instance, whilst raw wastewater can either be taken directly from drains and sewage outlets onto land for crop irrigation or indirectly used through the abstraction of diluted water from drains, small streams or natural water bodies whose water is mixed with wastewater discharged from domestic and commercial establishments for irrigation (IWMI, 2006; JIFSAN, 2010; Jiménez *et al*. 2010; Jeong *et al*. 2016).

Wastewater use, however, has numerous benefits for farmers. It is more reliable and readily accessible to farmers compared with freshwater, which facilitates all-season production (Keraita *et al*. 2008). It also provides renewable nutrients to replace fertilizer cost, and also improves cropping intensity, productivity, and output (Kanyoka and Eshtawi, 2012). Economically, wastewater irrigators are found to benefit about 30 to 50 percent of average farm income more than conventional irrigators in both Pakistan and Ghana (IWMI, 2006).

Notwithstanding these perceived benefits, there are equally both social and economic costs associated with the use of wastewater for irrigation including transmission of diseases, economic costs of treating the diseases and wastewater treatment costs (Kanyoka and Eshtawi, 2012). Spending more time near wastewaters, farmers are placed at higher risks of contracting both water-washed and water-based illnesses such as parasitic infections such as ascaris and hookworms, diarrhoea, skin infections, and nail problems (FAO, 2012; Kpoda *et al*. 2015). The use of watering cans and buckets during irrigation also increases farmers' exposure with wastewater, which is perceived to create conducive environment for transmission of coliform load, mosquitoes and other pathogenic organisms which have devastating effects on the health of farmers (Ambrose-Oji, 2009; Uyttendaele *et al*. 2015). Many other studies have linked wastewater use to common diseases such as cholera, skin diseases, and nail problems characterized by spoon-formed nails resulting from hookworm infections (Jiménez *et al*. 2010).

Similarly in Ouagadougou, farmers mainly depend on natural untreated water (well water), treated wastewater from water treatments plants, and diluted wastewater sources such as rivers, ponds, dugouts, and streams (Kpoda *et al*. 2015). The parasitological and microbial contamination levels of these surface water sources in the city such as streams, dugouts, ponds, rivers, among others, have exceeded the acceptable thresholds of WHO and FAO (Nitiema *et al*. 2013; Kpoda *et al*. 2015; Narė *et al*. 2015). Some urban farmers in the city use untreated wastewater from industries such as brewery and leather tannery (Nitiema *et al*. 2013). In addition, significant proportion of the urban farmers depend on rivers, streams, ponds, and dugouts for irrigation, which are polluted with raw animal and human wastes, agrochemical residues, sewage water discharges, and pollutants from industrial and municipal activities (JIFSAN, 2010), which have the potential of causing health problems for farmers, and increasing the intensity and duration of these illnesses and the resultant increase in medical expenditures.

Besides, if cases of water-related diseases increase among urban farm households due to their dependence on wastewater for irrigation, then the treatment and other related costs of the diseases may also lead to dissipation of household savings and existing agricultural assets such as draught animals and arable land (Onuche *et al*. 2014). This implies that the use of contaminated wastewaters for irrigation has the greatest potential of increasing the incidence and severity of water-related health shock conditions, and this may affect the overall costs of illness of these farming households. Similarly, the use of wastewaters for irrigation of farm field with the view to raise household farm productivity and income rather creates favourable conditions for increased risks and severity of certain types of diseases that can indirectly cost the household through loss of income from forgone wages as a result of absence from work, and diversion of income from sale of productive assets such as such as machinery, land, livestock, and savings, among others, into payment of hospital and/or pharmacy bills (www.siteresources.worldbank.org).

Although the effect of increased incidence of transient water-related diseases on farm productivity and income represent an indirect cost of illness, yet, the relationship between agriculture and health is observed to be reciprocal. This is because while agricultural production provides opportunities for improving health through the provision of fiber, food, shelter, and medicinal plants, it also, however, influences child malnutrition, water-related diseases, foodborne illnesses, livestock vector-borne diseases, and occupational hazards to farmers. Ill-health, on the other hand, causes a decline in household labour supply and management work performance, and thereby reduces household farm productivity and income, and this represents an indirect cost of illness to farm households, which, in the long-term, also reinforces ill-health (Hawkes and Ruel, 2006).

Over the past years, there have been some empirical studies that have analyzed the effects of wastewater use for irrigation on farmers' health and the factors that determine household incidence and costs of illness as well as how illness affects farmers' productivity and income in Burkina Faso. Some of these studies have confirmed the unacceptable levels of pathogenic, inorganic and organic contaminations loads in the various surface water sources used for irrigation farming and the potential health-related risks on urban farmers in Ouagadougou (Kinané e*t al*. 2008; Traoré and Kone, 2009; Kpoda *et al*. 2015; Naré *et al*. 2015). However, these studies have focused on the contamination levels of these wastewater sources and their potential health risks for the farmer. Therefore, there is the need to investigate further to find out empirically the specific relationship between the incidence of common illnesses and wastewater use for irrigation among farmers. This will importantly inform industry players and policy makers on how effectively wastewater use practices can be made safer and sustainable, and as well contribute towards reducing financial burden of diseases induced by wastewater use among urban farmers in the country.

Moreover, there are studies that have also investigated factors that determine household's health expenditures (costs of illness) in Burkina Faso (e.g. Su *et al*. 2006; Sauerborn *et al*. 1994). However, while Su *et al*. (2016) mainly focused on the general socio-economic and demographic factors that influence household's catastrophic payments for health care, Sauerborn *et al*. (1994) gave prominence to the effect of seasonal changes on household's total economic costs of illness in the country. Yet, due to the vast number of farmers in Ouagadougou engaged in the practice of wastewater use for irrigation of crops, it would be exceedingly relevant for policy making and regulation to analyze empirically how the practice impacts on farm households' economic costs of illness to ensure that farmers do not overstate the net benefits of wastewater use.

There is some general level of agreement among many other studies done in other countries about the determinants of costs of illness among households (Maumbe and Swinton, 2002; Bradford *et al*. 2003; Suhrcke, 2006; Mondal, 2010; Kallaru *et al*. 2015). Many of these studies, however, were done not only in environments with relatively high safety levels of irrigation waters, but also investigated general factors that affect households' health care expenditure and/or catastrophic expenditure. In Ouagadougou, however, where significant portion of surface water sources for irrigation have been polluted with domestic, industrial and institutional wastes as well as stormwater, and the pollution levels in these surface wastewater sources have exceeded WHO and FAO thresholds, there is a growing concern and interest among health professionals, policy makers, and academics about the effects of using these sources of water for irrigation of vegetables on farmers' production activities and economic status. Therefore, in order for policy makers and other stakeholders to formulate evidence-driven policies and strategies to reduce the economic burden of disease on poor urban farmers, there is the need to estimate empirically how the type of water (wastewater and safe water) use for irrigation affects both the out-of-pocket and indirect costs of coping with illnesses associated with wastewater irrigation in the city.

Other studies have also estimated how illness impacts on household farm labour use mix, productivity and farm income of farm households (Scicchitano and Whitlock, 2002; Ulimwengu, 2009; Asenso-Okyere *et al*. 2010; Osei-Akoto *et al*. 2013; Onuche *et al*. 2014; and Combary, 2016). Notwithstanding the theoretical consensus among these studies on the effect of illness on farmers' output and productivity, because of conceptual and methodological, as well as locational variations, the empirical evidence on the relationship between illness and productivity in Ouagadougou may be fundamentally different and more obvious than what is available in the literature so far. This will not only reveal the elasticity of illness on urban farmers' income and livelihood, but it will explain how households cope with illness, particularly the substitution of ill labour with hired labour on their farms.

Apart from these empirical gaps in literature so far, this study is being conducted as part of the projects of GlobE-UrbanFood^Plus^ (UFP), an interdisciplinary research partnership of African Universities, including University for Development Studies, and other West African, German and International Research Institutes such as International Water Management Institute (IWMI) to provide evidence-based solutions to sustainably manage water and land resources for food security, people's livelihoods, and the environment, and as well develop scalable agricultural water management solutions that have a tangible impact on poverty reduction and ecosystem heath in West African cities. As a project under the auspices of IWMI to develop small-scale wastewater treatment technologies for farmers in order to contribute to safe and sustainable irrigation practices, this study is done in Ouagadougou to compare its results to results already obtained of similar studies done in other partner West African countries such as Ghana, Ivory Coast, and Mali.

It is on the bases of these that the study seeks to analyze the effect of agricultural wastewater use on the incidence and cost of illness among urban farm households in Ouagadougou, Burkina Faso.

1.3 Research questions

The study is guided by the following research questions:

1. To what extent are transient illnesses among urban farm households related to agricultural wastewater use for irrigation?
2. What are the components of costs of illness and how does each component relate with agricultural wastewater use for irrigation among urban farm households?
3. What are the factors that determine incidences and costs of illness among farm households?

4. To what extent does the type of irrigation water determine costs of illness among farm households?
5. To what extent does transient illness affect household labour use, farm investments, and total value of output?

1.4 Research objectives

The general objective of this study is to analyze the effect of agricultural wastewater irrigation on the incidence and costs of illness among urban farm households in Ouagadougou.

Specific objectives:

The specific objectives are to:

1. Assess the relationship between transient illnesses and agricultural wastewater use for irrigation in Ouagadougou.
2. Identify and analyze the components of costs of illness and how each component correlates with agricultural wastewater irrigation among farm households.
3. Estimate the determinants of incidence and costs of illness among farm households.
4. Evaluate the effect of type of irrigation water on the costs of illness among farm households.
5. Measure the effect of transient illness on household farm labour, investments, and value of total output.

1.5 Significance of the study

The significance of this study is structured into four broad areas: knowledge, project-relevance, policy-relevance, and relevance to planning.

For relevance to knowledge, this study contributes to existing knowledge by uncovering how wastewater irrigation practices leads to higher prevalence of illnesses and dissipation of farmers' scarce financial resources into costs of treatment and loss of farm income and earnings, which hitherto has not been studied empirically by many previous researchers (e.g., Scicchitano and Whitlock, 2002; Su *et al*. 2006; Suhrcke, 2006; Mondal, 2010; and Combary, 2016; Ulimwengu, 2009; Asenso-Okyere *et al*. 2010; Osei-Akoto *et al*. 2013; and Onuche *et al*. 2014).

In terms of contribution to project development and implementation, the results and findings on the use rate of contaminated waters against safe water for irrigation, and the impact of wastewater irrigation on the costs of illness among urban farm households will serve as evidence-based databank for IWMI and UFP to investigate the effectiveness of biochar as a water filter and thereafter develop small-scale wastewater treatment technologies for urban irrigation farmers to ensure safe and sustainable irrigation farming in Ouagadougou and other project cities.

For policy and research relevance, findings on the total economic burden of illness on urban farmers (both direct financial burden and loss of earnings and labour) and how the burden is distributed among the diseases identified will reveal the amount of scarce productive financial and non-financial resources farmers spend on the treatment of these diseases, which will not only help policy makers in the prioritization of their interventions, but also help in ranking diseases according to their economic burden and how much of these scarce resources would have been saved if interventions were implemented to eradicate the diseases. In addition, findings on the main components of costs of illness and the size of the contribution of each component to total costs (components of the economic burden) will not only help inform health policy makers in prioritizing any cost containment policies to those cost components that weigh heavily on the limited budgets of urban farmers but also help to determine research and funding priorities by highlighting areas where inefficiencies may exist and savings be made.

Findings on the drivers of variability of costs of illness that explain the consumption pattern of health services among urban farm households will help health policy makers, farmers, and other Non-governmental organizations to feed the planning process with statistically accurate information in order to forecast the future quantity and economic burden of health-care services.

Establishing the link between the use of wastewater or contaminated waters for irrigation and incidence and costs of illness will help government and other stakeholders to develop suitable policies to reduce pathogenic and other related infections in the environment. Evidence from factors that significantly determine the choice between clean-water and wastewater for irrigation will effectively inform government and other stakeholders on the target variables that should feed into the formulation and implementation of policy and regulatory framework to effectively manage and regulate agricultural use of contaminated water in particular and urban irrigation farming in general to protect the safety of farmers, children and consumers in the country. The results will also support the introduction and enforcement of by-laws on water quality standards for irrigation of vegetables in the city in particular and the whole country as large.

CHAPTER TWO

LITERATURE REVIEW

2.1 Chapter outline

This chapter essentially focuses on review and presentation of both the conceptual/theoretical and empirical literature around wastewater irrigation and cost of illness among households. The conceptual framework that comprises the interrelationships among irrigation practices, farming activities, and cost of illness is presented to give a broad conceptual view of the study, while the theoretical review provides the essential theories that underpin these *a priori* interrelationships. Empirical literature on wastewater irrigation and cost of illness are also reviewed and presented in this section to show areas of agreements, divergences, and gaps.

2.2 Definitions of concepts

2.2.1 Wastewater

Jiménez *et al*. (2010) comprehensively defined wastewater as a combination of domestic effluent consisting of black-water from urine, faecal sludge and excreta and grey-water from kitchen; wastes from commercial establishments and institutions such as hospitals, factories; and storm-water and other agricultural run-offs. According to them, wastewater is generally decomposed into raw wastewater and diluted wastewater based on how it is used by farmers. Whilst raw wastewater comprises black-water and grey-water directly from domestic, commercial and other institutional sewage outlets which are used by farmers for irrigation either treated or untreated, diluted wastewater is water abstracted commonly from surface water sources such as streams, farm ponds, dugouts, drains which are polluted with domestic, industrial, and institutional effluents as well as storm-water and agricultural run-offs. Havelaar *et al*. (2001) defined diluted wastewater as water for irrigation abstracted from a water body containing raw wastewater. Therefore, use of raw wastewater is viewed as direct use of wastewater since water is directly disposed of on farm fields where it is used for crop irrigation, whilst the use of diluted wastewater is an indirect use of wastewater since the effluents are used after they are mixed with freshwater and/or storm-water.

FAO (2012) succinctly defined wastewater as the combination of liquid wastes discharged from domestic households, farms, institutions, commercial and industrial establishments eventually mixed with ground water, surface water, and storm water. Wastewater generally composed of pathogens (bacteria, viruses, helminthes, and protozoa), organic particles (faeces, food, plant materials, fibres), inorganic particles (salts, sand, heavy metals, grit), and pesticides and other toxins, which reaches farms through several routes, notably streams, drains or gutters, farm ponds, and shallow wells. This definition emphasizes both raw and diluted wastewater types. Kanyoka and Eshtawi (2012) similarly operationalized wastewater in their analytical framework for analyzing the trade-off between indirect use of wastewater and health hazards as a combination of domestic effluents, industrial, storm-water and water from commercial institutions that are released into the common sewerage network of a city.

Ambrose-Oji (2009) described urban ditches and streams as wastewater sources due to their concentrated coliform load and pathogenic organisms as well as the significant health hazards their use pose to farmers and consumers of irrigated products. This definition assumes that urban ditches and streams are predisposed to pollution with industrial and domestic wastes and excreta, and therefore defined them as wastewater sources.

These definitions have commonly agreed that wastewater can include liquid wastes directly from domestic households, institutions like hospitals and schools, industries and storm-water as well as water bodies such as streams, ponds, and drains among others that receive discharges from these sewage wastes.

However, in this study, wastewater is defined to include uncontrolled and unplanned indirect use of surface water sources that are polluted with storm-water, run-offs, and black-water and grey-water discharged from domestic, industrial and institutional establishments. This definition simply implies that wastewater in this study means diluted wastewater. The operationalized definition is fundamentally informed by a number of reasons. First, diluted wastewater is significantly used more frequently by overwhelmingly large number of urban farmers, particularly in wetter climates than the direct use of raw wastewater since raw wastewater is largely practised under controlled expensive sophisticated wastewater treatment plants (Jiménez *et al*. 2010). Second, during rainy seasons in Ouagadougou, there is increased concentration of organic and inorganic wastes in rivers, streams, ponds among others as a result of discharges by the run-off from domestic, industrial and municipal drainage systems into these water bodies, thereby raising their potential health hazards on farmers and other susceptible players in the usage chain (Kpoda *et al*. 2015). Third, of all the farm households interviewed, none of them directly used black-water or grey-water from sewage outlet or a treatment plant for irrigation. They either used deep/shallow wells or diluted surface water sources for irrigation.

2.2.2 Clean irrigation water

According to the World Health Organization criterion, clean water recommended for irrigation of vegetables must have a ‘zero-risk’ of microbial, chemical, and physical contaminations (WHO, 2001). Specifically, *E. coli* must not be detectable in any 100 milliliter (ml) sample of clean irrigation water, which is virtually equal to drinking-water quality standards. This quality standard by WHO is however unsustainable particularly for developing countries which lack the physical, financial and technical capacities to implement such guidelines. Uyttendaele *et al.* (2015) defined water quality based on the level of risks for the health of users. According to them, clean water sources including groundwater sources such as deep wells/bores, shallow wells/bores, and rainwater collected in closed system, among others, are those that contain generally lower level of microbial contamination.

On the basis of these definitions, clean water (as against wastewater) is defined to include water sources that are generally classified as lower risk sources and are used for drinking and other domestic activities including municipal potable water sources (pipe) and groundwater sources including deep wells/bores and shallow wells/bores, that are equally used for drinking

2.2.3 Cost Of Illness (COI)

Cost Of Illness (COI) analysis represents an evaluation of economic burden diseases impose on society as a whole in terms of consumption of health-care resources and production losses (Tarricone, 2006). It measures not only the amount of financial resources expended into the treatment of a disease but also the size of negative economic consequences of illness in terms of productivity loss to society (Suhrcke *et al*. 2006). This is intended to identify and measure either costs per patient or the total economic costs of a particular disease, which have been generally decomposed into direct, indirect (productivity costs), and intangible costs (Byford e*t al*. 2000; Tarricone, 2006 and München *et al*. 2015). Although cost of illness studies (COIs) are useful in many ways, they are however constrained by certain conceptual and methodological impediments. From an economic perspective, the approach used in COI studies to measure the costs of all morbidity associated with one disease or risk factor tends to overstate the true costs. This is because costs of a given situation, from an economist perspective, are measured by comparing that situation to its next best possible alternative situation called counterfactual. In COI studies, however, the absence of disease or risk factor that gives rise to illness is assumed to be the counterfactual. This counterfactual is often unachievable even with massive interventions or some interventions to eradicate disease or the risk factor may be a disutility to some individuals (Suhrcke, 2006). The methodology of COI studies do not also address causality between disease and the costs incurred.

2.2.3.1 Direct costs of illness

Direct costs can be classified into health-care and non-health-care costs. Whereas health-care direct costs comprise the expenditures for prevention, diagnosis, treatment, rehabilitation, continuing care, and terminal care, non-health-care direct costs refer to costs relating to transportation to and from health centres, certain household expenditures, research and training, costs of relocating, and other informal care (Rice, 1967; Tarricone, 2006). However, these costs do not measure the full economic costs imposed on a country by illness since they do not include the loss of output to the economy (Rice, 1967). Of all the costs components, direct cost is the easiest and less debated measurement among professionals and academics (Suhrcke, 2006).

However, in this household survey study, direct cost is defined as all out-of-pocket (OOP) expenses, health and non-health, that households incur during treatment of common illnesses recorded within the one month recall period.

2.2.3.2 Indirect costs of illness

Indirect costs of illness refer to productivity or output losses to a society or an individual due to illness (Rice, 1967; Tarricone, 2006). In other words, it measures the loss of human resources resulting from morbidity or premature death. These costs include wage and productivity losses resulting from work days lost due to morbidity. Unlike direct economic cost, measurement of indirect costs is a matter of much debate. Whilst the proponents of the human-capital approach to COI consider the loss of future earnings, and thereby restrict the estimate to the working population class, others use the willingness-to-pay method to examine how much people are willing to pay for relatively small changes in the risk of illness or death so that one can estimate the value people assign to life (Suhrcke, 2006). There are a number of economic principles that are applied in the estimation of indirect costs. These include earnings losses, labour participation rates, housewives' services, transfer payments and taxes, and measurement of intangibles such as pain and grief (Rice, 1967).

However, indirect cost is measured in this study to include all opportunity costs incurred by both the sick members and caretakers in both farm and non-farm activities. These may include wages forgone, sales income lost due to absence from market as a result of illness, and the estimated farm income lost due to productivity and output losses.

2.2.4 COI studies approaches:

The epidemiological data used in COI studies determine the type of approach adopted. There are many approaches to COI studies including prevalence or incidence approach, top-down or bottom-up, and prospective or retrospective studies.

2.2.4.1 Prevalence and incidence studies

While prevalence-based COI studies involve estimating the direct costs and production losses (indirect costs) attributed to all cases of a particular disease or group of diseases occurring in a given period, the incidence-based approach estimates the lifetime costs of cases of a disease or group of diseases first diagnosed in a given period, which provides a baseline against which new intervention can be evaluated (Byford *et al*. 2000; Tarricone, 2006). The fundamental rationale behind the prevalence-based approach is that all costs associated with a particular disease or group of diseases should be assigned to the year in which they are incurred or directly related, so that lost earnings resulting from morbidity is assigned to the year of illness. This approach produces large amounts of information particularly for diseases that produce long-term sequalae. However, the underlying principle driving the incidence approach is that the stream of costs related to a disease should be assigned to the year in which the stream begins. This implies that all direct and indirect costs are all discounted to the present value and assigned to the year in which the disease first appears (Tarricone, 2006; München *et al*. 2015). The prevalence approach is used when the objective of the study is to estimate the aggregate and disaggregated financial burden of a specific class of diseases, which is relevant for understanding the economic impact of diseases on a society and formulating effective cost containment policies. However, the incidence-based is preferred to the prevalence if the objective of the COI study is to analyze disease staging and provides an estimate of savings that potentially accrue if a preventive measure is implemented as well as to assess the cost-effectiveness of alternative preventive measures over a long time horizon (Thavorncharoensap, 2014).

However, the prevalence-based approach is adopted in this study to estimate the direct costs and production losses (indirect costs) attributed to all self-reported cases of all recurring diseases that occurred during the past four weeks from interview date. This approach is adopted because the study intends to provide a general picture of the financial burden of illnesses and to explain the economic impact of diseases on household's economic activities and expenditure as well as to determine how budgets can be allocated effectively to curb the diseases.

2.2.4.2 Top-down and bottom-up approaches

The top-down approach allocates portions of known total costs of illness by type of care such as hospital care, physicians, and services among the disease categories. Thus the total costs will be estimated, and then spread over the major costs components or inputs of health-care services. Therefore, by allocating costs among major illness categories, it avoids the risk that summing up treatment costs of an individual illness is greater than total health-care expenditure in a given country (Tarricone, 2006). On the other hand, the bottom-up approach, total costs of illness is estimated in two stages. In the first stage, the quantity of health inputs used is estimated (medical care services, drugs quantity, transportation services etc). In the second stage, the unit costs of the inputs used are estimated. Therefore, the total costs are then estimated by multiplying the quantities by the unit costs. Therefore, while top-down is applied in prevalence-based cost-of-illness studies where analysis is performed from the top-down by allocating portions of a known total expenditure to each of several broad disease categories, bottom-up approach is applied in incidence-based cost of illness studies which requires that analysis be performed from the bottom-up by summing up the lifetime costs of illness (Tarricone, 2006; Thavorncharoensap, 2014). Unlike the bottom-up method which requires a detailed data input, the top-down method is simple to apply but has the tendency of causing misallocation of costs as the major illness categories differ in terms of their contribution to the health service (Tarricone, 2006).

In this study however, the top-down strategy will be used to complement the prevalence-based approach to specifically allocate portions of the known estimated total costs of illness by type of care such as hospital care, home care, and other health and non-health services among the disease categories so that the costs can be spread over the major costs components or inputs of health-care services, which is more relevant for cost containment policies (Rice, 1967; Tarricone, 2006).

2.2.4.3 Prospective and retrospective COI studies

COI can be prospectively or retrospectively conducted depending on the temporal relationship between the initiation of the study and the data collection. Whilst in retrospective studies, all the relevant events have already occurred and all data are already recorded for use before the initiation of the study, in prospective studies, relevant events have not already occurred before the study is initiated (Tarricone, 2006). In addition, even though retrospective studies are affected by recall bias, yet they are more efficient for investigations of diseases that have a long duration requiring many years to reach the relevant end point. However, prospective studies are flexible in that the researcher comes out with a proper and well-fitting data collection design for the study which eliminates recall bias.

However, since this study is a cross-sectional sample survey, the data is gathered retrospectively using a semi-structured questionnaire. Therefore, the retrospective approach is used to elicit costs of illness information from households that recorded illness within the specified recall period.

2.3 Conceptual framework of agricultural wastewater use and costs of illness

The transmission mechanism of the effect of wastewater irrigation on the incidence and costs of illness of farm households as well as on their labour supply and demand, agricultural investments, and farm income is conceptualized in Figure 2.1. This framework is developed on the review of theoretical and empirical literature of the links between wastewater irrigation and costs of illness, including labour markets and farm productivity. In urban cities, wastewater used for irrigation is an accumulation of wastes from diverse sources, including industries, domestic households, institutions, and storm-waters (Jiménez *et al*. 2010; Uyttendaele *et al*. 2015). Wastewater from these sources are generally de-composed into two main categories; raw untreated wastewater which is usually drawn from wastewater treatment plants and/or sewage outlets, and diluted wastewater largely siphoned from surface water sources (streams, rivers, ponds) and storm-water. The use of raw (untreated) wastewaters from treatment plants and/or sewage outlets for irrigation of crops constitute direct agricultural use of wastewater, which in most cases, is planned and the potential hazards are effectively controlled and managed (IWMI, 2006).

However, the use of diluted (partly treated) wastewater from waste-polluted surface water sources and storm-water constitutes an indirect agricultural wastewater use, which is largely unplanned, and therefore the health and economic hazards associated with the process is uncontrolled (Jiménez *et al*.

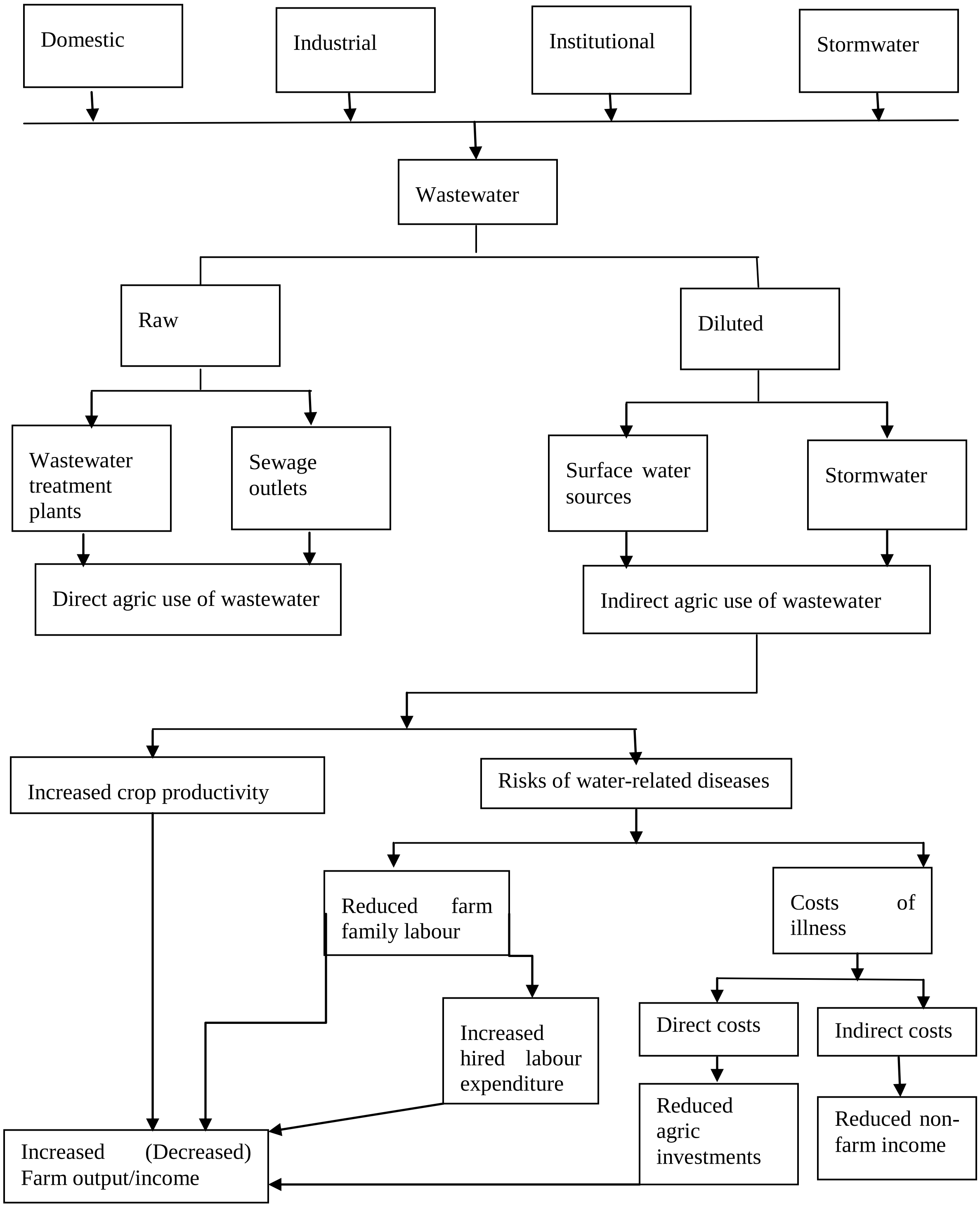


Figure 2.1: Conceptual framework of agricultural wastewater use and costs of illness
Source: Adopted from Jiménez *et al*. (2010)

2010; Jeong *et al*. 2016). Given that a significant proportion of farmers in urban centres engage in the latter case, this study therefore proceeds to assess the effects of indirect agricultural wastewater use on the incidence and costs of transient illness among urban farm households. The framework shows that the use of polluted surface sources of water and storm-water, including streams, ponds, canals, and dugouts, in which contamination levels of organic, inorganic, and other pathogenic micro-organisms have exceeded WHO and FAO thresholds (JIFSAN, 2010; FAO, 2012; Kpoda *et al*. 2015), has the potential to cause water-related diseases among farm households. These diluted wastewater sources serve as safe vectors for the survival and transportation of pathogens such as bacteria, viruses, protozoa, and helminthes from an infected person to a susceptible individual (farmer). Therefore, frequent contacts and proximity to pathogen-loaded wastewaters, and the consumption of wastewater irrigated vegetables, exposes the farmer to the higher risk of pathogenic infections, which in turn, causes various diseases such as malaria, skin infections, diarrhea, and upper respiratory problems among others for the susceptible farmer (Shuval, 1990; Blumenthal and Peassey, 2002; Ambrose-Oji, 2009). These water-related diseases are expected to directly and indirectly affect household farming activities and there are economic costs associated with treatment of illnesses.

For effects on household farming activities, wastewater-induced illnesses are expected to directly cause reduction in family labour use due to incapacitation and care provision for infants and elderly who are ill, and indirectly lead to a corresponding increase in hired (casual) labour intensity to replace family labour lost, and reduction in investments in fertilizers and agro-chemicals due to increased out-of-pocket payments (OOPPs) for healthcare.

Increased incidence of illness induced by wastewater use is also expected to directly lead to increase in economic costs of illness. These economic costs of illness are generally classified into direct and indirect costs (Rice, 1967; Tarricone, 2006). The direct costs are the out-of-pocket payments for both health care costs consisting of medical care expenditure for diagnosis, treatment, and medication among others and the non-health care costs relating to financial expenditure on non-health care services such as transportation to and from health care providers and extra-food expenditure among others (Rice, 1967; and Tarricone, 2006). In the framework, these are expected to increase since wastewater use increases the severity and incidence of water-related diseases, and therefore more utilization of healthcare services. This increase in direct economic costs of illness is likely to cause diversion of scarce household financial resources earmarked for agricultural investments in terms of chemicals into healthcare payments for treatment of illnesses.

The indirect component of economic costs of illness is linked to the opportunity costs of absence from work as a result of illness relating to wastewater use, which is linked to reduction in non-farm incomes such as losses of wages from wage labour services and sales revenue as a result of absence from work and\or lower productivity at work due to low mental and physical capacities resulting from illness (Rice, 1967; Shuval, 1990; Tarricone, 2006).

In all, the combined effects of reduced family labour and investments in healthcare as a result of illnesses associated with wastewater use are expected to cause a contraction in overall farm income (Singh *et al*. 1986; Smonsson, 2005; Onunche *et al*. 2014; Osei-Akoto *et al*. 2013). However, if the corresponding increase in casual labour intensity is greater enough to offset the negative effects of reduced family labour, then, farm income will not be affected significantly (Singh *et al*. 1986). It is also argued that wastewater use has the greatest potential to influence an expansion in farm income directly due to its significant organic matter and essential nutrient contents, and the opportunity it creates for multiple and all-season cropping, leading to improved crop yields (Havelaar *et al*. 2001; De Neergaard *et al*. 2009; Kanyoka and Eshtawi, 2012; FAO, 2012).

2.4. Theoretical framework of the study

2.4.1 Agricultural wastewater use and health risks

The theoretical model that analyzed the relative effectiveness of pathogens such as bacteria, viruses, protozoa, and helminth in causing enteric diseases of the intestinal human tract through wastewater irrigation was developed by Shuval (1990). The transmission channel of these diseases comprises the excretion of pathogenic microorganisms into the environment by an infected person (initial host); these pathogenic microorganisms will then be transported by a suitable vector such as contaminated water or food; and ingested by another susceptible human host (irrigator, vegetable consumer, child etc).

Fattal *et al*. (1986) however viewed the transmission channel as cyclical where pathogens carriers first introduced from outside the community, through wastewater irrigation of vegetables, are back to residents of the community. Their framework is presented in Figure 2.2.

Large numbers of the disease-causing pathogens are excreted in the urine and faeces of infected persons, and these pathogens contaminate the wastewater which is dumped into the environment. For instance, the calculated concentration of pathogenic microorganisms in the wastewater stream is many millions per litre for bacteria, thousands per litre for viruses, and a few hundred per litre for some of the helminth eggs.

The ability of pathogens to infect a susceptible individual depends on two fundamental conditions: first, the pathogens must be able to survive in the environment, including water, soil, food among others for a period; and the second is that they must be ingested in a sufficiently large quantity by the susceptible individual.

Besides, there are a number of epidemiological factors that theoretically determine the effectiveness of groups of pathogen causing infections in humans through wastewater irrigation. These include the persistence or survival period of pathogens in the environment, level of minimal infective dose, time length of human immunity, number of minimal concurrent transmission routes (such as food, water, personal hygiene), and whether there is a need for a soil development stage or not.

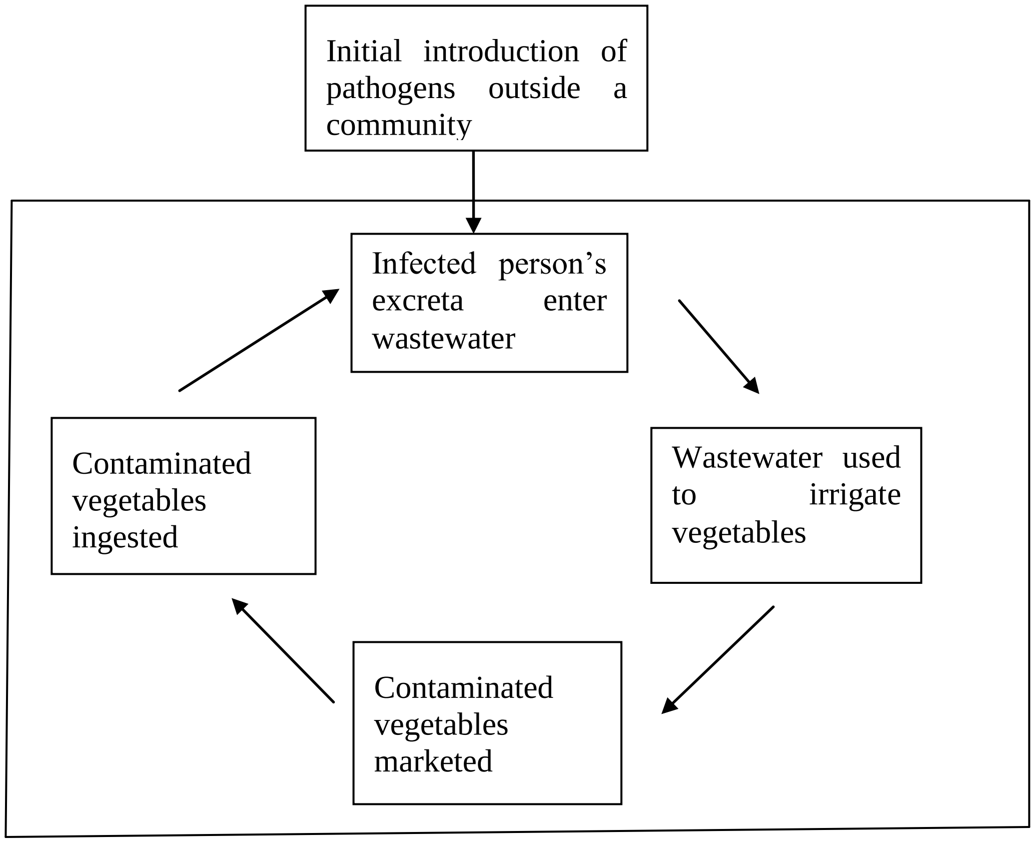


Figure 2.2: Transmission cycle of pathogens from wastewater
Source: Fattal *et al*. (1986)

Based on these factors, pathogens can be ranked in order of their effectiveness or risk of causing and transmitting infections to humans through wastewater. Table 2.1 reveals that helminths (worm) have the highest risk of causing and transmitting diseases to humans by irrigation with raw wastewater given that they persist in the environment for relatively long periods, have a low minimum infective dose, little or no immunity against them, limited concurrent infection at home, and latency is long and soil development stage is required for transmission.

In contrast, although enteric viruses have low minimum infective dose and the ability to survive in the environment for long periods, yet, they have the lowest risk of causing and transmitting diseases by irrigation with raw wastewater. This can be attributed to exposure of a greater proportion of the population to enteric viral infections due to poor hygiene at home and prevalence of concurrent routes of infection in some areas, leading to the acquisition of immunity to the infection for most of the population particularly from infanthood. Therefore, the underlying factor that makes enteric viral diseases least effectively transmittable through wastewater irrigation is the ability of humans to acquire immunity against them for life or at least for very long periods, thereby making re-infection of individuals exposed to them highly unlikely.

The effectiveness of bacterial and protozoan diseases being transmitted through wastewater irrigation is medium, lying between the highly risky helminthes and the least risky enteric viral diseases.

Table 2.1 Epidemiological characteristics of pathogens and their level of risk of infection

Pathogen	Persistence in environment	Minimum infective dose	Immunity	Concurrent routes of infection	Latency/Soil development stage	Risk of infection
Viruses	Medium	Low	Long	Home contact, food and water	No	Low
Bacteria	Short/Medium	Medium/High	Short/Medium	Home contact, food, and water	No	Medium
Protozoa	Short	Low/Medium	None/Little	Home contact, food, and water	No	Medium
Helminth	Long	Low	None/Little	Soil contact outside home and food	Yes	High

Source: Shuval (1990)

2.4.2 Household production and time allocation

The analytical framework that is widely applied in analyzing households' allocation of time into the production of commodities that they consume is provided by Becker (1965) as presented by Heckman (2014).

The theory assumes that a household produces and consumes commodities $Z = (Z_i),\ i, = 1,...,I$. The commodities relate to various activities undertaken in the household, including leisure activities, food consumption, child reproduction, staple production among others. The utility function of a household is therefore in the form:

$$U = U(Z_i,...,Z_I) \qquad [2.1]$$

and

$$Z_i = Z(X_i, T_i),\ i = 1,...,I. \qquad [2.2]$$

where X_i is a vector of goods inputs for the production of Z_i and T_i is time input available to a household. Therefore, the price of Z_i is determined by the prices of T_i and X_i. The household's production and consumption activities are subject to both time and cash income budget constraints. However, Becker under certain assumptions showed that the household effectively faces only time budget constraint. If the price of time is w across all uses, then the maximum income a person can earn is $Full\ Income\ B = wT + V$, where $T = \sum T_i$ and V is income transfers to the household. Therefore, time as a factor of production is used to produce commodities Z_i, which encompasses household activities such as leisure and child bearing among others as specified as follows:

$$\sum_{i=1}^{T} \pi_i Z_i = wT + V = B. \qquad [2.3]$$

where π_i is a scale-invariant price index for each commodity produced in the household.

This implies that the household maximizes its utility in equation [2.1] subject to both production and time constraints in equations [2.2] and [2.3] respectively. Therefore, household demand for inputs X_i and T_i are derived from the demand for Z_i. The degree of responsiveness of demands for commodities (Z_i) as a results of variations in the prices of goods input (X_i) and time input (T_i) depends, in part, on the intensities of X_i and T_i used in the production of Z_i

2.4.3 Theory of health capital and demand for health to explain costs of illness

Grossman (1972) constructed a model of individual's demand for health capital. The central proposition of the model is that health is a durable capital stock that can be used by the individual to produce an output of healthy time. The need for a model of demand for health is anchored by the view that farm households' demand for medical services is a demand for "good health" and not a demand for the service per se. Therefore, a farm household is assumed to have an inter-temporal utility function of the form:

$$U = U(\phi_0 H_0, ..., \phi_n H_n, Z_0, ..., Z_n). \qquad [2.4]$$

where H_0 is the initial inherited stock of health, H_i is the stock of health in the ith time period, ϕ_i is the service flow per unit stock of health (number of healthy days per unit stock), $h_i = \phi_i H_i$ is the total consumption of health services and Z_i is the total consumption of all other commodities (particularly farm produce) in the ith period by the household.

The model assumes the inherited initial stock of health can depreciate over time with age and factors that cause illness, and can be increased through investments such as medical care. So by definition, net investment in the stock of health equals gross investment minus depreciation as:

$$H_{i+1} - H_i = I_i - \delta_i H_i \qquad [2.5]$$

where I_i is gross investment and δ_i is the rate of depreciation during the ith period. The rates of depreciation are assumed to be exogenous, but they may vary with the age of the farmer and other factors such as contact with wastewater through wastewater irrigation which causes illness. Therefore, the farm household's gross investments in health capital and in the production of staple commodities in the utility function are defined by the following production functions:

$$\left.\begin{aligned} I_i &= I(M_i, TH_i; E_i) \\ Z_i &= Z(X_i, T_i; E\ ) \end{aligned}\right\} \qquad [2.6]$$

where M_i is medical care input, X_i is the variable goods input in the production of staple commodities Z_i, TH_i is time input for the production of gross investment in health stock, and T_i is time input for production of staple commodities, and E_i is the stock of human capital which comprises factors such as education, housing, diet, recreation, cigarette smoking, alcohol consumption, and contacts, inhalation, and ingestion of wastewater via wastewater irrigation among others. The stock of human capital is a non-input variable that increases the efficiency of the production process in both health capital (non-market) and staple commodities (market) production functions.

Therefore, the marginal products of time and medical care in the production of gross investment in health capital by farm households are both positive given as:

$$\left.\begin{array}{l} \dfrac{\partial I_i}{\partial TH_i} \succ 0 \\ \dfrac{\partial I_i}{\partial M_i} \succ 0 \end{array}\right\} \qquad [2.7]$$

These show that additional time input and visits to medical center for services will both raise farm household's gross investments in health capital.

Medical care input in the gross investment in health capital function is of great importance since it represents the actual effective demand for health by the farm household. Farm households, according to the model, demand for health for two reasons: first as a consumption commodity so that health enters directly the household's utility function - sick days a source of disutility – and second as an investment good, which determines the total amount of time input that can be used to produce both market (staple goods from the farm) and non-market (health capital) commodities. Therefore, an increase in demand for health (medical care) increases the stock of health, which in turn, reduces the time lost from the production of market and non-market activities, and therefore, the monetary value of this reduction becomes an index of the return to the investment in health.

Based on the fundamental law of the downward-slopping demand curve, the quantity of health (medical care) demanded should be inversely correlated with its price stated as:

$$M_i = M(P_i), \frac{\partial M_i}{\partial P_i} \prec 0 \qquad [2.8]$$

where P_i is the price of medical care services. However, there are many other variables besides price, which affect the optimal quantity of health demanded, and thereby alter the derived demand for gross investment. According to Grossman, the demand for health rises with age if the rate of depreciation on the stock of health rises over the lifecycle and falls with education if more educated people are more efficient producers of health. This implies that the demand for health is a function of price (P_i), age (A_i), and education (E_i) as specified:

$$M_i = M(P_i, A_i, E_i)$$

So that the effects of age and education can be shown as:

$$\left.\begin{aligned} \frac{\partial M_i}{\partial A_i} \succ 0 \\ \frac{\partial M_i}{\partial E_i} \prec 0 \end{aligned}\right\} \qquad [2.9]$$

Time inputs for the production of health stock capital and market staple commodities are scarce resources, so that a farm household maximizes its utility function subject to a time budget constraint which requires that Ω, the total amount of time available to the household in any period, must be exhausted by all possible uses as:

$$\Omega = TW_i + TL_i + TH_i + T_i \qquad [2.10]$$

where TW_i is hours of work, TL_i is time lost from market and nonmarket activities due to illness. The time budget constraint indicates that without sick time (TL_i) in the market and nonmarket time, total time would not be exhausted by all possible uses. This follows in this model that sick time is inversely related to farm stock of health (H_i) but positively correlated with demand for health (M_i) as shown below:

$$M_i = M(P_i, A_i, E_i, TL_i), \frac{\partial M_i}{\partial TL_i} \succ 0 \qquad [2.11]$$

$$H_i = H(M_i, I_i, TL_i), \frac{\partial H_i}{\partial TL_i} \prec 0 \qquad [2.12]$$

These imply that sick days have a positive effect on farm household demand for health but a negative effect on household's health stock (disutility to the household). If Ω is measured in number of days and h_i is defined as the total number of healthy days, then total sick days can be said to be:

$$TL_i = \Omega - h_i \qquad [2.13]$$

It can further be argued that sick days (TL_i) in farm household's demand function for health is not exogenously determined since its number can be significantly affected by many socio-demographic, dwelling, and farm production characteristics and practices of the farm household. Agricultural wastewater use is one of these important practices that can affect the number of sick days in a household. This is underpinned by FAO framework that predicts that farm households' frequent contact, proximity, inhalation, and ingestion of wastewater via the use of wastewater by farm households to irrigate their crops predispose them to pathogenic, bacterial, parasitic, viral, and helminthic infections (FAO, 2012), thereby affecting sick days. Therefore, the effect of wastewater irrigation, denoted as WI_i, on sick days can be captured as:

$$TL_i = TL(WI_i, TL), \frac{\partial TL_i}{\partial WI_i} \succ 0 \quad [2.14]$$

This implies that sick days increase with agricultural wastewater use because of the high risk of pathogenic and other infectious diseases. Therefore, the augmented farm households' demand function for health can be formulated as:

$$M_i = M[P_i, A_i, E_i, TL_0, TL_i(WI_i)] \quad [2.15]$$

So that the overall effect of agricultural wastewater use on farm households' demand for health can be obtained as:

$$M_i = M[P_i, A_i, E_i, TL_0, TL_i(WI_i)], \frac{\partial M_i}{\partial WI_i} = (\partial M_i / \partial TL_i)(\partial TL_i / \partial WI_i) \succ 0 \quad [2.16]$$

Therefore, the demand for health by the farm household rises with agricultural wastewater irrigation practice via the wastewater-induced increase in sick days.

From now, based on equation [2.7) where medical care increases gross investment in health capital, while in equation [2.16], agricultural wastewater use increases medical care through increase in sick days, then wastewater irrigation is expected to cause a rise in gross investment in health capital through increased sick days and consequently medical care. This is expressed mathematically in equation [2.17] below;

$$I_i = I\{M_i[TL_i(WI_i)], TH_i, E_i\} = \frac{\partial I_i}{\partial WI_i} = [(\partial I_i/\partial M_i)(\partial M_i/\partial TL_i)\partial TL_i/\partial WI_i] \succ 0$$

[2.17]

This implies that sick days and, in particular wastewater irrigation practice, contribute to the depreciation process of farm household's inherited health capital stock, which is reversed by farm households by increasing their gross investments in health capital via increased in demand for medical care.

Farm households also allocate a proportion of their fixed time resources and other market variable resources to the production of market staple goods as shown in equation [2.6]. Therefore, since number of healthy days (h_i) seldom equals the total number of days available for market and non-market activities due to the phenomenon of sickness, which is largely caused by many socio-demographic, dwelling and farm production characteristics and practices in the farm household, it is important to find out how illness can affect farm production. Therefore, sick days, which reduce the total amount of scarce time available for the production of staple market goods, is modeled to reduce output of staple goods as:

$$Z_i = Z(X_i, T_i, E_i, TL_i), \frac{\partial Z_i}{\partial TL_i} \prec 0 \quad [2.18]$$

Now in the production of staple goods, wastewater irrigation can affect the production process directly as an exogenous capital input (water) (WI^k), and indirectly through its effects on sick days (TL_i) since sick days can reduce farm labour use and intensity. Therefore the effect of wastewater irrigation as a capital input on production of staple market commodities Z_i is expected to be positive given as:

$$\frac{\partial Z_i}{\partial WI^k} \succ 0 \quad [2.19]$$

This implies that the application of wastewater irrigation by a farmer causes production of staple commodities to increase since the water contains essential copious nutrients for plant growth (FAO, 2012; JIFSAN, 2010; Ashraf et al. 2010). Therefore, if equations [2.14], [2.18] and [2.19] hold, then equation [2.19] below, which captures the overall effect of wastewater irrigation on farm household's output of staple commodities, also holds.

$$Z_i = Z[X_i, T_i, E_i, WI^k, TL_i(WI_i)] = \frac{\partial Z_i}{\partial WI} = [\partial Z_i / \partial WI^k + (\partial Z_i / \partial TL_i)(\partial TL_i / \partial WI_i)] \neq 0$$
[2.20]

This implies that wastewater irrigation acts as both a positive and negative stimulus to the production of staple goods. Therefore, the overall net benefit of using wastewater irrigation will depend on the discrepancy between the positive magnitude of $(\partial Z_i / \partial WI^k)$ and the negative value of $[(\partial Z_i / \partial TL_i)(\partial TL_i / \partial WI_i)]$.

Therefore, the decision to adopt wastewater irrigation will at least, in part, depend on the sign of the outcome of equation [2.20].

2.4.4 Modelling the effect of illness on farmer's inputs and output

The theoretical model of the effect of health on household farm income in terms of labour productivity was developed by Singh *et al* (1986). The theoretical framework assumed that every household has a utility function of;

$$U = U(Z_a, Z_m, Z_I). \qquad [2.21]$$

Where the commodities comprise household-produced staple (Z_a), purchased good (Z_m), and leisure good (Z_I). Every household maximizes their utility subject to cash income and time budget constraints. The income constraint is in the form;

$$P_a(Q_a - Z_a) + R - P_m Z_m - w(L - L^f) - W_x X = 0 \qquad [2.22]$$

where P_a and P_m are the prices of home-produced staple and purchased good respectively; Q_a and X are respectively household production level of the staple and variable input (such as seeds, chemicals, tools); L is the total labour input, while L^f is family labour input so that positive $L - L^f$ implies the use of hired labour, while a negative difference represent household off-farm employment; W_x and w are unit price of the variable input and market wage rate for labour input respectively; and R represent any exogenous non-labour, non-farm income such as remittance, windfall.

The time constraint ensures that households are unable to allocate more time to leisure, on-farm production, or off-farm employment than the total amount of time available T. Therefore, the direct effects of illness on effective family and hired labour inputs are respectively given by;

$$L^f = L^f(TL, L^f) = \partial L^f / \partial TL < 0 \qquad [2.23]$$

$$L^h = L^h(TL, L^h) = \partial L^h / \partial TL \succ 0 \qquad [2.24]$$

These imply that whilst sick time reduces family labour input, it increases household hired labour use. The positive effect of illness on hired labour implies substitution of sick family labour with healthy outside labour. Therefore, the net effect of illness on total labour use is based on the difference between the negative family labour effect and that of the positive hired labour effect as given as;

$$(\partial L^f / \partial TL) - (\partial L^h / \partial TL) \neq 0 \qquad [2.25]$$

Therefore, the sign of equation [2.25] depends on the level of substitution between sick family labour and healthy hired labour and other factors. But for an indirect effect of illness on farm production, analysis is made with respect to effective investment in variable input, which is given by;

$$X = X[M^e(TL), X] = \partial X / \partial TL = (\partial X / \partial M^e)(\partial M^e / \partial TL) < 0 \qquad [2.26]$$

Where M^e is household medical expenditure, $\partial X / \partial M^e$ measures the rate of decrease in household variable inputs (farm assets such as chemicals, machinery) as a result of an increase in household medical expenditure, and $\partial M^e / \partial TL$ indicates how fast household medical expenditure increases in response to an increase in sick time.

Household production function for the staple is as follows;

$$Q_a = Q(X, L^F, L^H, N) \qquad [2.27]$$

Where L^H and N are respective hired labour input and fixed inputs (land and capital). Therefore, the effect of ill-health on household production is shown in the following production functions;

$$Q_a = Q\{L^F(TL, F^F) + L^H, X[M^e(TL,), X], N\} \qquad [2.28]$$

So that the overall effect of ill-health on production is given by

$$\partial Q_a / \partial TL = (\partial Q / \partial L^F)(\partial L^F / \partial TL) + (\partial Q / \partial X)[(\partial X / \partial M^e)(\partial M^e / \partial TL)] < 0 \qquad [2.29]$$

Therefore the reduced production is as a result of a reduction in family labour input and investments in agricultural variable capital inputs. However, this reduction may be partially off-set by the substitution of hired labour for lost family labour input.

2.5 Review of empirical literature on agricultural wastewater use and cost of illness

2.5.1 Type of irrigation water and incidence of related health risks among farmers

Unlike clean-water, the use of raw and diluted wastewater sources in agricultural production, in which concentration levels of pathogens and other microbial and parasitological contaminants have exceeded the recommended WHO thresholds is believed to have the greatest potential of causing pathogenic infections and other diseases resulting from ingestion, inhalation, and feet and hand contacts with wastewater. A scientific examination of bacteriological and parasitological concentration levels in diluted surface wastewater sources in Ouagadougou (Nitiema *et al*. 2013) revealed that concentrations of microbial indicators of faecal pollution in these sources used for truck farming have exceeded the thresholds set by WHO, which exposes farmers in particular to high health risks such as intestinal amoebiasis (diarrhea related disease) and other ill-health conditions. In a similar study in Ouagadougou, Kpoda *et al*. (2015) established that the main health risk associated with the use of diluted wastewater for irrigation by farmers is intestinal helminthic infection. These studies however have mainly focused on scientifically testing and establishing whether these water sources used for farming have fulfilled the irrigation water quality standards of WHO, and linking the potential health effects of using these water sources for irrigation. However, the magnitude of the contribution of wastewater to the incidence of these wastewater-related illnesses among farm households in the city is yet to be established.

In a study to analyze the impact of farmers' health status on agricultural efficiency and poverty in rural Ethiopia, Ulimwengu (2009) found that not only do farm households have a higher likelihood of being affected by sickness than non-farm ones, but households closer to irrigation dams are hit with higher incidence of diseases in rural Ethiopia. This study however focused on the impacts of irrigation practices in general without emphasis on the type and quality of water used by farmers.

Ashraf *et al*. (2010) analyzed the effects of polluted water irrigation (diluted wastewater) on environment and health of people in Jamber, Pakistan combining scientific examination of the physio-chemical parameters of ground water samples and survey of inhabitants and farmers. They observed that about 76 percent of people living in areas where polluted water is used for irrigation of crops were infected with various diseases such as skin problems, nail infections, fever, and diarrhea compared to a less than 50 percent infection rate in other control areas. These infections were significantly higher among female farmers than male farmers. They therefore concluded that in geographical locations where polluted water is used for irrigation, the phenomenon accelerates the propensity and intensity of a household being hit by wastewater-related health shocks in a year in that area compared to its counterpart areas. The study linked nail, skin and diarrheic diseases to community-wide use of wastewater rather than a household use. However, high level of theoretical consensus is built on the effect of wastewater use on the health of farmers and other farm workers in a household than on the health of community people. As a result, modeling household-level health effects of wastewater use will provide complete and better insights into the problematic unplanned use of diluted wastewater and give relevant policy guidelines suitable for the effective management of the risks resulting thereof.

Farmers face the greatest risk of dysentery and cholera infections resulting from exposure to faecally-contaminated and bacteria-laden wastewater (Bradford *et al*. 2003). Furrow or canal irrigation system using wastewater aggravates incidence of illness among farmers by increasing farmers' contacts with and exposure to untreated wastewater because farmers stand in the furrows in the flowing wastewater rather than risk damaging the crops. This study generally assessed wastewater irrigation practices and systems, and their implications for health and livelihoods in India. Empirical evidence on the relationship between wastewater use and incidence of diseases in households would inform a health and extension policy more accurately and relevantly in the city and other African cities on the continent.

2.5.2 Components of costs of illness

Sauerborn *et al*. (1994), in their study of household costs of illness in Burkina Faso, categorized household's total economic costs of illness into time costs of illness to the sick person, time costs of illness for caretaker, and financial costs of treatment. They found that total time costs of illness (indirect costs of illness) were more than double the financial costs of illness, contributing 71.5 per cent to total household annual costs of illness. Moreover, of the total time costs, 55.2 per cent was due to work incapacity, measured as the opportunity costs of wages foregone, while 44.5 percent was incurred by caretakers of the sick members of the household. Out of the total direct financial costs of illness, costs incurred on drugs were the highest. These findings showed that of the total economic costs of illness, the opportunity costs far outweigh the direct financial costs. However, for chronic illness, direct medical costs such as drugs, hospitalization, diagnostic procedures and laboratory investigations were found to contribute the largest to households' total costs of illness with about 90 percent share of total costs, followed by households' non-medical costs including travel cost, while indirect costs contributed least to total costs (Kallaru e*t al*. 2015).

However, Mondal *et al*. (2010) categorized direct health expenditure services into out-patient care (minor illness), in-patient care (chronic illness), and birth delivery services in their study that analyzed catastrophic out-of-pocket payment for health care and its impact on household socio-economic activities in India. They observed that inpatient care service exerted the greatest economic burden on households, while birth delivery services contributed the least to total household economic burden of illness. Bonfrer and Gustafsson-Wright (2016) in Kenya showed that households' expenditure on drugs was the highest, while transport costs took the smallest share of the total expenditure on health treatment.

However, these studies have estimated the total costs of illness and the relative shares of the components. It would be interesting to further find out how each cost component behaves in relation to the level and type of risks households are exposed to, which includes the type of irrigation waster farmers used for vegetable production.

2.5.3 Factors that determine incidence and costs of illness among farm households

2.5.3.1 Pesticides use

The quantity of carbofuram pesticide applied significantly increases crop production but lowers neurobehavioural health among potato producers in Ecuador (Antle *et al*. 1998). The authors, however, showed the net benefit of reducing pesticides use to be an increase in both productivity and health status of farmers since the productivity gains from improved health surpass the negative productivity effects of reduced pesticide use. Based on these findings, Maumbe and Swinton (2002) further investigated the hidden health costs of pesticide use among smallholder cotton farmers in Zimbabwe but added a cost of illness function to assess the economic burden of pesticide application on smallholder farmers. They corroborated the findings of the previous study by observing that the use of pesticides without protective clothing significantly influenced acute pesticide symptoms. In addition, acute pesticide symptoms resulting from pesticide use without protective clothing significantly increased both direct medical treatment and time costs of illness among the farmers. This implies that farmers who applied pesticides to control pests and weeds in order to increase crop growth eventually suffered a significant jump in the amount of household resources spent on medical care services and in the income they lose resulting from sickness related to pesticide use. Though these studies empirically addressed the effect of pesticide use on incidence and costs of illness among farmers, they targeted non-urban, non-irrigation and extensive farmers. A study that investigates the effect of pesticide use on the incidence and costs of illness among urban wastewater irrigation farmers would provide a broader perspective and insight into the combined health effects of pesticide and wastewater use since the two are strongly linked. Bradford *et al*. (2003) found that irrigation with wastewater, which is laden with nutrients, causes a problematic growth in the incidence of weeds and pests, which in turn, leads to increased quantity of pesticide use among farmers. Therefore, controlling for wastewater use will provide accurate estimates of pesticide health effects for better policy formulation and guidance.

2.5.3.2 Healthcare-related factors

Melgarejo (2011) examined the determinants of health care expenditure (HCE) in Colombia using the country's General System of Health Social Insurance, a universal insurance programme in the country. Findings from the study revealed that average premium for the insurance service and the per capita unit value for each insurance regime significantly influenced health care expenditure upwardly in the country. This study was done with respect to subscribers of a universal health insurance scheme, thereby assessing health expenditure of the limited number of households subscribed to the scheme. A cost of illness model for specific group of society, and in this case urban wastewater irrigation farmers, that examines both health-related characteristics and non-health factors determining the economic burden of illness will point to specific drivers, risks, and other factors for specific policy guidelines and measures to address specific problems among a specific group of the society would be worthwhile.

In a tobacco study, using Smoking Attribution Fraction (SAF) method, number of patients and average costs of health-care play significant role in increasing costs of illness related to lungs problems (Thavorncharoensap, 2014). He further found that total direct expenditure of illness is generally influenced positively by a number of factors, including number of sick people, types and incidence of diseases, and days of illness. Kallaru *et al*. (2015) also found severity, measured as number of days of illness, to have significantly increased both direct and indirect costs of illness. Therefore, as disease severity increases, the total costs spent on the treatment of the illness also rises significantly. Hospitalization, which is directly linked to severity, was also found to influence costs of illness positively. These studies focused mainly on health-related, market and habitual lifestyle drivers of costs of illness among non-farm households. A similar study that give due consideration to the effects of health-related, market, lifestyle, and farming practices on both farm and non-farm households would be more insightful and holistic for policy makers to address the problem of increasing economic burden of illness through effective costs containment policies.

Mondal *et al*. (2010) examined out-of-pocket catastrophic health care expenditure among households in India. They found the probability of households burdened with out-of-pocket catastrophic health expenditure to increase significantly with increasing number of illness episodes in a household. Hospitalization cases were also revealed to have significant positive effects on households' probability of incurring catastrophic health expenditures. Thus chronic illness, which causes hospitalization, is a significant determinant of households incurring catastrophic health payment in West Bengal, India. Similarly in Kenya, Bonfrer and Gustafsson-Wright (2016) examined health shocks, coping strategies and foregone health care among agricultural households and also found illness episodes to be significantly responsible for farm households' catastrophic health care payments in the country. Although these studies have pointed out how illness episodes, hospitalization and hospital visits significantly affect catastrophic health payments among farm households, they rather focused on health costs beyond certain thresholds. Catastrophic health care payments models leave out important costs households incur on treatment as well as time costs of illness. A cost of illness study that explains the drivers of every infinitesimal costs incurred by farm housing using wastewater for irrigation would be more informative and provide accurate measurable estimates to guide policy making more effectively and make policy targeting more precise.

2.5.3.3 Socio-economic and demographic characteristics

O'Donnell *et al*. (2005) did a comparative analysis of the incidence of catastrophic expenditures on health care in Bangladesh, Vietnam, Sri Lanka, Hong Kong, India, and Thailand using Probit and multiplicative heteroscedasticity linear regression models. The probability of a household incurring catastrophic health payment was found to be strongly positively correlated with household total consumption expenditure, but strongly inversely associated with education of household members across all the six countries. This implies that higher likelihood of a household incurring catastrophic payment for health care was related with higher level of household consumption expenditure, but lower level of education in the household in all the countries. The finding on education was attributed to efficiency in the use of modern medical care and production of gross investment in health capital stock. They further observed that incidence of catastrophic payments for health care was rising with increasing proportion of elderly and infant members of households. This implies that the chance of a household incurring catastrophic expenditure on health care is higher for households with higher proportion of elderly adults and infants in a household in some of the countries.

Odoh and Nduka (2014) used public healthcare expenditure data series from 1977 to 2008 and analyzed the factors that determine heterogeneity in public healthcare expenditure in Nigeria. They did not only find the elasticity of public healthcare expenditure with respect to per capita income to be positive and income inelastic, but also per capita income, under-five mortality, population below the age of 15 years, and petroleum prices were significant positive long-term determinants of public healthcare expenditure in the country. These findings implied that healthcare services are necessary goods, whose consumption rises with upward-trend of population of infants, mortality rate among children under-five years, petroleum prices and income per capita. At the micro-level, Oyinpreye and Moses (2014) also examined the factors that determined out-of-pocket healthcare expenditure in Nigeria using data from the National Living Standard Survey between 2009 and 2010 and employing the Heckman two-stage selectivity model. They found an increasing likelihood of households incurring out-of-pocket healthcare expenditure with rising age and income. Thus while aged members of a household are more likely to spend more resources treating age-related illnesses, households with higher income are more likely to spend on healthcare which is considered a normal good in the study. The positive income effect also implies that richer households are more health-seeking compared to poorer ones. In Kenya, Bonfrer and Gustafsson-Wright (2016) also found that the largest chunk of the catastrophic health expenditures were financed using savings by majority of households, followed by sale of livestock and other landed assets.

In contrast, Mondal *et al*. (2010) analyzed catastrophic out-of-pocket payment for health care and its impact on household socio-economic activities in West Bengal and found income to significantly decrease the chances of households facing catastrophic health payment. Thus the probability of incurring catastrophic direct health expenditure is highest among the poor than the rich. Su *et al*. (2006) equally investigated catastrophic household expenditure for health care in Nouna District in Burkina Faso and similarly established that though higher income households reported significantly higher number of illness episodes than poor households, yet the likelihood of the latter incurring catastrophic health care expenditure was significantly higher than the former in the District. They further showed that while the average number of illness episodes for household aged adults significantly increased the probability of catastrophic health payments, average illness episodes among under-five infants was insignificant in determining catastrophic health care payments.

Moreover, Maumbe and Swinton (2002), in their study of hidden costs of pesticide use among smallholder cotton farmers in Zimbabwe, concluded that male farmers, extension meetings and larger farm sizes all significantly caused acute pesticides symptoms and increased overall costs of illness. This implies that larger farm sizes required large amounts of pesticides application, leading to more exposure and increase in the incidence and costs of acute pesticide symptoms among the farmers. However, extension meetings by farmers, which was expected to significantly decrease symptoms and costs of illness rather caused significant increases in symptoms and costs. According to them, extension either lacked health focus and rather concentrate on chemical pest control without adequate safety precautions or farmers who attended extension meetings more were more able to link skin, eye and stomach illness symptoms with pesticide exposure and reported them as such than those who attended less meetings.

However, all these studies mainly focused on explaining the general drivers of household out-of-pocket catastrophic health care expenditure, expenditures that are non-recurring health costs for households. But beyond the effects of general drivers on sporadic non-recurring financial health payments, there is the scientific need to also investigate the effect of using wastewater for irrigation on the heterogeneity of not only out-of-pocket costs but also the full economic costs, taking cognizance of both direct financial and indirect time costs of common recurring illnesses that weigh heavily on the scarce resources and income generation activities of households throughout the year. Findings from such a study can provide important information capable of supporting and furnishing guidance to policy makers to reduce significantly the incidence and economic burden of common diseases that accumulate to cause infrequent catastrophic health expenditures.

Besides, some of the findings of these studies either contradict one another or are inconsistent with theoretical predictions. For example, while some of these studies conclude that under-five infants, aged adults, and higher income households have the higher likelihood of being stricken by catastrophic out-of-pocket health care payments, others showed otherwise, pointing to a gap in literature about the effect of income and age on household health care expenditure. Thus the relationship is inconclusive and therefore, the need for further studies to bring conclusion to it.

Methodologically, while some used aggregated data models to predict public health care expenditure, majority of these studies employed micro limited dependent models to explain the probability of households incurring catastrophic health expenditure. However, household costs of illness behaviour would be explained significantly differently from these previous studies if sample selection and treatment effects models. Furthermore, due to the unique role urban farming plays in ensuring food security and sustainable livelihoods in cities of the world, examining the contributions of socio-demographic, health, and wastewater use as well as other farming practices to full economic burden of diseases among urban farm households would not only help toward streamlining unplanned and uncontrolled wastewater use in the cities to control its hazardous effects, but it would furnish farmers the information to accurately evaluate the net benefits of using wastewater for irrigation considering its effects on their health and the benefits of increased productivity and income.

2.5.4 Factors that influence wastewater use among urban farmers

Many studies have pointed to socio-economic, geographical, and policy factors as the main determinants of agricultural wastewater use. Havelaar *et al.* (2001), in their paper that highlighted the current position of wastewater use in developing countries, attributed increasing wastewater use to low incomes of farmers vis a vis high costs of accessing commercial irrigation facilities using freshwater, implying lack of affordability for clean irrigation water. According to the authors, lack of financial capacities to procure sophisticated wastewater treatment technologies has worsened the wastewater use problem. De Neergaard *et al*. (2009) share this view by arguing that lack of access to cheaper and reliable clean water source in rapidly growing urban cities is the main motivation behind the acceleration of wastewater use among urban farmers.

Similarly, Jiménez *et al.* (2010) observed, in their analysis of the dynamics in the use of wastewater, sludge, and excreta use in developing countries, that rapid urbanization, paucity of financial and physical resources to access fresh water or treated wastewater use, and agricultural production in proximity to cities where water sources are at greater risk of pollution due to market incentives, among others, are responsible for increasing use of wastewater for agricultural production. These observations imply that wastewater use is high among populations with low income, living in urban cities and producing near to places with polluted water sources for irrigation.

Kanyoka, and Eshtawi (2012), in their analysis of the trade-offs of wastewater reuse in agriculture, indicated that wastewater use among urban vegetable growers is high due to poor drainage and sanitation infrastructure, which causes indiscriminate pollution of water bodies used for irrigation. Thus wastewater use is high due to high incidence of water pollution by domestic and industrial effluents in the cities.

Even though these studies have identified some factors that directly and indirectly influence farmers' use of wastewater for irrigation, a significant number of the studies have been done at continental or national levels, which faced aggregation problems in their findings. This particular study will, however, investigate the specific socio-demographic, economic, and geographical features of farmers that particularly determine the use of wastewater at the household level. This will identify specific micro-level factors that influence wastewater use so that policymaking will target the root causes of the problem, and as a result, sustainable solution can be reached even at the national level.

2.5.5 Determinants of farm family and hired labour use

2.5.5.1 Ill-health

A number of empirical studies have confirmed the economic theory that predicts a strong negative effect of ill-health on family labour supply, intra-household labour and inter-family-non-family labour substitutions. Larochelle and Dalton (2006) investigated the effect of transient health shocks on agricultural labour demand among irrigated rice-producing households in Mali by estimating separate models for direct and indirect effects of illness episodes on family labour supply. They found that both illness episodes among dependants (children) and adult family farm workers have significant negative impacts on family labour supply to farm activities, which shows significant indirect and direct effect of illness on total family labour use respectively. The indirect effect implies that adult labourers spend their time taking care of sick children at the expense of farm work. In addition, the number of dependants significantly decreases intra-family labour substitution among farmers, implying that increases in the number of dependants significantly constrained households from substituting sick farm workers with healthy working-age members. They further observed that hire labour and family labour are not perfect substitutes since the positive effect of illness on hired labour is less than the negative effect of illness on family labour, leading to a reduction in total labour use on farm, and this confirms the assumption of non-separability of production and consumption decisions in farm households.

Asenso-Okyere *et al*. (2011) in their survey of evidence about the interaction between farm labour productivity, and health and nutrition confirmed these findings by arguing that ill-health of adult members of a farm household affects the duration and intensity of labour force participation and farm work effort, which may cause final output to shrink. According to the authors, household family farm labour shortage gets worsened when, apart from the labour hours lost due to the disability of a working adult on the farm, there are arrangements put in place to take care of the sick person by other working members in the household. In addition to these, they found that illness disables farmers from attending extension meetings and field experimentations to learn about new technologies, which constrain their ability to innovate and to apply agricultural technologies to farm production to augment output and productivity.

In Ghana, Osei-Akoto *et al*. (2013) in their analysis of the effects of health shocks on agricultural productivity using panel data and three-stage-least-squares (3SLS) method similarly found a significant negative effect of common illnesses reported in households on the amount of hours family labour allocate for farm activities such as land preparation, management, and harvesting. They found a much stronger negative effect of illness on family labour supply to the household farm during land preparation and farm management (land and produce) as labour requirements during these production stages are substantially higher. However, the effect of illness in a household on hired labour demand depends on both the production stage and the severity of the effect of illness on family labour availability to the farm. The study found a significant positive effect of illness on hired labour during farm management but negative effects during land preparation and harvesting. Therefore, during farm management, there is a significant positive substitution of family labour lost for hired labour.

However, in Burkina Faso, Combary (2016) who estimated the impact of rural households' use of services of Health and Social Promotion Centre (HSPC) for treatment of transient illnesses during rainy season on labour supply and productivity did not find any significant negative effect of incidence of illness among household members during farming season on family labour availability and productivity.

There is some level of consensus among these studies that transient illnesses significantly reduce household family labour availability and intensity, but increase non-family labour intensity and demand, and intra-family labour and inter-family-hired labour substitutions. Nevertheless, there are still some studies that did not find any relation between ill-health and family labour and hired labour use, and therefore the relationship between illness and household labour use needs further investigation. Besides, all these studies focused on non-irrigated farms where labour use intensity is significantly lower compared to manual irrigated farms, and therefore, the effect of illness on household labour use is expected to vary enormously between irrigated and non-irrigated farming households. These and other factors formed the basis for this study to further investigate the impact of transient illnesses on household labour use among urban wastewater irrigation farm households in Ouagadougou.

2.5.5.2 Socio-economic and demographic characteristics

Besides illness, there are many other factors that have been shown to affect household labour use in crop production. Anim (2011) modelled factors that determine rural household farm labour supply in farming communities of South Africa using double-logged OLS regression model. He showed that family farm labour input responds significantly and positively to female farmers and increases in land size cultivated by the farm household but inversely to the number of educated household members and the number of off-farm workers in the household. This implies that educated members supply less labour to farm due to the efficiency with which they utilize other complementary inputs in production and the scale of diversification of their knowledge into non-farm and off-farm activities.

Similarly, Bedemo *et al*. (2013a) used multinomial logit model to examine the determinants of labour market participation choice of farm households in rural Ethiopia to produce results that confirm these findings. Their results indicated that education of household head, proportion of household members educated, farm size cultivated, number of dependants, value of variable inputs like fertilizer, and credit obtained all contribute significantly to households' probability of hiring labour (reduction in family labour availability) and substituting hired labour for family labour on the farm. Thus they increase the odds of a household participating in the labour market as a buyer and/or both a seller and buyer simultaneously. In Ghana, Osei-Akoto *et al*. (2013) corroborated the results on the effect of education on labour use by revealing that household family labour supply and demand for hired labour both responded positively and significantly to number of literate adults in a household. In contrast, Bedemo *et al*. (2013b) did not observe any significant impact of education of household head on family labour because the impact of education on family labour supply comes indirectly through its impact on farm output and profitability. Bagamba *et al*. (2007) confirmed the education effect on labour use when they analyzed the determinants of smallholder farmer labour allocation decisions in Uganda using the Heckman Selectivity Maximum Likelihood Model and also they did not find any significant relationship between education of the head and household demand for hired labour in all the studied locations in Uganda.

Moreover, Bedemo *et al*. (2013a) in their study observed that the number of adult family farm workers causes a decrease in the odds of a household buying (hiring) labour but increases the probability of supplying labour to the farm. In addition, they found credit accessed as a means of raising the financial ability of households to buy labour (hired labour demand) to either complement family labour or replace unhealthy or non-available family farm workers. However, Bagamba *et al*. (2007), who analyzed the determinants of smallholder farmer labour allocation decisions in Uganda using the Heckman Selectivity Maximum Likelihood Model, found credit access to have a negative and significant effect on households demand for hired labour in the Southwest of Uganda. According to them, households that borrow are viewed as low-income groups making hired labour unaffordable to them.

Besides, Bedemo *et al*. (2013b) again employed instrumental variable estimation method to analyze the determinants of household demand for and supply of farm labour to check whether findings would vary from findings from the previous study that they used multinomial logit. Interestingly, they found family farm labour supply to significantly increase with the number of adult labourers but reduces with number of dependants in a household, while labour bought to work on household farm responded positively and significantly to size of land cultivated, off-farm income, education of household head, value of variable inputs, and number of dependants, but negatively to number of adult labourers just as they found in the other study. Value of variable inputs like fertilizers, pesticides, seeds among others was found to have the largest impact on the demand for hired labour, followed by size of land cultivated.

In Ghana, Osei-Akoto *et al*. (2013) found family labour supply for farming activities significantly increases with increases in factors such as number of economically active male and female members.

Although there is some level of agreement among these studies about the impact of adult members, infants and aged, cultivated farm size, and value of variable inputs on the supply of both family and hired labour for household farm activities, there are still a great deal of disagreements and contradictions concerning the direction and significance of the effects of credit accessed, education of household head, education of household members and other factors on family and hired availability and use by households on their farms. Besides, many of these studies focused on household supply of and demand for labour for farm activities in rural settings, where according to the traditional Lewis two-sector structural development model labour surplus is said to exist and the marginal product of labour is zero, making their supply inelastic and wage rate below the market rate (Todaro and Smith, 2012). Therefore, the results of these studies would be unreflective of the labour demand and supply situation in an urban area where the labour market is relatively competitive and the farmer competes with other off-farm and non-farm sectors for the same labour. In addition, the labour requirements for urban irrigation farming are profoundly different from non-irrigation farming yet all these studies focused on non-irrigation farm households. These and many other reasons underpinned the need to further investigate the impact of socio-economic and demographic factors on the supply of family labour and demand for hired labour for household farming activities in Ouagadougou, the capital city of Burkina Faso.

2.5.6 Effect of ill-health and other inputs

The theoretical prediction of a negative effect of ill-health on agricultural investments is due to depletion and diversion of household scarce financial and physical resources into health care service expenditures, which otherwise would have been used to purchase complementary inputs such as fertilizers, pesticides, new seeds, among others to increase farm output.

Asenso-Okyere *et al*. (2011) in their survey of evidence about the interaction between farm labour productivity, and health and nutrition argued that farmers' spending on health care during treatment of illness deprives them of necessary financial resources to purchase important farm inputs, particularly fertilizers and pesticides, which affects output. This implies that apart from the traditional factors of production such as labour, land, machinery, and seeds, the acquisition and application of technologies such as fertilizers and pesticides depends largely on the availability of extra-income so that the use of the extra-income for treatment of illnesses deprives the farmer of resources to purchase fertilizers and pesticides to improve productivity and output.

In Ghana, Osei-Akoto *et al*. (2013) examined the impact of health shocks on agricultural productivity which revealed that common illnesses reported in households in Ghana were found to have strong negative effects on household's demand for complementary inputs such as seeds, fertilizers and agro-chemicals, and tractor services among others.

Knepper (2002) used Post Harvest Survey data from 1997 to 2000 collected by government to estimate factors that affect the use of fertilizer by small and medium-sized farming households in Zambia and found that male-headed households are highly probable in using fertilizer more than female-headed households just like households with higher number of male and female active labour force. This implies that households with higher number of labour force are more likely to use more fertilizer than households with small number of labour force because fertilizer use and family labour are complementary inputs and not substitutes. Traditional factors such as household income level, educational level of household members, number of economically active males and females have been proven statistically to have significant positive effect on the quantity of fertilizers and agro-chemicals used (Osei-Akoto *et al*. 2013).

However, Waithaka *et al*. (2007) who examined factors that determine the use of fertilizers by smallholder farmers in Western Kenya though found size of land cultivated, income, education of household head to contribute significantly to increase in the amount of fertilizer used by farmers, they did not find any significant effects of sex of household head and the number of economically active labour force on fertilizer quantity used.

The findings of these studies are specific to non-irrigated and medium to large-scale crop farmers whose use pattern of fertilizer and agro-chemical completely vary from that of irrigated and small-sized farmers in urban areas. Besides, access to health care and its accompanied costs to farm households and safety regulatory and organic controls placed on farmers' use of fertilizers and pesticides in environments where these previous studies have been conducted may differ significantly from what pertains in Ouagadougou. Therefore, a different study into the effect of illnesses and other socio-economic factors on urban farmers' use of fertilizers and agro-chemicals Ouagadougou may produce relevant results that were not captured by previous studies.

2.5.7 Effect of ill-health on farm output/productivity

The theoretical relationship between ill-health and farm output and productivity is both direct and indirect. While the expected direct negative effect of illness on farm productivity stems from the negative effect of illness on the management capacities of the farmer, the indirect effect of illness on farm productivity is transmitted through the negative effect of illness on the inputs.

Ajani and Ugwu (2008), who analyzed the impact of adverse health on agricultural productivity of farmers in North-Central Nigeria using stochastic production frontier approach, concluded that among all the socio-economic characteristics of farmers that affect their inefficiencies in Kainji basin, average days lost to incapacitation of farmers due to illness has the largest significant negative impact on efficiency in farm production. Specifically, one additional day lost to farm work due to illness will cause efficiency of a farmer to decrease by 31 percent. This finding was corroborated by a similar study that analyzed the effect of ill-health on agricultural production in Nigeria, in which Onuche *et al*. (2014) revealed a significant negative effect of the number of days lost to illness by farmers on farm output. This implies that household farm output significantly declined with increasing number of days household member were unavailable to undertake farming activities on account of illness. These findings, however, show that loss in agricultural productivity due to illness is as a result of losses in labour induced by illness. Also, in Osun State, Nigeria, Egbetokun *et al*. (2012) examined the impact of farmers' health on technical efficiency using stochastic production frontier model. They confirmed that productivity of farmers can be improved if the stock of health capital of the farmer is raised.

Ulimwengu (2009) used a stochastic production frontier model to examine the impact of farmer's health status on agricultural efficiency and poverty in rural Ethiopia. His results, after controlling for household characteristics and locational features, confirmed a significant negative effect of the probability of a household being hit by an illness shock on agricultural efficiency. This finding implies that households hit by illness shocks experience lower agricultural efficiency with respect to land, fertilizer, and animal because illness reduces the time household members allocate to application of inputs and mechanization processes.

Osei-Akoto *et al*. (2013), in their analysis of the effect of health shocks on agricultural productivity in Ghana, observe that the number of days household members were ill significantly reduces farm output directly, which corroborates with both theoretical and conceptual models.

Elsewhere in West Bengal, India, Mondal *et al*. (2010) investigated catastrophic out-of-pocket payment for health care and its impact on households and observed that even though health care payment for chronic illnesses contributes substantially to catastrophic payment for health care, medical care costs for minor illnesses such as malaria, fever, headache among others have a devastating impact on household economic activities, particularly farm income.

Despite these avalanches of studies confirming the significant impact transient diseases have on farmers' output, there are equally significant number of studies produced contrasting results. Elsewhere, Conly (1975) evaluated the impact of malaria on economic development using Mexico as a case study showing that coping processes at the household level in terms of intra-family labour substitution and reallocation have offset the effect of malaria on farm production. This implies that the effect of malaria on farm production is manifested through its effect on family labour.

In Africa, Nur and Mahran (1988) also looked at the effect of malaria on agricultural labour based on theoretical and empirical investigations in economics and tropical diseases. They revealed that households reallocated women and children to replace sick and disabled men working on farm as a coping mechanism against the effect of illness on farm output. They found that these women and children were able to compensate for 62 per cent of total loss of farm work hours due to malaria and schistosomiasis, though they worked 20 percent extra-time to ensure that final output remained unreduced.

Audibert and Etard (1998) used quasi-experimental design to evaluate the impact of schistosomiasis on rice output and inputs in Mali. They famously concluded that ill-health does not have any significant direct effect on rice output in Mali because ill-health actually significantly increased family labour intensity in rice–growing but did not affect non-family labour intensity in the same activity, which compensated for the farm work lost due to illness. This implies that even though illness affects the labour efficiency of farmers and farm workers, output is unaffected because other family members unaffected by illness actually compensate for the reduction in labour efficiency of affected members by increasing their work intensity and work time. Similarly in Côte d'voire, Audibert *et al*. (2011) who investigated the impact of malaria on production and income of producers of coffee and cocoa did not find prevalence of malaria to have a significant negative effect on production and income of farmers.

Ajani and Ashagidigbi (2008), who examined the effect of malaria on rural households' farm income in Oyo State, Nigeria using linear OLS regression model, did not find a significant negative effect of number of farmers' work days lost due to incapacitation from malaria on annual farm income. Rather, they found financial costs of treating malaria measured as income lost due to malaria to have a significant positive effect on farm income, suggesting that increases in financial costs of malaria treatment causes farm income to rise. Thus increase in income lost due to malaria is an indication of households' investment in health capital, which contributes positively to increase in farm income.

Larson *et al*. (2005) did a baseline survey of the impact of household health on cocoa production among smallholder farming households in Western Region of Ghana using Information for Cocoa Swollen Shoots Virus Disease (CSSVD). Chronic diseases such as heart attack, cancer, HIV/AIDs, and TB, among others, were found to have no statistically significant negative effect on cocoa yields. Rather mortality among working-age adults per year was found to cause total cocoa output to fall by 0.17- 0.26 percent.

Analysis from these studies is clear that the effect of ill-health on farm output and productivity remains inconclusive since these studies have produced divergent results to support their findings, and therefore, the scientific interest to further investigate the relationship in an environment significantly different from places the previous studies were done. Besides, some of the studies assumed direct and exogenous effect of illness on output. However, the validity of this assumption is doubtful given the predictions of the agricultural household model of Singh *et al.* (1986) that illness directly affects farm inputs but indirectly affect output. Also, the epidemiological profile of Ouagadougou varies significantly from that of the places in which these previous studies have been conducted, and therefore discrepancies in incidence of transient illnesses like malaria, diarrhea, cold among others among farm households in these study locations may reveal economic responses by farm households to these illnesses significantly different from what these previous studies have produced.

2.5.8 Other factors that determine farm output/productivity

Many of these studies have confirmed that factors such as cultivated farm size, labour supply (man-days or man-hours), animals, amount of credit accessed, number of extension contacts, quantity of fertilizers and agro-chemicals, education of farmers, and seed determined agricultural output and productivity significantly and positively (Ulimwengu, 2009; Osei-Akoto *et al*. 2013; Onuche *et al*. 2014).

Bedemo *et al*. (2013b) employed instrumental variable estimation method to analyze the determinants of household demand for and supply of farm labour in rural Ethiopia. They estimated value of output produced function and found it to be responding significantly and positively to household head education (human capital), family farm labour, hired labour, variable inputs, and land size cultivated. Family farm labour, however, was not only found to have a larger impact on value of output than hired labour because of discrepancy in work incentives in favour of the former, but also has the largest output elasticity compared to all farm inputs in this study. Ajani and Ashagidigbi (2008) who examined the effect of malaria on rural households' farm income in Oyo State, Nigeria using linear OLS regression model found increases in farm size and non-food expenditures of a household significantly raised farm income.

Kanyoka and Eshtawi (2012) also investigated the economic effects of indirect wastewater irrigation and showed that irrigation, especially with wastewater, provides farmers with renewable nutrients to replace fertilizer cost, contributes to alleviation of freshwater scarcity and environmental pollution, services as a drought-resistant source of water, and improves cropping intensity and crop output. Similarly, the amount of organic matter and a diversity of nutrients including iron, magnesium and zinc that raw wastewater is able to recycle for optimal growth of crops is far greater than any commercial fertilizer can supply, making it a cost-effective resource capable of reducing cost of fertilizers and increasing food supply and incomes with their indirect effects on education and improved health conditions (Jiménez *et al*. 2010).

However, Ajani and Ugwu (2008), who analyzed the impact of adverse health on agricultural productivity of farmers in North-Central Nigeria using stochastic production frontier approach, interestingly found contrasting results for the effects of land, labour, seed, and pesticides on output. They did not find land and labour to significantly cause output to increase due to abundance of family labour surplus and land in the basin, while the impacts of seed and insecticides on output were found to significantly decrease output due to over-utilization beyond their output-maximizing limits.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Chapter outline

This chapter presents the research design and sampling strategy, showing systematically how the sampled urban farm households were randomly selected for data collection. Subsequently, the details of the materials and techniques employed to obtain the required data from the sampled households are discussed and eventually the theoretical and econometric analytical models used to analyze the data collected are shown.

3.2 Study area

Ouagadougou is the capital city of Burkina Faso, which is bordered to Ghana, Togo, Benin, Mali, Cote d'ivoire, and Niger (Figure 3.1). It is located in the Sudanese savannah arid zone with low and highly erratic mono-modal rainfall season (Bellwood-Howard *et al*. 2015; Kpoda *et al*. 2015). The city has two climatic seasons; a rainy season which lasts from May to September, and a dry season, stretching from October to April, with a mean rainfall quantity of 700mm. Even though Mossi is the largest ethnic group living in the city, yet still, it is fairly diverse ethnically, including Lobi, Dagaati, Fulani, and Peul due to its cosmopolitan status.

The city is predominantly populated by young rural immigrants who came seeking socio-economic opportunities. The high exodus of rural-urban migration contributed tremendously to the exploded annual demographic growth rate of 4.2

between from 1996 to 2006 (Onadja *et al*. 2013). Currently, the population of the city is close to two million people, while a large proportion of them, particularly farmers are unschooled, with the highest being women (Onadja *et al*. 2013; Bellwood-Howard *et al*. 2015).

Vegetable production is the major source of income for the farmers in the city, which helps them to secure sustenance for an average of 7 people in a household (Kinane *et al*. 2008). The cultivation of these vegetables is done on open-space landholdings, which are generally smaller and therefore intensively cropped in about 24 locations in the city (Kpoda *et al*. 2015; Bellwood-Howard *et al*. 2015). Although the top-soils of these urban farmers lack adequate natural contents of organic matter, nutrients, and total N, the fertility of these soils is generally improved for higher farm productivity due to both favourable climatic conditions (shorter rainy season and evapo-transpiration) and enormous investments in soil fertility amendments such as organic manure and compost, chemical fertilizers, and pesticides (Bellwood-Howard *et al*. 2015).

A large proportion of farmers who cultivate vegetables on open-space sites make use of contaminated sources of water for irrigation. Major drainage channels in the city are being polluted with human biological and industrial wastes, which, in turn, flow into public reservoirs currently used for fishing activities, irrigation of vegetables, and other domestic activities as well as contingent source of drinking water during dry season (Traore *et al*. 2015). As a result of these and the absence of a public health insurance scheme, the population is epidemiologically burdened with infectious diseases such as malaria, which continues to be one of the leading causes of deaths and non-communicable diseases (Onadja *et al*. 2013).

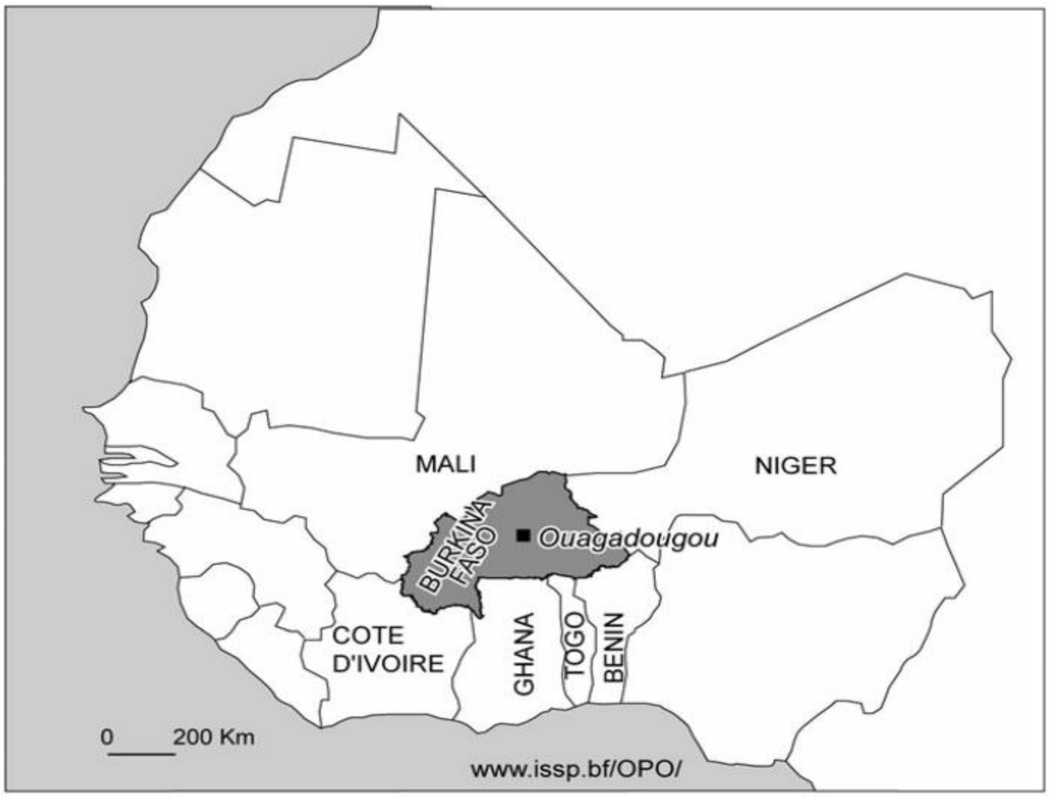


Figure 3.1: Location of Ouagadougou in West Africa

Source: Rossier *et al*. (2012)

3.3 Research design

A single-visit cross-sectional household survey was adopted in this study with which primary data pertaining to households' socio-demographic characteristics, farm production activities, incidence of diseases, and irrigation practices for the past 2016 farming season (over a six-month recall period) was obtained from sampled farm households. This particular design was used because the study is mainly interested in estimating how significantly costs of illness of households vary with the use of wastewater for irrigation, and how illness affects farm production for the past 2016 farming season.

However, for the costs of illness aspect of this study, both the prevalence-based and the top-down approaches were employed to estimate the direct costs and production losses (indirect costs) attributed to all self-reported cases of all diseases that occurred during the past four weeks from interview date. The prevalence-based approach was adopted because this study intended to provide a general picture of the financial burden of illnesses and to understand the economic impact of diseases on households' economic activities and expenditure as well as to determine how budgets can be allocated effectively to curb the diseases. The top-down approach on the other hand was picked to complement the prevalence-based approach to specifically allocate portions of the known estimated total costs of illness by type of care such as hospital care, home care, and other health and non-health services among the disease categories so that the costs can be spread over the major costs components or inputs of health-care services, which is more relevant for cost containment policies (Rice, 1967; Tarricone, 2006). Data on the incidence and costs of self-reported household illnesses were retrospectively obtained over four weeks recall period since all the relevant illnesses and expenses on treating these illnesses had already occurred and all data had been mentally recorded for use before the initiation of this study. Even though, retrospective studies are affected by recall biases, short recall period was used and related questions were asked in different forms to ensure that respondents recalled their experiences and the costs incurred. Moreover, the four weeks recall period used in this study has been used to estimate rural household economic costs of illness by other studies in Burkina Faso (Sauerborn *et al*. 1994; Su *et al*. 2006).

3.4 Sampling

3.4.1 Sample size

The sample size for this study was determined using statistically proven procedure to ensure that inferences can be made for the whole population. Based on (Anderson *et al*. 2011), the sample size was determined using the desired margin of error formulae as follows:

$$E = Z_{\alpha/2} \frac{\sigma}{\sqrt{n}} \qquad [3.1]$$

where E denotes desired margin of error, n is the sample size, σ is the sample estimate of the standard deviation, and $Z_{\alpha/2}$ is the Z-critical value which is determined from the confidence level. From equation [3.1], the sample size formula is deducted as follows;

$$n = \frac{Z_{\alpha/2}^2 \sigma^2}{e^2} \qquad [3.2]$$

The study used a 3 per cent desired margin of error, which is recommended for largely quantitative studies (Bartlett *et al*. 2001), and a sample standard deviation of 0.24 for wastewater use, which was computed from a pilot study conducted during pretesting of questionnaires in the field. Therefore, at 95 percent confidence level, which corresponds to 1.96 z-critical value ($Z_{\alpha/2}$), the sample size of 246 farm households was arrived at as follows;

$$n = \frac{1.96^2 (0.24)^2}{0.03^2} = 245.8624$$

Therefore, the sample size for the study is approximately 246 urban farm households.

3.4.2 Sampling technique

The adoption of appropriate probability sampling method to select a totally representative sample of farm households for data collection is as significant as the data and the results that would be generated from the study to inform policy decisions and influence industrial behaviours. In this study, it was planned to directly sample farm households randomly using either the lottery system or random numbers, but the difficulties that emerged included paucity of data on the complete list of names and/or numbers and locations of all urban farm households in the city to form a complete sampling frame, on which basis the random sampling was to be performed. Although data on names of members of some farmer associations operating in the city was available, using that to randomly select the sample would have undermined the main purpose of this study because there are a significant number of non-organized farmers and farms in isolated home gardens and other interstitial spaces, as well as irrigated open spaces and on irrigated fields in the city who would have been predefinely excluded from the study. It was on the bases of these that a systematic spatial sampling strategy was chosen to ensure that all these various classes of farms and farm households were randomly sampled.

The sampling technique therefore used was a systematic spatial (aerial photography) random sampling. In the first step, 10 predefined open space sites strictly dedicated to urban farming activities were identified and classified, excluding built-up areas and open spaces used for other commercial, municipal and industrial activities with the aid of high-resolution satellite photography of the entire city as shown in Figure 3.2. These distinct non-overlapping open space sites varied significantly in terms of land space and number of farmers engaged in cultivation of various crops, and therefore, each open space site was assigned a code ranging from 1OS to 10OS. Some of these open space sites included, among other things, Barrage Ouaga 1, Barrage 2, and Barrage 3. A large proportionate number of unique coded Global Positioning System (GPS) points were generated from each of the open space site, and each GPS code represented a cultivated farm field belonging to a farm household (e.g. Figure 3.3).

In the second step, using Microsoft Excel, a proportionate sample of these GPS points was randomly selected to make up the total sample size of the study. This implied that, sites with relatively large area size and higher number of farmers were allocated a relatively higher number of GPS points.

In the last step, Garmin handheld GPS devices were used to track and pick these points and interviewed farmers of the farm fields on which these points were picked. However, some of the GPS points randomly sampled were further excluded from the survey because they fell on pathways, water bodies closer to open space sites, and uncultivated areas. In other instances, some GPS points became redundant in the survey because two or more GPS points were picked either on one farm field or more belonging to one household. In the end, 208 unique households using unique GPS points were randomly sampled from all the 10 open space sites for interview across the city.

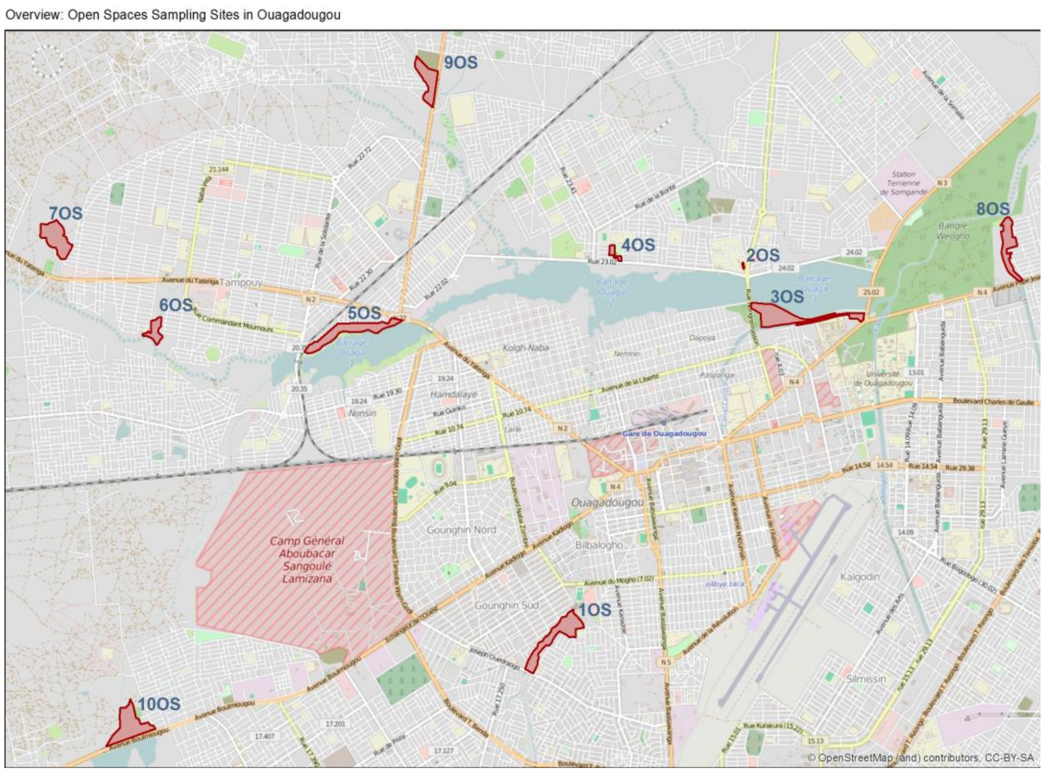


Figure 3.2 Ariel map of open space sampling sites (1OS-10OS) in Ouagadougou, Burkina Faso

Source: Field Data (2016)

Figure 3.3 Global Positioning System (GPS) points at open space sampling site 1 (1OS)

Source: Field Data (2016)

3.5 Data collection

3.5.1 Sources of data

Wastewater in this study refers to diluted wastewater which is abstracted from waste-polluted surface water sources such as rivers, streams, dugouts, drains, and ponds. Agricultural diluted wastewater use is known in the literature as indirect agricultural wastewater use (Havelaar *et al*. 2001; Jiménez *et al*. 2010). Illness is also defined in this study as the non-chronic transient epidemiological conditions that cause morbidity among household members within the recall period specified. These may include malaria, cold, diarrhea, skin infections, waist problems, animal bites among others.

The main aim of this study is to analyze systematically and empirically the effects of wastewater irrigation on the incidence of transient diseases, overall costs of illness, and agricultural labour supply, investments and farm productivity for the past 2016 farming season. Towards meeting this purpose, two recall periods were used to gather data in this study. Whereas a recall period of six months (the past 2016 farming season, spreading between April to September) was used to obtain primary data on socio-demographic, farm characteristics, irrigation practices, and incidence of illnesses, a recall period of four weeks (one month) was adopted to elicit information on past self-reported illnesses and the total direct and indirect economic costs of treatment of illnesses among others from 208 randomly sampled open space farm households. Although community health-care centres are probably the most reliable sources of data on household incidence of illness since illnesses are professionally determined and confirmed by physicians, this study relied on self-reported cases of illness by household members since record keeping by institutions is generally poor, and the number of health-care centres, and visits to hospitals by sick people are abysmally low in developing countries, particularly in a poor West African country like Burkina Faso. Self-reporting incidence of illness has the likelihood of causing bias and endogeneity in the incidence and costs of illness estimations. Data collection began at the beginning of the dry season, which lasted one month, from 9th September to 10th October, 2016.

3.5.2 Data materials and methods

Semi-structured household questionnaires containing both closed and open-ended questions were administered face-to-face to the most knowledgeable members of the sampled farm households in the language that was most intelligible to them to collect primary data. As part of the efforts to ensure reliable and accurate information from farm households, the questionnaire was made more flexible and recall-friendly to respondents by decomposing it into seven sections or departments, including socio-economic and demographic characteristics, living situations, farming characteristics, general health costs, direct costs, indirect costs, and other illness situations (Appendix A). In addition to these, interpreters from the University of Ouagadougou, who were not only sufficiently financially motivated, but also highly proficient in both English and the native languages such as French, Mossi and other smaller local languages were used during data collection to reduce distortion and misinterpretation of data from respondents. Although face-to-face interviews were largely conducted at the farm fields to obtain information on household characteristics and illness incidence and costs, personal observations by the researchers were significantly adopted to particularly obtain information on the various sources of water for irrigation for appropriate classification of farmer into wastewater and non-wastewater users so that data accurately and reliably reflect the practices of households.

Prior to data collection, the informed consent form and the ethical approval were obtained from the ethics committee of the Ministry of Health (MoH) of Burkina

Faso. This form was used to obtain a written informed consent for participation in the study from all respondents before commencement of all interviews.

3.6 Data analysis and presentation methods

3.6.1 Relationship between wastewater use and incidence of illness

Data collected was entered using Microsoft Excel 2007, which was then imported into STATA version 14.0 for analysis and generation of the results of this study. The data was generally analyzed by employing both quantitative and qualitative methods. The type and nature of data collected, determined fundamentally by the various specific objectives of this study, partly determined the choice of the specific quantitative and qualitative analytical methods used to generate results of this study. Therefore, the choice of a specific method of analysis was made with due consideration to the type and nature of data to be analyzed, and the potential estimation problems that may come thereof.

Firstly, frequency tables and descriptive statistics such as the mean-comparison t-test table were used to analyze data requirements of the objective of analyzing the incidence of the various illnesses identified among farm households, and how significantly the differences in mean incidence of each of these illness between irrigators and non-irrigators, and wastewater users and non-wastewater users. Specifically, incidence of malaria, skin infections, diarrhea/stomach problems, respiratory, farm injuries, and waist/spine was measured based on the number of times (frequency) a household reported these illnesses during the entire rainy season (April to interview day). The results on the incidence of these illnesses are displayed on a pie chart for comparative analysis and discussions. Additionally, the relationship between incidence of malaria, skin infections, and stomach/diarrhea diseases in particular and the use of wastewater for irrigation was established by statistically testing the significance level of the mean difference in the incidence of these diseases between wastewater users and non-wastewater users in particular using mean-comparison t-test. The following table shows the theoretical presentation, and the hypotheses of the mean-comparison t-tests between irrigators and non-irrigators.

Hypothesis 1A: For malaria (Table 3.1), the *a priori* sign for the difference in incidence between non-wastewater and wastewater irrigators is negative. This is because irrigation with wastewater can create favourable conditions for parasitic vectors to thrive and cause malaria. In addition, vectors such as mosquitoes and black files spend part of their life cycle in wastewater and transmit pathogens that cause malaria and other water-related diseases (Kpoda *et al*. 2015). Therefore, wastewater irrigators are at the greater risk of malaria than 'clean' water irrigators.

Hypothesis 1B: The expected sign for the difference in incidence between non-wastewater and wastewater irrigators is negative for diarrheal diseases. The argument states that microbial organisms such as *Salmonella Enterica,* which is a major cause of diarrheal disease, particularly among children, are commonly found in polluted waters and irrigated vegetables. Therefore, irrigating with wastewater increases the likelihood of contracting diarrheal diseases through inhalation and ingestion of the wastewater, as well as consumption of the irrigated vegetables the household produces (JIFSAN, 2010; Traorė *et al*. 2015).

Hypothesis 1C: The difference between non-wastewater and 'clean' water users relating to the incidence of skin infections is negative *a priori*. It is contended that most wastewaters are commonly contaminated with inorganic materials from industrial, agricultural, and municipal wastes, leading to the concentration of pesticides, salt, metals, and dangerous toxins, among others in these waters (JIFSAN, 2010; Kpoda *et al*. 2015). Therefore, frequent human contacts with such waters cause water-washed diseases, particularly skin irritations and other infections. Therefore, urban farm households that irrigate their fields with wastewater throughout the season are expected to be more exposed to skin infections than their counterpart non-wastewater users.

Table 3.1 Mean-comparison t-test of incidences of illnesses between wastewater users and clean-water users

Disease	**Clean-water (0) Mean incidence**	**Wastewater (1) Mean incidence**	**Difference (D)=(0-1) $H_0 : D = 0$**
Malaria	XXXX	XXXX	$H_1 : D < 0$
Skin Infections	XXXX	XXXX	$H_1 : D < 0$
Stomach/diarrhoea	XXXX	XXXX	$H_1 : D < 0$
Waist/Spinal Prob.	XXXX	XXXX	$H_1 : D \neq 0$
Farm injuries	XXXX	XXXX	$H_1 : D \neq 0$
Respiratory problems	XXXX	XXXX	$H_1 : D < 0$
Other diseases	XXXX	XXXX	$H_1 : D \neq 0$

descriptive statistics such as totals and mean-comparison test table were employed to analyze data collected to meet the objective of analyzing the components of costs of illness such as drugs, medical care, transportation, food, and indirect cost and how each of these components relate with the use of wastewater for irrigation. Total cost of drugs, medical care, food, transportation, direct and indirect costs were specifically computed, and the share of each of these components in the overall costs of treating illnesses by households. For easy recollection of costs information by household members, cost of illness was measured for the last four weeks of illnesses from interview date. This implies that the incidence of household illness, and for that matter the costs of illness, covered the period from August to September as data collection began 9th September to 10th October. Therefore, the cost of illness data is based on illness of any household member since the last four weeks, which spanned from August to September. The results generated are presented in pie charts.

3.6.2 Relationship between wastewater use and costs of illness

Also, the mean-comparison test table was used to generate the mean costs of each item of treating illnesses for irrigators, non-irrigators, wastewater users, and non-wastewater users. Comparative bar charts are used to present these results. Below is a table describing the costs of illness variables used in this study.

Table 3.2 Definition of cost of illness and its components

Cost variable	**Description**
Drugs	These are financial costs specifically related to expenditure on drugs for treatment of illness. They included both modern and herbal drugs purchased at pharmacy, hospital, chemical sellers, and traditional healers.
Medical care	This is financial cost related to diagnosis, consultation, registration (folder), bed or accommodation, outpatient care, and other specialized services such as X-rays, theatre operations and laboratory fees at both modern and traditional health facilities.

Transportation	Financial costs incurred relating to movement to and from health facility for the sick person and attendants if any. It included taxi fare, fuel cost for own vehicle
Food	This is financial cost incurred specifically on prepared and purchased food for the sick person and other attendants (if any) that would not have been incurred should that person was not sick.
Direct costs	These included the sum of financial costs for drugs, medical care, transportation, and food incurred by the household during treatment of illness.
Indirect costs	These comprise incomes or wages lost as a result of illness of a household member. They included loses such as farm, trade, and wage incomes lost by both sick and non-sick household members resulting from the sickness and it treatment.

Mathematically, the direct, indirect, and economic costs of illness for a household during the four-week recall period were respectively computed as follows;

$$DC_h = \sum_{i=0}^{n} (C_{di} + C_{mi} + C_{tri} + C_{fi}) \quad [3.3]$$

$$IDC_h = \sum_{i=0}^{n} [(T_{si} * w) + (T_{ci} * w) + (T_{si} * S) + (T_{ci} + S) + (Q_h * p)] \quad [3.4]$$

$$EC_h = \sum_{i=0}^{n} (DC_i + IDC_i) \quad [3.5]$$

where DC_h is total direct financial cost of illness for a household; IDC_h is total indirect costs of illness for a household; EC_h is the economic costs of illness; C_d is the financial cost of drugs and herbs; C_m is financial cost of medical care; C_{tr} is financial cost of transport or travel; C_f is financial cost of food or sustenance; T_s denotes time or hours lost by the sick member; T_c denotes time or hours lost by caretaker or attendant; w is the wage rate; S is average sales per day; Q_h is the total household output lost from sickness of member(s); and P is average price of farm output.

3.6.3 Determinants of cost of illness among farm households

3.6.3.1 Theoretical specification of Heckman model for incidence and costs of illness

In estimating the cost of illness model in which cost is measured as a continuous variable, OLS regression technique, depending upon the functional form, is reckoned to be the best technique as long as the Best Linear Unbiased Estimator (BLUE) properties are sufficiently met (Greene, 2003). In this study, costs of illness are related to only direct financial costs associated with treatment (preventive costs are excluded), which were observed for households that recorded at least one incident of illness within the recall period (in the last four weeks during the rainy season from date of data collection). This was to ensure accuracy and precision in the measurement of all costs incurred during the treatment of illness(s) as recalled by households. Given this condition, about 75 households, representing 36 percent of total households either recorded at least one incident of illness outside the recall period or did not record any incident of illness at all so that their costs of illness were excluded from the observations. This leads to an important estimation problem, which is the presence of as many as 75 unobserved "zeroes" in the costs of illness observations.

The presence of these many zeroes is as a result of infrequent incidence of illnesses in a household just like other household activities such as gambling, cigarette smoking, alcohol use, and other consumer durables, which pose distributional problems for common estimators like Ordinary Least Squares (OLS) because of a sizeable probability mass at zero (Humphreys and Lee, 2009). Alternative statistical techniques have been developed to overcome the distribution impediments associated with the presence of zeroes, including among others the Tobit, double hurdle, and Heckman sample selection models (Maddala, 1983; Greene, 2003). However, while in the Tobit and the double hurdle models, all zeroes are attributed to either corner solutions or abstentions or both, for the Heckman selectivity model, the processes that generate the zeroes can be attributed to infrequency (Jones, 2000; and Humphreys and Lee, 2009). Therefore, given these considerations and the interest in modelling the effect of wastewater irrigation on costs of illness, the Heckman selectivity model, also known as incidental truncation model (Greene, 2003) was chosen.

The underlying reasoning behind the use of Heckman model in this study is to control for sample selection biases. The potential source of sample selection biases may be the possibility that the determinants of household costs of illness are non-random so that households with very low or no incidence of illness are the same households with low or no costs of illness or that the unobservable variables that significantly influence household illness status are correlated with unobservable variables that determine household costs of illness. Thus if there are unobserved factors that are correlated with household's illness status and costs of illness, then the coefficients of the costs of illness equation based on OLS will be biased (Greene, 2003; Vance and Buchheim, 2005). Therefore, regressing cost of illness on characteristics for the sub-sample of the population which recorded at least one incident of illness within the recall period and to the extent that households which did not record at least one incident of illness are excluded from the sub-sample of observations on the costs of illness will cause estimates to be biased upward (Heckman, 1979; Vance and Buchheim, 2005). The Heckman sample selection model assumes that there is underlying relationship between cost of illness and its covariates specified as;

$$C_i = \beta X_i + \varepsilon_i \qquad [3.6]$$

where C_i is the direct financial cost of illness for the ith household; β is a vector of associated unknown parameter estimates; X_i is a vector of observed explanatory variables that relate to the ith household's socio-economic and other factors; and ε_i is an unobservable random variable that captures other factors that determine cost of illness for ith household.

However, there are many households whose financial cost of illness is not observed. Instead, cost of illness is only observed if and only if a household recorded at least one incident of illness within the recall period and therefore consumes healthcare services for treatment. Therefore, financial cost of illness is observed only when the following selection equation, which defines a dichotomous variable showing whether a household recorded at least one incident of illness within the recall period or not (household illness status) holds:

$$I_i^* = Z_i\gamma + v_i \qquad [3.7]$$

$$\begin{matrix} I_i & = & 1 & if & I_i^* & > & 0 \\ I_i & = & 0 & if & I_i^* & = & 0 \end{matrix} \qquad [3.8]$$

Where I_i^* is an unobserved latent variable indicating the incidence of illness in a household; I_i is an indicator of whether a household recorded at least one incident of illness or not (household illness status); Z_i is a vector of independent variables that determine the likelihood of a the *ith* household recording at least one incident of illness or not; γ is a vector of unknown coefficients to be estimated, and v_i is the stochastic error term. In equation [3.7], γ is estimated using the Probit Maximum Likelihood Method (MLM) so that in the second stage of Heckman, the outcome equation in equation [3.6] will be an OLS regression of cost of illness at $I = 1$ specified as:

$$E(C_i|I_i = 1, X_i) = \beta X_i + E(\varepsilon_i|I_i = 1) = \beta X_i + E(\varepsilon_i|v_i > -Z_i\gamma) \qquad [3.9]$$

This implies that C_i is observed only for households that recorded at least one incident of illness case within the recall period. It is assumed that both error terms are normally distributed with zero means and constant variances, and that the error terms are correlated, where $\rho\sigma_\varepsilon\sigma_v$ is the correlation coefficient as shown in equation [3.10] below;

$$(\varepsilon, v) \approx N(0, \quad 0, \quad \sigma_\varepsilon^2 \quad \sigma_v^2 \quad \rho\sigma_\varepsilon\sigma_v) \qquad [3.10]$$

The key problem of sample selection comes from equation [3.9], where the error term v_i is restricted to be above a certain value so that households which did not record at least one incident of illness within the recall period are excluded from the regression. However, given equation [3.10] where the two error terms are correlated with $\rho\sigma_{\varepsilon}\sigma_{v}$ being the correlation coefficient, the lower bound on v_i implies that ε_i too is restricted. Therefore, given that the joint distribution of ε_i and v_i is bivariate normal (Vance and Buchheim, 2005) and the non-observable variables in the selection equation are not considered in the outcome equation, then the sample selection problem is diagnosed as a specification error of an omitted variable (Heckman, 1979 Greene, 2003), which can be addressed by taking the expected value of ε_i conditional on v_i to get the Inverse Mills Ratio (IMR) as;

$$E(\varepsilon_i | v_i > -Z_i\gamma) = \rho\sigma_{\varepsilon}\sigma_{v}\left[\frac{\phi(-Z_i\gamma)}{\Phi(-Z_i\gamma)}\right] = \rho\sigma_{\varepsilon}\sigma_{v} \quad \lambda_i(-Z_i\gamma) = \beta_{\lambda} \quad \lambda_i(-Z_i\gamma) \text{[3.11]}$$

where σ_{ε} and σ_{v} are respectively the error variances of the OLS and Probit models and the term in the bracket is the IMR, (the same as $\lambda_i(-Z_i\gamma)$), which is measured as the ratio of the probability density function of the standard normal distribution to its cumulative density function. Therefore, plugging the IMR into the outcome equation addresses the potential biases that may arise from sample selectivity. Therefore, the outcome equation to be estimated eventually after addressing the problem of bias or the omitted variable problem will be

$$E[C_i | I_i = 1] = \beta X + \rho\sigma_{\varepsilon}\lambda_i(\alpha_v) + u = \beta X + \beta_{\lambda}\lambda_i(\alpha_v) + u \qquad \text{[3.12]}$$

where $\alpha_v = -Z_i\gamma$, $\lambda(\alpha_v) = \dfrac{\phi(-Z_i\gamma/\sigma_v)}{\Phi(-Z_i\gamma/\sigma_v)}$, Greene (2003).

Also ρ provides the covariance estimate of the effects of unobserved variables on household illness status and cost of illness so that if significant, then there is evidence of the presence of sample selectivity. A positive value of ρ shows that there are unobserved variables that increase both the probability of illness episodes and the costs of illness, while a negative value indicates an increase in the probability of illness episodes but a reduction in the costs of illness for households (Bagamba *et al*. 2007). The two equations can be estimated using the ML technique, using the estimates of the IMR as the starting values in the iteration process, which produces a relatively small standard errors and efficient estimates than the two-step technique (Vance and Buchheim, 2005 and Cameron and Trivedi, 2009).

The marginal effect of the regressors on C_i in the observed sample comprises of two components: the first is β which measures the direct effect on the mean of C_i, and for the second component, if a regressor appears in both X and Z in the costs of illness and illness status equations respectively, assuming that I_i^* is positive, then it will influence C_i through its presence in λ_i. Therefore, the full marginal effect of that regressor on C_i will then be;

$$\frac{\partial E[C_i|I_i = 1]}{\partial X_{ik}} = \beta_k - \gamma_k\left(\frac{\rho\sigma_\varepsilon}{\sigma_\nu}\right)\delta_i(\alpha_\nu) \qquad [3.13]$$

where $\delta_i = \lambda_i^2 - \alpha_i\lambda_i$ (Greene, 2003). If the expected value of C_i is higher when I_i^* is positive than when it is negative and assume that ρ is positive, then the additional term will reduce the marginal effect since $0 \prec \delta_i \prec 1$. By implication, when ρ is positive and the effects of the regressor on I_i and C_i are both positive, then the estimated β will overstate the marginal effect of the regressor for those within $I_i = 1$ and understate it for those within $I_i = 0$. Therefore, the second term in equation [3.13] compensates for this overstatement by reducing the marginal effect. Nevertheless, the sign, magnitude, and statistical significance of the full marginal effect in equation [3.13] might all vary from those of the estimate of β, depending upon the research setting (Greene, 2003).

3.6.3.2 Empirical specification of Heckman model

The empirical model is specified as;

Outcome equation:

$$DC_i = \beta_0 + \beta_1 Dep_i + \beta_2 HHH\_sex_i - \beta_3 HHH\_ed_i - \beta_4 Lit\_adult_i + \beta_5 Nonfarm\_inc_i$$
$$- \beta_6 Trad\_transp_i + \beta_7 Hosp\_visit_i - \beta_8 Insect\_app_i + \beta_9 Nonmal\_inc\_4wk_i$$
$$+ \beta_{10} Mal\_inc\_4wk_i + \beta_{11} Ill\_day\_4wk_i + \beta_{12} Attend_i$$
$$+ \rho\lambda_i + \varepsilon_i \qquad [3.14]$$

Selection equation:

$$Irrig\_wat_i = \gamma_0 - \gamma_1 HHH\_sex_i + \gamma_2 HHH\_ed_i + \gamma_3 Lit\_adult_i + \gamma_4 Wat\_drink_i$$
$$+ \gamma_5 Farm\_time - \gamma_6 Dep_i - \gamma_7 Insect\_app_i + \nu_i \qquad [3.15]$$

However, on the basis of economic reasoning and meaning of coefficients, the overall explanatory power of models (R^2), number of significant variables in the model (Z-test), relative levels of multicollinearity and heteroscedasticity, several different functional forms were tested for fitness of data on the costs of illness including linear, semi-log, double-log, quadratic and transcendental models. Eventually, the linear model emerged the functional form that best fitted the costs of illness model in the Heckman Sample Selection model.

3.6.3.3 Hypothesis Testing

Hypothesis 2A: Education variables, including educational level of household head and number of educated adult household members, are expected to significantly decrease both incidence and financial costs of treating illnesses recorded in a household. This hypothesis is based on Grossman (1972) theory of health capital stock that predicts that household demand for medical care decreases with education as stated in equation [2.9] in Chapter two.

Hypothesis 2B: Dependant population, measured as the number of children less than five years of age and aged adults in a household, is expected to significantly increase both incidence and financial burden of illness *a priori.* This is similarly predicated on the theory of health capital stock by Grossman (1972) which predicted a positive relationship between age and demand for health care services as indicated in equation [2.9] in Chapter two.

Hypothesis 2C: Income is theorized to have a significant positive effect on household financial spending on healthcare services for illnesses occurred in the household, *ceteris paribus.* The expected positive relationship is based on the intuition that households that are economically better-off will highly probably prefer to utilize high-cost modern specialized medical facilities and relatively expensive drugs for treatment of illness over home and other orthodox treatment alternatives.

Hypothesis 2D: Epidemiological factors such as incidence of malaria and non-malaria diseases, duration of illness, and other health-related factors including number of visits to hospital, and number of care-takers are all expected to increase household financial burden of illness, while the use of traditional means of transportation is expected to lower the financial burden of treating illnesses in a household, *ceteris paribus.*

Table 3.3 Definition of variables in Heckman costs of illness model

Variable name	Definition
DC	Direct financial cost of illness measured in Franc CFA
Ill_status	Whether a household has recorded any illness in the last four weeks or not
Dep	No. of dependants (infants under 5 years and aged 65+ years)
HHH_sex	Sex of household head, with 1 = male and 0 = female
HHH_ed	Educational level of household head measured in completed schooling years
Lit_adults	No. of adult literates (15 and above years) in the household
Nonfarm_inc	Total household non-farm income in 1000 Franc CFA
Wat_drink	Household drinking water source,1 = pipe only, 0 = otherwise
Insect_app	Insecticide application method;1 = machine;0 = manual (broom or leaves)
Farm_time	No. of months spent farming during the rainy season
Mal_inc_4wk	Incidence of malaria in the last four weeks measured in number of cases
Nonmal-inc_4wk	Incidence of non-malaria in the last four weeks measured in No. of cases
Attend	No. of attendants with ill members of the household during treatment
Hosp_visit	No. of times ill members have visited the hospital in a household
Trad_transp	No. of times traditional transports (foot/bicycle) were used during treatment
Ill_day_4wk	No. of days household members have been ill in the last four

	weeks

The two equations were estimated simultaneously using the MLM. However, just as any other systems of equations, these two equations must be identified before estimation can be implemented. As a result, sufficient number of relevant instruments or predetermined variables was introduced into both equations, including malaria incidence, non-malaria incidence, number of attendants, hospital visits, among others, to ensure that they are fully identified for estimation.

Besides, a high degree of collinearity between the explanatory variables and the IMR is a well-known econometric problem that is embedded in the implementation of the Heckman model. This impediment, which could be traced to the method with which the IMR is predicted and estimated, causes parameter instability and overstating of the standard errors of the coefficient estimates. To effectively overcome this obstacle, and address the sample selection bias in the outcome regression equation, exclusion restriction variables should be introduced. These exclusion restriction variables generate nontrivial variation in the selection equation that uniquely and exogenously determine household illness status but does not determine cost of illness in the outcome equation directly (Vance and Bechheim, 2005 and Cameron and Trivedi, 2009). In this study, variables such as source of drinking water and period of farming during the season (number of months farmer engaged in cultivation during the farming season) were used as instruments (though weak) that uniquely and exogenously determine the probability of a household recording at least one incident of illness (illness status) but does not influence cost of illness directly. Thus, for instance, households that drink water from other sources apart from pipe and borehole (covered wells) are directly more prone to infectious illness, thereby increasing the probability of recording illness, all other things being equal. However, this is not the case for costs of illness.

The variables in the model can be generally categorized into household socio-demographic attributes, farming characteristics, and illness treatment-related factors. There exist a significant level of agreement among a large volume of empirical literature that extensively worked on the effects of socio-demographic, economic and other agricultural related factors on the probability and cost of household illness.

3.6.4 The effect of irrigation water on costs of illness among farm households

3.6.4.1 Theoretical specification of endogenous treatment effects model for costs of illness

There is a certain level of consensus in theory and conceptual frameworks that connects the type (quality) of irrigation water used in crop production to incidence and costs of illness among farm households (FAO, 2012). Given this, the benefit of using clean water compared with wastewater for irrigation of farm fields can be evaluated using a general OLS model of the form:

$$C_i = \mathbf{x}'\beta + \delta W_i + \varepsilon_i \qquad [3.16]$$

where C_i is the direct financial cost of illness for the ith household (outcome); β is a vector of associated unknown parameter estimates; $\mathbf{x}$ is a vector of observed exogenous variables that relate to the ith household's socio-economic and other factors; W_i is type of irrigation water which is a binary treatment indicator ($W = 1$ if farm household uses clean water; $W = 0$ if farm household uses wastewater for irrigation) and ε_i is an unobservable random variable that captures other factors that determine cost of illness for the ith farm household. The effect of irrigation water on costs of illness is evaluated by the estimation of the coefficient δ in equation [3.16]. However, the variable, irrigation water, is not exogenous since the use of clean water or wastewater for irrigation is purely the choice of farm households based on their comparative advantages and the expected benefits they can derive from each alternative choice (Maddala, 1983). Besides, the coefficient of irrigation water does not measure the value of irrigation water because a typical farm household would have costs of illness whether or not it used clean water or wastewater for irrigation (Greene, 2002). Therefore, irrigation water is endogenous in equation [3.16] since the decision of farm households to irrigate their farms with clean water or wastewater is predicated on individual self-selection, thereby violating Gauss-Markov exogeneity assumption of independent variables, thereby causing selectivity bias and if OLS is used to estimate δ, it will actually overestimate the effect of irrigation water on costs of illness (Greene, 2002; Wooldridge, 2013).

In this case, the basic selectivity model outlined in the foregoing is extended to address the problem of self-selection in evaluating the financial benefits of using clean water compared with wastewater for irrigation. The Endogenous Treatment Effect model (Instrumental-Variable Technique) is used to estimate equation [3.16]. Generally, in the endogenous treatment model, clean water and wastewater users each have a cost of illness equation formulated as follows;

$$\begin{aligned} C_{1i} &= X_i\beta_1 + \varepsilon_{1i} \quad cleanwater \\ C_{2i} &= X_i\beta_2 + \varepsilon_{2i} \quad wastewater \end{aligned} \qquad [3.17]$$

So that the treatment equation, which defines a dichotomous decision function of using clean-water or wastewater for irrigation as follows;

$$\begin{aligned} W_i^* &= \mathbf{Z}_\mathbf{i}'\gamma + \nu_i \\ W_i &= 1 \quad if \quad W_i^* \succ 0 \\ W_i &= 0 \quad if \quad W_i^* \leq 0 \end{aligned} \qquad [3.18]$$

where W_i^* is an unobserved latent variable indicating the marginal utility (benefit) a household derives from using a certain type of irrigation water; W_i is an observed indicator of whether a household used relatively clean-water or wastewater for irrigation (irrigation water); $\mathbf{z}$ is a vector of independent variables that determine the likelihood of a the ith household using either clean-water or wastewater for irrigation; γ is a vector of unknown coefficients to be estimated, and ν_i is the stochastic error term.

On the basis of equation [3.18], the observed costs of illness, C_i, is defined as;

$$\begin{aligned} C_i &= C_{1i} \quad if \quad W_i = 1 \\ C_i &= C_{2i} \quad if \quad W_i = 0 \end{aligned}$$

Following the normality assumption and the assumption considered in equation [3.10] above that the two error terms, ε_i and ν_i are correlated, $\rho\sigma_\varepsilon\sigma_\nu$, the gross benefit for the ith household that uses relatively clean-water for irrigation, $(W_i = 1)$ is

$$E[C_i | W_i = 1, \mathbf{x}_i, \mathbf{z}_i] = \mathbf{x}_i'\beta + \delta + E[\varepsilon_i | W_i = 1, \mathbf{x}_i, \mathbf{z}_i] \\ = \mathbf{x}_i'\beta + \delta + \rho\sigma_\varepsilon\lambda(-\mathbf{z}_i'\gamma) \quad [3.19]$$

While the gross benefit for the ith household that uses wastewater for irrigation is

$$E[C_i | W_i = 0, \mathbf{x}_i, \mathbf{z}_i] = \mathbf{x}_i'\beta + \rho\sigma_\varepsilon\left[\frac{-\phi(\mathbf{z}_i'\gamma)}{1 - \Phi(\mathbf{z}_i'\gamma)}\right] \quad [3.20]$$

Therefore, the difference in expected benefits between relatively clean-water and wastewater users is, then,

$$E[C_i | W_i = 1, \mathbf{x}_i, \mathbf{z}_i] - E[C_i | W_i = 0, \mathbf{x}_i, \mathbf{z}_i] = \delta + \rho\sigma_\varepsilon\left[\frac{\phi_i}{\Phi_i(1 - \Phi_i)}\right] \quad [3.21]$$

where ρ provides the covariance estimate of the effects of unobserved variables on households' choice between clean-water and wastewater and cost of illness so that if significant, then there is evidence of the presence of self-selectivity. Hence in evaluating the effect of irrigation water on cots of illness, the self-selectivity bias is corrected by the IMR, λ_i in the outcome equation.

3.6.4.2 Empirical specification of endogenous treatment effect model

Outcome equation:

$$DC_i = \beta_0 + \beta_1 Dep_i + \beta_2 HHH\_sex_i - \beta_3 HHH\_ed_i - \beta_4 Lit\_adult_i + \beta_5 Nonfarm\_inc_i$$

$$-\beta_6 Wat\_drink_i - \beta_7 Irrig\_wat_i - \beta_8 Insect\_app_i + \beta_9 Nonmal\_inc\_4wk_i$$

$$+\beta_{10}Mal\_inc\_4wk_i + \beta_{11}Ill\_day\_4wk_i + \beta_{12}Attend_i - \beta_{13}Trad\_transp_i$$
$$+\rho\lambda_i + \varepsilon_i \qquad [3.22]$$

Treatment equation:

$$Irrig\_wat_i = \gamma_0 - \gamma_1 HHH\_sex_i + \gamma_2 HHH\_ed_i + \gamma_3 Nonfarm\_inc_i + \gamma_4 Ext\_acc_i$$

$$-\gamma_5 Farm\_type_i - \gamma_6 Farm\_loc_i - \gamma_7 Wat\_drink\_cost_i + \nu_i \qquad [3.23]$$

Though there is some fundamental theoretical consensus on the effect of irrigation, particularly the type of irrigation water used on households' incidence and direct costs of illness, empirical literature is very limited, and findings are largely inconclusive, while in some cases, contradictory. Based on this, the main research interest of this study is to empirically establish how significant direct cost of illness gap between wastewater and relatively clean-water irrigating farm households.

3.6.4.3 Hypothesis testing

Hypothesis 2E: The treatment variable, the type of irrigation water, in the substantive equation (direct costs of illness) is expected to be negative, implying that direct costs of illness for farm households that use relatively clean-water for irrigation is expected to be lower compared with those that use wastewater, *ceteris paribus.* This is based on the modified Grossman (1972) theory of health capital stock that predicts that irrigating with wastewater increases direct costs of illness through increase in the demand for healthcare. The relationship is mathematically stated in equation [2.16] in Chapter two as;

$$M_i = M[P_i, A_i, E_i, TL_0, TL_i(WI_i)] = \frac{\partial M_i}{\partial WI_i} = (\partial M_i / \partial TL_i)(\partial TL_i / \partial WI_i) \succ 0 \qquad [2.16]$$

According to FAO (2012) and World Bank analytical framework on wastewater use, even though irrigation supports crop productivity and food security, farmers' long period of proximity, inhalation and ingestion, and physical contacts with wastewater predisposes them to both water-washed and water-based diseases. Besides, water-related vectors thrive in wastewaters, which increase the risks and severity of household water-washed illnesses and their treatment cost (www.siteresources.worldbank.org).

Hypothesis 2F: Household socio-economic characteristics such as income, education, and female-heads are expected to influence positively the adoption of clean-water for irrigation over wastewater. This is deduced from Grossman (1972) theory of health capital stock and intuitive reasoning that a more educated farmer has the mental capacity to manage his or her health capital more efficiently, and also recognize and appreciate the serious dangers of using wastewater on the health of both the producers and consumers.

The positive effect of income on adoption of clean-water relative to wastewater is based on the fact that investments in building household health capital stock in terms of creation of proper and conducive environment, good sanitation, and preventive measures such as the use of protective clothing, mosquito nets and repellants, and provision of clean potable drinking and irrigation water, among others, all directly depends on the amount of income available to the household.

Therefore, higher income households will be able to afford sufficient clean-water to drink and irrigate their farms to prevent water-related infections.

Hypothesis 2G: Farm characteristics such as farm type (open space or backyard) and farm location (urban core or peri-urban) are expected to influence negatively the adoption of clean-water as compared to wastewater, while extension access is expected to influence positively the use of clean-water compared to wastewater. This is because most open space farms are located near water sources such as streams, wells, drains, and rivers, which are all at higher risk of pollution, particularly through run-offs, thereby increasing the likelihood of households using wastewater over clean-water. However, for backyard farms, their main source of water for irrigation is household source of water for household activities including pipe, boreholes, and deep wells, thereby increasing the likelihood of households owning backyard farm to use clean-water over wastewater.

Also, regarding the farm location, the urban core is a hub for industrial and institutional conglomerates, which emit large amounts of effluents, putting water sources being used for irrigation at great risks of pollution. Therefore, farms located in the urban core are more likely to be irrigated with polluted water compared to clean water.

Table 3.4 Definition of variables in the Endogenous Treatment Effects model of irrigation water and direct costs of illness

Variable name	Definition
DC	Direct financial cost of illness measured in Franc CFA
Dep	No. of dependents (members aged 5 or less years and above 65 years)
HHH_sex	Sex of household head, with 1 = male and 0 = female
HHH_ed	Educational level of household head measured in completed

	schooling years
Lit_adults	No. of adult literates (15 and above years) in the household
Nonfarm_inc	Total amount of household non-farm income in 1000 Franc CFA
Wat_drink	Source of household's drinking water; 1 = pipe/borehole; 0 = otherwise
Irrig_wat	Type of irrigation water used on farm, 1 = clean-water; 0 = wastewater
Wat_drink_cost	Households' monthly costs of water for domestic activities: Franc CFA
Insect_app	Insecticide application method; 1 = machine; 0 = manual (broom or leaves)
Farm_type	Whether open space farm or backyard farm; 1 = open space' 0 = backyard.
Mal_inc_4wk	Incidence of malaria in the last four weeks measured in number of cases
Nonmal-inc_4wk	Incidence of non-malaria in the last four weeks measured in No. of cases
Attend	No. of attendants with ill members of the household during treatment
Trad_transp	No. of times traditional transports (foot/bicycle) were used during treatment
Ill_day_4wk	No. of days household members have been ill in the last four weeks
Farm_loc	Location of farm in the city; 1 = urban core; 0 = urban periphery
Ext_acc	Whether household accessed extension or not; 1 = yes; 0 = No

3.6.5 Effect of ill-health on labour supply, input investments, and total output

3.6.5.1 Theoretical specification of 3SLS model for illness and farm production

Neoclassical production theory formulates production as a function of inputs notably, labour and capital. These inputs can be technically competitive, complementary, supplementary or independent (Coelli *et al*. 2005). However, in agricultural production process, labour, capital, and other inputs such as chemicals, land, and seeds can rarely be technically independent because a change in any one of these inputs, invariably affects the marginal productivity of the others inputs. Given the interrelationships among agricultural labour, capital inputs, and output, the effect of illness on labour supply, agricultural investments, and output can be estimated simultaneously in a system of linear equations using the three-stage-least-squares method (Osei-Akoto *et al*. 2013). Based on Kapteyn and Fiebig (1981) and Greene (2003) therefore, the linear system of M structural equations with M jointly dependent and G predetermined variables is formulated generally as;

$$y_1 = Y_i\gamma_i + X_i\beta_i + \varepsilon_i \qquad i = 1, 2, ..., M,$$
$$= Z_i\delta_i + \varepsilon_i,\ Z_i = (Y_i X_i),\ \delta_i = \begin{pmatrix}\gamma_i \\ \beta_i\end{pmatrix}, \qquad [3.24]$$

Where the T-vector of y_i contains observations on the ith dependent variable to be determined by the ith structural equation; $Y_i(T \times m_i, m_i < M)$ contains observations on jointly dependent variables included as independent variables in the ith structural equation (endogenous variables); $X_i(T \times I_i, I \leq G)$ is the matrix of predetermined (exogenous) variables included in the ith structural equation; γ_i and β_i are the vectors of unknown coefficients to be estimated; and ε_i is the T-vector of structural disturbances which satisfies the following assumptions;

$$\begin{matrix} E(\varepsilon_i) = 0, \\ E(\varepsilon_i\varepsilon_j) = \sigma_{ij}I_T, \end{matrix} \quad i, j, = 1, 2, ..., M, \qquad [3.25]$$

The system of linear simultaneous equations can be generalized in the following matrix formulation;

$$[y_1 \quad y_2 \quad \cdots \quad y_M]i \begin{bmatrix} \gamma_{11} & \gamma_{12} & \cdots & \gamma_{1M} \\ \gamma_{21} & \gamma_{22} & \cdots & \gamma_{2M} \\ & & \vdots & \\ \gamma_{M1} & \gamma_{M2} & \cdots & \gamma_{MM} \end{bmatrix} + [x_1 \quad x_2 \quad \cdots \quad x_K]i \begin{bmatrix} \beta_{11} & \beta_{12} & \cdots & \beta_{1M} \\ \beta_{21} & \beta_{22} & \cdots & \beta_{2M} \\ & & \vdots & \\ \beta_{K1} & \beta_{K2} & \cdots & \beta_{KM} \end{bmatrix}$$

$$= [\varepsilon_1 \quad \varepsilon_2 \quad \cdots \quad \varepsilon_M]i$$

$$= \mathbf{y}'\Gamma + \mathbf{x}_i'\beta = \varepsilon_i' \qquad [3.26]$$

where each column of the parameter matrices denotes the vector of coefficients in a particular structural equation, whilst each row applies to a specific variable. However, to ensure determinacy in the system, one of the variables in each equation should be chosen as a dependent variable so that its coefficient in the model will be one (1).

However, the assumption that the distribution of the structural disturbances is independent of the predetermined variables in the system such that $E[\varepsilon|\mathbf{X}] = 0$ and $E[\varepsilon\varepsilon'|\mathbf{X}] = \sum$ is violated in a linear simultaneous systems of equations. This is because the structural disturbances are correlated with the joint determination variables or endogenous variables, which causes simultaneity, thereby rendering the estimates of the structural coefficients inconsistent and inefficient. The reduced- form of the model is the solution of the problem of simultaneity to ensure that the system of equations determines the endogenous variable y_i in terms of predetermined variables only $\mathbf{x}_i$ and the stochastic disturbance term ε_i. The reduced-form system of equations is formulated as;

$$y'_i = [x_i \quad x_2 \quad \cdots \quad x_k]i \begin{bmatrix} \pi_{11} & \pi_{12} & \cdots & \pi_{1M} \\ \pi_{21} & \pi_{22} & \cdots & \pi_{2M} \\ & & . & \\ & & . & \\ & & . & \\ \pi_{k1} & \pi_{k2} & \cdots & \pi_{kM} \end{bmatrix} + [\nu_1 \quad \cdots \quad \nu_M]i$$

$$= -\mathbf{x}'_i \beta \Gamma^{-1} + \varepsilon'_i \Gamma^{-1}$$

$$= \mathbf{x}'_i \prod + \nu'_i \qquad [3.27]$$

where $\prod$ is the matrix of reduced-form coefficients, which is a nonlinear combinations of structural coefficients.

Another fundamental problem embedded in simultaneous equation models is whether numerical estimates of the structural parameters can be obtained from the reduced-form coefficients. This is the problem of identification. Therefore, all equations are either exactly identified $K_j^* = M_j$ or over-identified $K_j^* > M_j$ so that both the order and rank conditions of identification are satisfied.

However, the simultaneous equation models are of different forms. In some of the models, the first dependent variable is determined completely by predetermined variables, while, the second is determined by both the first dependent and exogenous variables, the third is determined by the first two dependent variables and predetermined variables, and so on in that fashion till the last equation. This implies then that the joint determination of the variables is recursive. In this case, the system will take the form as follows;

$$\begin{aligned} y_{i1} &= f_1(\mathbf{x}_i) + \varepsilon_{i1} \\ y_{i2} &= f_2(y_{i1}, \mathbf{x}_i) + \varepsilon_{i2} \\ &\vdots \\ y_{iM} &= f_M(y_{i1}, y_{i2}, \ldots, y_{iM-1}, \mathbf{x}_i) + \varepsilon_{iM} \end{aligned} \quad [3.28]$$

The full system of equations can be formulated as in equation [3.29] in order to specify the estimation methods of simultaneous equation models.

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_M \end{bmatrix} = \begin{bmatrix} Z_1 & 0 & \cdots & 0 \\ 0 & Z_2 & \cdots & 0 \\ \vdots & \vdots & & \vdots \\ 0 & 0 & \cdots & Z_M \end{bmatrix} \begin{bmatrix} \delta_1 \\ \delta_2 \\ \vdots \\ \delta_M \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_M \end{bmatrix} \quad [3.29]$$

Which can be summarized as $y = Z\delta + \varepsilon$ as formulated in equation [3.24]. Therefore, if $X(T \times G)$ represents the matrix of all predetermined variables, then pre-multiplying equation [3.24] by X' produces

$$X'y_i = X'Z_i\delta_i + X'\varepsilon_i, \; i = 1, 2, \ldots, M, \quad [3.30]$$

The error variance-covariance matrix of equation [3.30] is $\sigma_{ii}X'X$. Therefore, the estimation of δ_i in equation [3.30] yields the two-stage-least-squares (2SLS) estimator for δ_i. However, even though the 2SLS enjoys simplicity in its computation and a relatively smaller finite-sample variance, yet the 3SLS estimator is widely preferred to it for several reasons. Thus, the 3SLS is not only consistent, more asymptotically efficient, but also has an asymptotic distribution as the Full Information Maximum Likelihood estimator and remains robust to non-normality. So let R be a non-singular $G \times G$-matrix such that $X'X = RR'$. Therefore, a Generalized Least Squares (GLS) in equation [3.30] is identical to OLS in equation [3.31] (pre-multiplying equation [3.30] by R^{-1})

$$R^{-1}X'y_i = R^{-1}X'Z_i\delta_i + R^{-1}X'\varepsilon_i,\ i = 1,\ 2,\ \ldots,\ M, \qquad [3.31]$$

When these M equations are stacked into one system, it yields

$$\left(I_M \otimes R^{-1}X'\right)y = \left(I_M \otimes R^{-1}X'\right)Z\delta + \left(I_M \otimes R^{-1}X'\right)\varepsilon \equiv A\delta + w, \qquad [3.32]$$

Where A and w are implicitly defined. Therefore, the error variance-covariance matrix of the error vector w is $\sum \otimes I_G$.

Hence, GLS estimation of δ in equation [3.32] yields the 3SLS estimator of δ, δ_{3SLS}, whilst OLS estimation in equation [3.32] would produce the 2SLS estimator of δ, δ_{2SLS}.

3.6.5.2 Empirical specification of the model

The study estimated a system of four equations simultaneously to analyze the effect of illness on family labour supply, hired labour expenditure (household demand for hired labour), value of fertilizer and agrochemicals(household demand for chemicals), and finally, on the total value of output for the 2016 rainy season. Simultaneous estimation of the effect of illness on households' family and hired labour use will essentially reveal whether there is substitution of hired labour for sick family labour, which may offset the effect of illness on labour productivity and output. Unlike other studies in which the effects of illness on household family labour supply, demand for hired labour, investments, and output are estimated as separate regression equations, this study estimated these regression equations as a system considering that the number of days of illness is endogenous in the system. Sufficient valid instruments were used to ensure that all the four equations satisfy both the order and rank conditions of identification. The empirical model is specified below based on Osei-Akoto *et al*. (2013).

$$lflab = \beta_0 + \beta_1 ill\_days + X\beta_I + \varepsilon_I \quad [3.33]$$

$$lhlab\_\exp = \beta_0 + \beta_2 ill\_days + X\beta_{II} + \varepsilon_{II} \quad [3.34]$$

$$lche\_val = \beta_0 + \beta_3 ill\_days + X\beta_{III} + \varepsilon_{III} \quad [3.35]$$

$$lfarm\_inc = \beta_0 + \beta_4 ill\_days + \alpha_1 lflab + \alpha_2 lhlab\_\exp + \alpha_3 che\_val + X\beta_{IV} + \varepsilon_{IV}$$
[3.36]

Table 3.5 Description of endogenous variables in 3SLS regression model

Endogenous variables	Measurement	Description
1flab	No. of hours	Log(Family labour supply in hours)
1hlab_exp	FCFA	Log(Hired labour expenditure)
1che_val	FCFA	Log(Value of fertilizer and agrochemicals)
1farm_inc	FCFA	Log(value of total output)

3.6.5.3 Hypothesis testing

The following hypotheses are formulated based on theoretical and conceptual models on the relationship between illness and agricultural labour use, input use, and farm productivity. Table 3.6 presents the variables and their expected directional effects on family and hired use by farm households

Hypothesis 3A: Ill days per season, which measures the total number of days household members have been ill throughout the farming season, is expected to decrease family labour supply to household farm production but increase household expenditure on hired labour (hired labour supply). This is underpinned by the agricultural household model developed by Singh *et al*. (1986). The model states that all other factors unchanged, family labour input reduces with sick time, which represents the direct effect of sickness on household farm production. The relationship is mathematically stated as;

$\partial L^f / \partial TL < 0$, where L^f denotes family labour input and TL represents sick time of days.

Hypothesis 3B: However, given the general negative relationship between household family labour supply and hired labour demand, the effect of ill days per season on hired labour expenditure is positive *a priori* (table 3.6). This is because household hired labour demand is conditional upon household family labour supply to the farm such that the higher the household family labour supply to the farm, the less the household demand for hired labour. Therefore, the higher family labour input reduces with household illnesses, the higher household demand for hired labour. However, economic theory predicts a more ambiguous effect of poor health on labour supply in general. The consequence of illness is a reduction in wages as a result of lower labour productivity (low physical and mental capabilities due to illness), which will, in turn, cause a rise in leisure time and a decline in labour supply as the economic return from working diminishes (Suhrcke *et al*. 2006). This effect is known as the substitution effect of illness on labour supply.

Hypothesis 3C: Irrigation is expected to cause increases in both family labour supply and household hired labour expenditure to the farm increase, *ceteris paribus*. The intuition is that irrigation farming involves additional farm activities notably watering, which is undertaken many times daily. Therefore, due to continued watering, and relatively frequent weeding of the farms, irrigation consumes larger amount of labour input in terms of labour days and/or hours. Hence, irrigators have both higher family and hired labour consumption than non-irrigators *a priori*.

Table 3.6 Description of variables in the family and hired labour use models

Independent Variables	Measurement	*A Priori* signs	
		Family	Hired
Ill_day_sea	Number of days	-	+
EAL_male	Number	+	-
EAL_female	Number	+	-
HHH_sex	1= Male and 0 = Female	+	-
Lit_adults	Number	-	+
Dep	Number	-	+
Farm size	Number of beds	+	+
Irrig_use	1 = Yes and 0 = No	+	+
Insect_app	1 = Yes and 0 = No	+	+
FBO_memb	1 = Yes and 0 = No	+	+
Lettuce_cul	1 = Yes and 0 = No	+	+
Burunbula_cul	1 = Yes and 0 = No	+	+
Rice_cul	1 = Yes and 0 = No	+	-
Farm_act_wgt	Weighted Number		+

Hypothesis 3D: In Table 3.7, the relationship between agricultural investments such as chemicals and illness of household members is modelled to be negative. Based on the agricultural household models developed by Singh *et al*. (1986), the effect of illness of household members on household demand for chemicals (agricultural investments) is considered as an indirect effect of illness on farm production. The relationship is stated in equation [2.26] in chapter two as;

$$X = X[M^e(TL), X] = \partial X/\partial TL = (\partial X/\partial M^e)(\partial M^e/\partial TL) < 0 \qquad [2.26]$$

where M^e is household medical expenditure, X is household total variable inputs, $\partial X/\partial M^e$ measures the rate of decrease in household variable inputs (demand for chemicals) as a result of an increase in household medical expenditure, and

$\partial M^{e} / \partial TL$ indicates how fast household medical expenditure increases in response to an increase in sick time or incidence of illness.

Hypothesis 3E: Based on the Green Revolution approach to agricultural development, irrigators are expected to have higher demand for chemicals than non-irrigators (Norton *et al*. 2010). This is because there are strong complementarities between the application of fertilizers and pesticides and irrigation. Therefore, given irrigation, the demand for fertilizers and pesticides is higher, causing the relationship to be positive (Table 3.7).

Table 3.7 Description of variables in the value of fertilizers and agro-chemicals model

Independent Variables	Measurement	Expected signs
Ill_day_sea	Number of days	-
HHH_sex	1=Male: 0 = Female	+
Lit_adults	Number	+
Nonfarm_inc	FCFA (1000)	+
Farm size	Number of beds	+
Irrig_use	1 = Yes and 0 = No	+
Credit amount	FCFA	+
FBO_memb	1 = Yes and 0 = No	-
Extension_cont	Number	+
Lettuce_cul	1 = Yes and 0 = No	+
Burunbula_cul	1 = Yes and 0 = No	+
Maize_cul	1 = Yes and 0 = No	+

Hypothesis 3F: In Table 3.8, ill day per season is expected to have an inverse relationship with farm income through its negative effects on household labour supply and demand for chemicals. Based on Singh *et al*. (1986) household model the overall effect of sick days on production is given in equation [2.29] in chapter two as;

$$\partial Q_a / \partial TL = (\partial Q / \partial L^F)(\partial L^F / \partial TL) + (\partial Q / \partial X)[(\partial X / \partial M^e)(\partial M^e / \partial TL)] < 0 \qquad [2.29]$$

Table 3.8 Description of variables in the total farm income model

Independent Variables	Measurement	A priori sign
Ill_day_sea	Number of days	-
HHH_sex	1 = Male and 0 = Female	+
HHH_ed	Completed years of schooling	+
FBO_memb	1 = Yes and 0 = No	+
Extension_cont	Number	+
Irrig_use	1 = Yes and 0 = No	+
Credit amount	FCFA	+
Farm size	Number of beds	+
Log(flab)	Number of hours	+
Log(hlab_exp)	FCFA	+
Log(che_val)	FCFA	+
Seed value	FCFA (1000)	+

Therefore the reduced level of production is as a result of a reduction in family labour input and investments in agricultural variable capital inputs. However, this reduction may be partially off-set by the substitution of hired labour for lost family labour input. Besides, economic theory underpins the effect of illness on farm productivity based on the concept that healthier workers do not only have better physical and mental capacities to produce more output per hour worked (increased labour productivity), but also have the potential to make better and more efficient utilization of new technologies, machinery, and equipment, and thereby leading to higher productivity and output (Suhrcke et al. 2006).

Hypothesis 3G: Irrigation, despite the negative effect it may have on the health of farmers and their families, is expected to have a positive effect on farm income due to its nutrients and complementarities to other farm inputs for plant growth and productivity.

CHAPER FOUR

RESULTS AND DISCUSSIONS

4.1 Chapter outline

This chapter presents results on the socio-economic and demographic characteristics of farm households, incidence of transient diseases and the accompanied costs of illness vis á vis wastewater use for irrigation, and the difference in costs of illness between wastewater users and clean water users as well as the effect of transient diseases on households' labour and output using tables and graphs. These results are then discussed within the framework of theory and existing literature around the problem of wastewater and costs of illness to produce major findings.

4.2 Descriptive statistics of farm households

The summary of descriptive statistics of selected characteristics of farm households has been presented in Table 4.1. These statistics have significant bearing on the choice between clean-water and wastewater irrigation and incidence and costs of illness.

4.2.1 Socio-economic and demographic characteristics of farm households

Of the 208 farm households, a significantly higher number of them were headed by males, representing 83 percent, while the rest of the 17 percent of the farm households were headed by females. This shows that farm households in the city were predominately male-headed, and on that basis, most of the household decisions including the types of crops to grow, the type of water to use for irrigation, where to seek treatment of illness, family labour allocation between farm and non-farm household activities, the use of hired labour, among others, are more likely to be taken primarily by men with or without consultation with other household members.

Regarding household composition, the average number of people living in a farm household was 4.49 members, which is lower than the pooled average household size of 9.3 people in both formal and informal areas under the Ouagadougou Health and Demographic Surveillance System (HDSS) (Rossier *et al*. 2012) and that of 9 members reported by Bellwood-Howard *et al*. (2015). The discrepancy may be attributed to differences in target groups and the geographical space covered in these studies. In addition, farm households in the city were composed of an average of 2.03 and 1.66 economically active male and female labourers respectively, with standard deviations respectively being 1.29 and 1.60 male and female labourers, while the mean dependent population (number of household members within the non-working-age group) was found to be 0.82 per farm household. These imply that farm households in the city are, on average, endowed with both male and female family labour, which are more than double of the population of dependents, and can be used for both farm and non-farm production activities. However, on average, 2.6 of the total economically active labour force per household were literate, which implies that a little than half of farm household family labour are literate, mirroring relatively lower number of quality human resources available to farm households in the city.

Table 4.1 Descriptive statistics of farm households' characteristics

Variable name	Measurement	Mean	Median	C.V.	S. D.
HHH_sex	1=Male, 0=female	0.83*	-	0.45	0.38
Inc_tl	FCFA	1250946	876000	1.14	1431235
Nonfarm_inc	FCFA	822582	504000	1.69	1390590
Wat_drink_cost	FCFA	1732.207	1360	0.97	1690.671
HH_size	Number	4.49	4	0.46	5.35
EAL_male	Number	2.03	2	0.63	1.29
EAL_female	Number	1.66	1	0.69	1.6
Wat_drink	1=pipe,0=otherwise	0.58*	-	0.85	0.5
HHH_ed	completed years	2.46	0	1.32	3.26
Lit_adults	Number	2.6	2	0.61	1.6
Dep	Number	0.82	1	1.01	0.83
Flab_day	Hours	4.50	4	-	-
Flab_sea	Hours	1,795.21	1680	0.57	1033.21
Farm_inc	FCFA	590508	285000	1.28	761709
Farm size	Beds	47.94	40	0.67	32.18
Che-val	FCFA	59596.04	40000	0.88	52920.67
Che_fert_cost	FCFA	25185.8	20000	0.92	23179.77
Man_fert_cost	FCFA	20211.6	12000	1.29	26205.73
Insect_cost	FCFA	11081	8375	1.12	12502.96
Hlab_exp	FCFA	68760.2	38000	1.38	95414.66
Credit amount	FCFA	55067.3	50000	0.75	41346.22
Extension_cont	Number	3.15	3	0.49	1.55
Seed value	FCFA	31827.6	17300	1.30	41576.33
Ext_acc	1=Yes, 0=No	0.51*	-	0.97	0.500998
Farm_loc	1=core,0=periphery	0.42*	-	1.18	0.494465
Farm_type	1=OS,0=backyard	0.62*	-	0.79	0.487678
Irrig_use	1 = Yes, 0 = No	0.80*	-	0.49	0.40
Irrig_wat	1=well,0=waste	0.53*	-	0.95	0.50
Insect_app	1=machine,0=manual	0.39*	-	1.25	0.49
FBO_memb	1 = Yes, 0 = No	0.30*	-	1.52	0.46
Ill_status_4wk	1 = Yes, 0 = No	0.64*	-	0.75	0.48
Ill_days_4wk	Number	8.3	7	0.73	6.09
Med_cost_4wk	FCFA	934.62	200	3.14	2941.45
Food_cost_4wk	FCFA	958.7	600	0.83	796.39
Drug_cost_4wk	FCFA	8357.33	5000	1.10	9216.1
Transp_cost_4wk	FCFA	683.83	250	1.81	1239.6
DC_4wk	FCFA	9572.37	5800	1.07	10256.24

IDC_4wk	FCFA	3008.27	0	2.18	6573.88
TCI_4wk	FCFA	12580.6	7500	1.15	14479.71
Mal-inc_4wk	Number	1.18	1	0.74	0.88
Nonmal_inc_4wk	Number	0.32	0	1.84	0.6
Trad_transp	Number	0.74	1	1.23	0.91
Hosp_visit	Number	0.64	1	1.11	0.71
Attend	Number	0.22	0	2.13	0.47
Ill_status_sea	1 = Yes, 0 = No	0.93*	-	0.27	0.3
Ill_day_sea	Number	17.11	14	0.75	12.97

*these are proportions
Source: Field Data (2016)

Majority of farm households in the city mainly sourced drinking water from pipe and/or borehole, representing 58 percent, whilst the rest of the 42 percent of households depended mainly on shallow and/or uncovered wells. Though the number of households that mainly drink water from pipe/boreholes is relatively high compared with their counterparts, this however implies that about 42 percent of farm households are unable to access potable drinking water, and for that matter, one of their basic needs. This has important implications for the disease profile of households, and consequently, the standard of living of individuals in the households. The relatively high average rate of dependence of households on other unsafe sources of drinking water can be attributed to relatively high costs of accessing potable water among the households in the city. This is because households are shown in Table 4.1 to have spent an average of 1,360 FCFA ($2.86) on potable water for household activities per month, while inequality in costs of potable water was as high as 1,690 FCFA ($2.79)[1]. It is worth noting that

[1] Households paid an average of 200 FCFA per bucket (30cm size, 12 litres), which is equivalent to 16.67 FCFA per litre of drinking water. This was used to compute the monthly costs for all households

costs of potable safe water is highly likely to have important impact on farm households' choice between clean-water and wastewater for irrigation of crops.

Based on this available family labour, farm households were able to undertake both crop production activities and non-farm economic activities such as wage labour, salaried employment, petty trading, among others, to provide household food and income. From these two production sectors, farm households generated a total seasonal average income of 1,250,946 FCFA, out of which an average income of 822,582 FCFA and 590,508 FCFA were respectively generated from non-farm and farm production activities[2]. Income inequalities relating to household mean total income, farm income, and non-farm income stood at 1,431,235 FCFA, 761,709 FCFA, and 1,390,590 FCFA respectively. This implies that while average contribution to household total seasonal income from non-farm sector is larger than the farm sector, income inequalities in term of coefficient of variation among household participants in the former is wider (169%) than among those engaged in the latter (128%). On the basis of the average household size and total income, the average per capita income earned per day at the farm household level is pegged at 773.91 FCFA, which is equivalent to $1.27[3] US dollars. Obviously, this per capita daily income of individuals living in these farm households is above the international poverty line of $1.25 US dollars per day ($2 per day in Purchasing Power Parity dollars) (Todaro and Smith, 2012). In effect,

[2] Average farm and non-incomes do not add up to average total income due to differences in sample observations.

[3] Based on 2016 exchange rate of 605.7 Communaute Financiere Africaine francs (XOF) per US dollar CIA World Factbook, (2017) Burkina Faso Economy 2017. www.theodora.com.

farm households earn an average pooled income (income from both farm and non-farm sources) of over one million FCFA per the 2016 farming season, and average per capita daily income of household members is significantly above the international extreme poverty line in the city.

4.2.2 Household farm production characteristics

From the randomly sampled farm households, 167 of them, representing 80 percent were small open space intensively irrigated farmers cultivating a wide range of vegetables notably lettuce, cabbage, burunbula, chinochibido, carrot, onion, and eggplant, while the remaining 20 percent were extensive annual crop farmers of maize, millet, rice among others. Of the 167 vegetable farm households, 53 percent of them relied on groundwater sources such as deep wells and shallow wells, while 47 percent drew water from diluted surface water sources for irrigation of crops. By implication, an extremely large number of urban farms are irrigated, and a relatively small number of these farms are can-watered from diluted wastewaters which have important implications for public health safety particularly for the farmers and their household members as well as consumers.

Moreover, landholdings of these open space farm households in Ouagadougou are generally small as cropping, which is largely intensive and irrigated, is done on an average land size of 47.94 beds, equivalent to 0.8 acre of land. This finding on urban farm landholdings is consistent with the average cultivated landholdings of 0.87 ha by urban open space farmers in Ouagadougou reported by Bellwood-Howard *et al*. (2015). Therefore, urban farm households in Ouagadougou generally depended on an average of 0.8 acre of land for crop production. Based on this, households contribute to urban food security, job creation and sustainable livelihoods in the city (Ambrose-Oji, 2009; Addo, 2010).

Labour is another important productive resource that farm households depend largely on for crop production. Table 4.1 indicates that farm households used both unpaid family and purchased (hired) labour resources for crop production during the 2016 farming season. Of the total number of economically active male and female working members in farm households who were allocated to crop production, an average of 1,795.21 hours of labour were supplied for the whole 2016 farming season, with a standard deviation of 1,033.21. This implies that with an average of 4.50 hours of family labour supplied per day per a working individual per farm household, each household family labourer allocated an average of 486.51 hours of effective labour to household farm activities throughout the 2016 farming season, which is equivalent to an average of 4.5 hours of family labour supply per day during the season. This family labour input quantity has direct significant implications for household's decision to purchase non-family labour and other complementary variable inputs, and indirectly for final farm output and income.

Table 4.1, however, shows that beyond family labour input, farm households also spent a median expenditure of 38,000 FCFA on hired labour to replace and/or complement unpaid household labour to undertake critical and labour-exhausting farm activities such a weeding, watering and planting for the season, with expenditure inequalities among households standing as high as 95,415 FCFA in

Ouagadougou. Intriguingly, household expenditure on market labour used on farm contributes the largest share to total household farm expenditure regardless of the available family labour input. Therefore, the decision of households to participate in paid labour market, despite its heaviest economic burden on household financial resources, may be motivated by multivariate factors including shadow wage rate of labour, intra-household labour substitution between farm and non-farm activities, incapacitation and death of family labour among others. This large volume of investment in hired labour also has important implications for household consumption and non-food expenditures, farm productivity and output, food security and total income for the season.

It is also relevant to note that households voted substantial financial resources into the acquisition of seeds, soil fertility amendments like inorganic fertilizers and livestock manure, and crop protection technologies such as insecticides. From Table 4.1, households on average invested financial resources to the tune of 31,827.6 FCFA, 25,185.8 CFA, 20,211.6 FCFA, and 11,081 FCFA on seeds, inorganic fertilizers, livestock manure, and insecticides respectively for improvement of soil fertilizer, crop yields, and quality of produce. By implication, soil fertility amendments (pooled expenditures on inorganic and animal manure) are the most important variable inputs used by households, followed by seeds, while insecticides were the least prioritized variable input. This trend of input usage is consistent with the findings of Bellwood-Howard *et al*. (2015). The ratio of mean inorganic fertilizer expenditure to mean livestock manure expenditure by households is computed as 1.25, indicating that the former is 25 percent higher than the latter. It is, however, worth-noting that the level of application of organic fertilizers in Ouagadougou is relatively higher than in Tamale, which confirms perceptions of Ghanaian vegetable traders that vegetables produced in Burkina Faso are relatively organic and have a longer shelf life than Ghanaian locally-produced ones.

Of all the farm households in this study, about 38 percent of them cultivated backyard field, whilst 62 percent farmed entirely on 'public' open space fields. Open space farms in the area were generally located near water sources such as wells, rivers, streams, drains, and dugouts among others, whilst backyard farm fields were located at homes without necessarily considering their proximity to water sources. As a result, whether household farm is an open space field or a backyard one may impact significantly on the decision of individual households to irrigate their farms either with clean-water or wastewater. Closely linked to the type of farm cultivated is whether the farm is located in the core-urban or urban periphery (peri-urban). The statistics in Table 4.1 reveals that majority of farms (58 percent) cultivated by households was located in peri-urban areas, while the rest (42 percent) were located in the core-urban centre. This relatively high density of farm households in peri-urban areas compared with core-urban locations is supported by the results of the Ouagadougou Health and Demographic Surveillance System between 2009 and 2011 (Rossier *et al.* 2012). Given the high density of farm households in peri-urban centres, locations where extreme poverty is relatively over-represented, a large chunk of investments in the construction of deep wells and other support incentives from government and

NGOs for urban farmers are 'discriminately' channeled to these areas compared with the urban core areas. This has the tendency of influencing the type of irrigation water being used by households on their farms.

The ability of farm households to innovate, adopt and appropriately and safely apply new technologies depends largely on the quality and quantity of extension services provided to them. Of all farm households, 51 percent of them accessed extension services for the 2016 farming season from various sources including government agricultural officers, radio/TV, NGO, and farmer-based organizations among others, while the rest indicated they had not. Quantitatively, for households that accessed extension services, at least 3.15 contacts were made with extension service providers in the season. This implies that the slightly higher number of farm households in Ouagadougou had at least 3 contacts with extension service suppliers in the season, with a deviation of 1.55 contacts. Farmer-based organizations (FBOs) are however less prevalent among farm households in the city as only 30 percent of farmers are members of FBOs that were identified to be effectively existing and operational. Households belonging to various FBOs derived benefits including access to extension information, free insecticides and inorganic fertilizers, market information such as price and new markets, and credit information among others, which may have implications for variations in household productivity and incidence of farming-related diseases among households among others.

4.2.3 Household costs of illness characteristics

Monthly incidence of transient illnesses such as malaria, skin problems, diarrhea, and upper respiratory problems, among others, were used to estimate household monthly expenditures on health care payments. About 64 percent of farm households (133 households) recorded at least one illness incident during a typical one month period, whilst the remaining 36 percent either did not suffer any illness episode at all or recorded transient diseases outside the one month recall period (Table 4.1). It is worthwhile to mention that in affected farm households, illness episodes lasted an average of 8.3 days after which treatment is completed. Therefore, in any farm household that recorded at least one illness episode, it will take a sick individual at least 8 days before the disease is completely treated, and this may affect the efficiency and availability of household labour for various economic activities as well, as exact a financial burden for treating illnesses on the household. Average household monthly economic cost of illness is 12,580.6 FCFA, whilst average monthly direct and indirect costs of illness are estimated to be 9,572.37 FCFA and 3,008.27 FCFA respectively. Thus on average, the direct out-of-pocket financial burden of common illnesses on farm households (direct costs of illness) is more than triple the opportunity costs of illnesses (indirect costs of illness), including wages, sales income, and farm productivity losses due to illnesses in Ouagadougou. As part of households' direct financial costs of illness, every farm household that recorded a monthly illness episode directly spent at least 8,357.7 FCFA and 934.62 FCFA on drugs and medical care services respectively (health care services), whilst travel cost and food-related expenses were at least 958.7 FCFA, and 683.83 FCFA respectively. This implies that healthcare-related costs have the higher economic burden on farm households compared to the non-health care related direct financial cost of illness. Mean monthly episodes of malaria among farm households is 1.18, while mean episodes of all other diseases such as skin infections, diarrhea, cold/cough, and nail problems among others is 0.32. Therefore every farm household recorded at least 1 episode of malarial disease within a month, confirming the disease as one of the most prevalent diseases in Burkina Faso (CIA, 2016b), and in West Africa as a whole.

However, unlike monthly episodes of transient illnesses, a high number of farm households, representing 93 percent, recorded at least one episode of non-chronic illness for the entire 2016 farming season. On average, individuals infected with non-chronic diseases during the season suffered the diseases for at least 17.11 days, which is about more than double average days of monthly illness episodes among households. Therefore, the high infection rate of seasonal episodes of illnesses among farm households has significant implications for household labour, investments in inputs, and final output compared to monthly episodes of illness.

4.3 Sources of water for irrigation

Farm households that irrigate their fields using both groundwater and surface water sources are very high in Ouagadougou (see Table 4.1). Figure 4.1 indicates that wells (both deep and shallow), which are widely reckoned to be relatively clean, less risky and less polluted with wastes (domestic, institutional, and commercial) were the main groundwater sources of irrigation for majority of farm households in the city, representing 53 percent of total number of irrigators, whilst the use rates of highly waste-polluted surface water sources such as streams, dugouts, and drains are respectively 27%, 13%, and 7% (see Figure 4.2 for photos of wells and some wastewaters used by households).

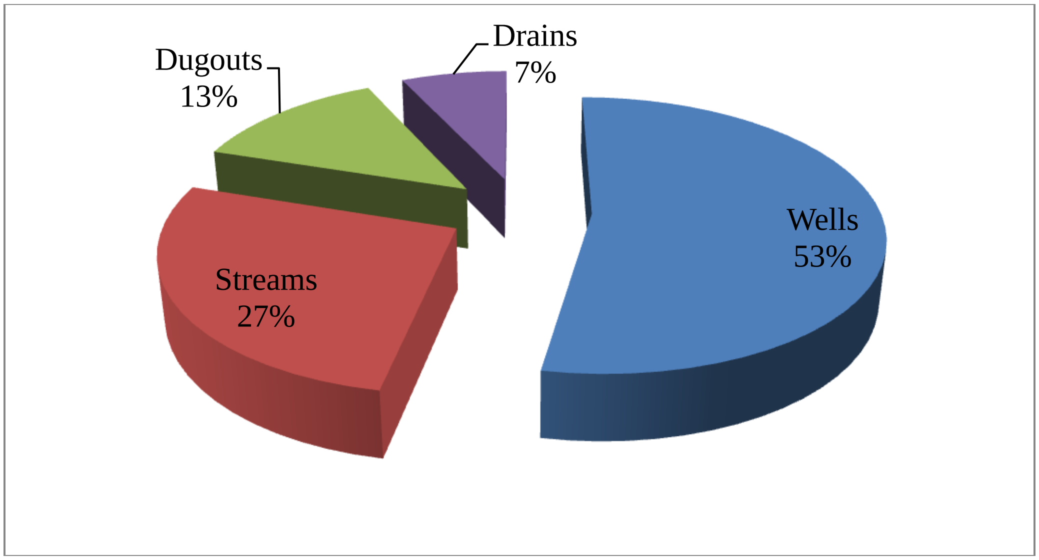


Figure 4.1 Irrigation water sources in Ouagadougou

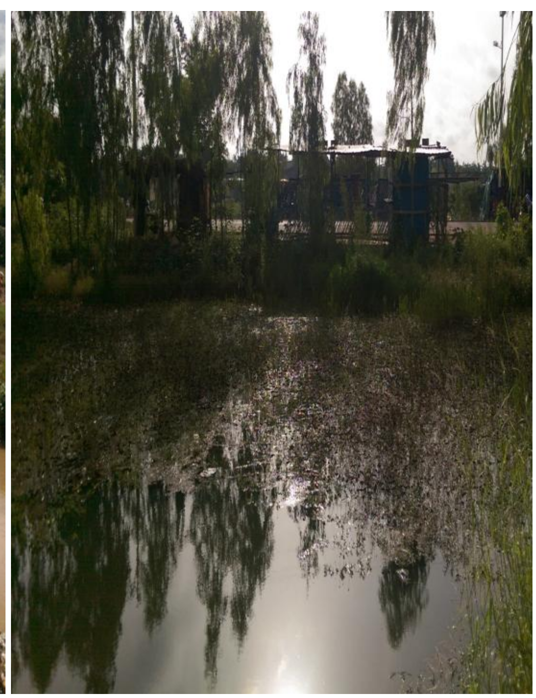
Source: Field Data (2016)

Though the proportion of farm households that preferentially used relatively clean irrigation water types (deep and shallow wells) is quite higher compared to uncontrolled and unplanned indirect users of wastewater (diluted wastewater from surface waters), yet the phenomenon of indirect wastewater use has serious health and economic ramifications for both the producing and consuming public in the city. Although insignificantly treated wastewater (diluted) sources such as streams and dugouts are predominantly used among wastewater irrigators, drains, with the least percentage of users, are sources of raw blackwater which pose more dangerous risks for farmers' health and paradoxically provide impetus for crop growth and improved output and farm income compared to the former (FAO, 2012; Havelaar *et al*. 2001; Ambrose-Oji, 2009).

A. Clean-water (well)

B. Clean-water (well)

C. Wastewater (Stream)



D. Wastewater (dugout)

Figure 4.2: Photos of some wells and wastewaters used for irrigation in Ouagadougou

Source: Field Data (2016)

4.4 Relationship between agricultural wastewater use and incidences of transient illnesses

4.4.1 Incidences of transient illnesses among farm households

Farm households self-reported a wide range of transient diseases that members suffered during the last 2016 farming season. Significant among these diseases are malaria, skin-related problems, diarrhoea, respiratory, farm injuries, and spinal/waist problems. Farm households reported aggregate all-disease episodes of 768, of which water-related illnesses such as malaria, diarrhoea, and skin-related problems altogether account for about 74 percent, whilst the remaining 26 percent of the episodes are attributed to respiratory problems, spinal/waist, farm injuries and other minor diseases.

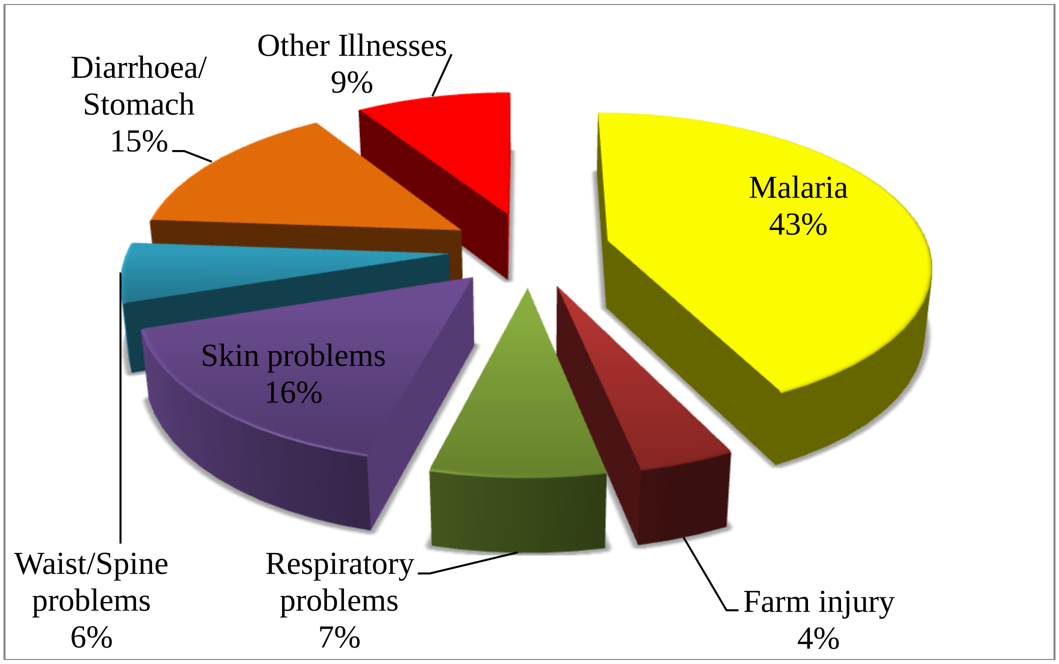


Figure 4.3: Incidence of transient diseases among urban farm households in Ouagadougou

Source: Field Data (2016)

This shows how profound the prevalence of water-related diseases is among urban farm households in Ouagadougou during farming seasons. For specific disease episodes, the total episodes of malaria, diarrhoea, and skin-related infections recorded by farm households for the entire season are estimated to be 328, 113, and 122, respectively, representing 43%, 15% and 16% of aggregate disease episodes, while seasonal episodes for farm injuries is the least incident among farm households, representing only 4 percent of gross illness episodes (see figure 4.3). By implication, malaria has the highest rate of incidence among farm households followed by skin-related infections and diarrhoea, while occupational accidents in terms of injuries related to farming is the least prominent among farm households in Ouagadougou.

The predominance of malaria among farm households is strongly supported by the Maternal and Child Health Integrated Programme (MCHIP) (2013) report that malaria is not only endemic in Burkina Faso, but the leading cause of morbidity in the country. It is however worth-noting that the prevalence rate of these diseases may differ significantly between irrigators and non-irrigators and more particularly between wastewater irrigators and cleaner-water users. Table 4.2 and 4.3 below summarize the average incidence levels of these diseases among farm households by their irrigation status and the type of water used for irrigation.

4.4.2 Incidence of transient diseases among farm households by irrigation status

Theoretical and conceptual models both predict a strong association between agricultural systems, particularly irrigation and various pathogenic, vector-borne and other water-related diseases (FAO, 2012, Kpoda *et al*. 2015). Therefore, to test whether or not the various water-related diseases including malaria, diarrhoea, and skin-related infections reported by farm households in particular have significant association with irrigation as an agricultural system, the mean-comparison t-test was performed on the differences in mean episodes of these diseases between irrigating and non-irrigating farm households. The results, presented in Table 4.2, indicate that while the mean difference in incidence of malaria between irrigating and non-irrigating farm households is statistically significantly at 1 percent significance level, the mean differences in incidences of diarrhoea and skin-related infections between irrigators and non-irrigating farm households are both statistically significant at 5 percent significance level.

Table 4.2: Incidence of transient illnesses among farm households by irrigation status

	Farmer Groups					
	Non-irrigators		Irrigators		Difference	
Illness type	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E**
Malaria	1.3333	0.0983	2.1295	0.09624	-0.7962***	0.2357
Farm injuries	1.1818	0.1219	1.125	0.08539	0.0568	0.1442
Respiratory	1.3684	0.1137	1.1538	0.07216	0.2146*	0.1286
Skin-related	1.1111	0.1111	1.4487	0.0649	-0.3376**	0.1954
Waist/Spine	1.6315	0.1746	1.0625	0.0625	0.5691***	0.19901
Diarrhea	1.1764	0.0953	1.5	0.0821	-0.3235**	0.16501
Others	1.45	0.1697	1.025	0.025	0.4250***	0.12418

Significance level: ***1%; **5%; and *10%

Source: Field Data (2016

These results suggest generally that mean incidence of water-related diseases such as malaria, diarrhoea, and skin-related infections is significantly higher among irrigating farm households compared with non-irrigating ones during the farming season. This finding is explained on the ground that a significant number of irrigation water bodies in general carry and transmit water-borne pathogens to humans directly through inhalation, frequent contacts and ingestion of water, while others serve as habitat for vectors such as mosquitoes and black flies that transmit parasitic and pathogenic diseases like malaria to irrigating farm households that spend more time in proximity to the water bodies. This strong positive correlation between irrigation and the incidence of water-related and water-borne diseases among urban farm households confirms the perceptions and beliefs of laypeople, and predictions of theoretical and conceptual models as well as established evidence by other empirical studies that irrigation creates a conducive environment for the breeding, growth, thriving, and transmission of water-based, water-borne, and other water-related sicknesses for farmers and those living close to irrigation water bodies (FAO, 2007; Ulimwengu, 2009; Jimenéz *et al*. 2010; and Kpoda *et al*. 2015). It is however unclear whether the relatively high incidence of malaria, diarrhea, and skin-related illnesses among irrigating farm households is motivated by irrigation water per se or by the type of water used for irrigation. Therefore, the generalization that irrigation, regardless of the quality of water used, significantly correlates positively with the prevalence of malaria, diarrhoea and skin-related diseases among farm households may be unsustainable when confronted with scientific evidence. As a result, the mean-comparison t-test was performed to further unearth whether there is a significant difference in mean incidences of these water-related diseases between wastewater irrigators and relatively clean-water (well-water) irrigators significantly matter. The results are presented in Table 4.3 thereof.

Table 4.3 Incidences of transient illnesses among farm households by type of irrigation water

	Irrigation farmer Groups by Water Source					
	Wastewater Users		**Clean-water Users**		**Difference**	
Illness type	**Mean**	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**
Malaria	2.4348	0.1408	1.8286	0.122045	0.6062***	0.1862
Injuries	1.125	0.125	1.125	0.125	0	0.1768
Respiratory	1.2727	0.1408	1.0667	0.6667	0.2061*	0.1431
Skin	1.5690	0.0782	1.1	0.0688	0.4690***	0.1396
Waist	1	0	1.1111	0.1111	-0.1111	0.1270
Diarrhea	1.6341	0.1033	1.2381	0.1176	0.3961**	0.1673
Others	1	0	1.0385	0.0385	-0.0385	0.0527

Significance level: ***1%; **5%; and *10%

Source: Field Data (2016)

In contradistinction to these findings are that differences in mean incidence of respiratory, spinal/waist problems and other minor diseases such as dental problems, Apollo 11 disease, among others, between irrigators and non-irrigators are significant in favour of the latter. This implies that these other non-water-related diseases are significantly predominant among non-irrigating farm households, who generally practice large-scale extensive farming.

4.4.2 Incidence of transient diseases among farm households by irrigation status

Since a strong positive correlation between irrigation farming and higher prevalence of water-related health shocks such as malaria, diarrhoea, and skin-related infections has been established, Table 4.3 shows further results on intra-irrigator incidences of these types of diseases and other non-water-related sicknesses. As expected, it is observed in table 4.3 that differences in average incidence of water-related illnesses such as malaria, skin-related infections and diarrhoea between wastewater user farm households and relatively clean-water irrigators are all positive and statistically significant at 1 percent and 5 percent significance levels, suggesting a strongly positive correlation between the prevalence levels of water-related diseases and wastewater use for irrigation in Ouagadougou. By implication, since the incidences of malaria, diarrhoea, and skin-related infections are significantly non-problematic for farm households that preferentially use relatively clean-water sources like deep or shallow wells for irrigation, then it is fundamental to note that in contradistinction to the foregoing results in Table 4.2, irrigation per se does not necessarily precipitate the incidence rate of these water-related health shocks, and hence the type of water is what fundamentally matters. In sum, wastewater use for irrigation is significantly linked to increased incidences of water-related diseases such as malaria, diarrhoea, and skin infections among farm households in Ouagadougou. These results overwhelmingly confirm the theoretical **Hypotheses 1A, 1B, and 1C** and the scientific conclusions of both Nitiema *et al*. (2013) and Kpoda *et al*. (2015) who both established scientific evidence on how the continued reliance on waste-polluted surface water sources for farming is positively and significantly correlated with the risk of intestinal amoebiasis and intestinal helminthic infections in Ouagadougou, which obviously cause dysentery and/or diarrhoea among the people. The findings further corroborate conclusions of Bradford *et al*. (2003) and Ashraf *et al*. (2010) that the use of faecally-contaminated water (wastewater) for irrigation does not only expose farmers to the risk of dysentery in India, but also it accelerates the incidences of skin problems, diarrhoea, fever, and nail problems in communities they are practiced compared to areas cleaner water is used for irrigation in Pakistan respectively.

It is however striking that the difference in average episodes of respiratory problems between farm households that use wastewater for irrigation and those that rely on relatively clean irrigation water is positive and significant at 10 percent significance level, implying that respiratory illnesses are significantly more prevalent in farm households that use wastewater for irrigation compared to farm households that use relatively clean water for irrigation contrary to results in Table 4.2 that respiratory sicknesses are significantly and positively correlated with non-irrigating farm households. Majority of the respiratory problems farm households reported is cold which may be closely linked to frequent and continued inhalation of wastewater or storm-water by farmers and their families.

4.5 Costs of illness among farm households

Results in Table 4.4 indicate that total monthly economic costs of transient illnesses for all the 133 farm households that recorded at least one episode of illness were estimated to be 1,673,225 FCFA ($2,762.47 US dollars). Out of this aggregate cost, households' direct financial payments per month contributed a whopping amount of 1,273,125 FCFA ($2,101.9 US dollars), representing 76 percent, while time costs (indirect costs) per month was 400100 FCFA ($660.06 US dollars), representing 24 percent.

Table 4.4 Costs of illness among farm households

Components of costs	Total Cost (FCFA)	Percent
Direct financial	1273125	76
Indirect	400100	24
Total	**1673225**	**100**

Source: Field Data (2016)

By implication, for the entire 2016 farming season, total economic burden of transient diseases among farm households in Ouagadougou can be estimated to be 10,039,350 FCFA ($16,575 US dollars), while direct out-of-pocket health and non-health financial burden on farm households will be 7,638,750 FCFA ($12,611 US dollars) per the season. This clearly shows that direct financial burden of recurrent diseases among farm households in the city is more than triple that of total time costs contrary to the findings of Sauerborn *et al*. (1994) that total time costs of illness (indirect cost) are more than double of financial costs of illness (direct costs) in their household cost of illness study in Burkina Faso. These contrasting findings can be attributed to differences in socio-economic and cultural attributes of locations the two studies are conducted. Whilst, this study estimated total economic costs of illness in the capital city of Burkina Faso, Ouagadougou, which can be described as the hub of high-cost modern health care facilities, and utilization of these high-cost services by households is relatively high compared to the use of home care and other orthodox treatment alternatives, causing financial burden to be heavier than the time economic burden for households. By contrast, Sauerborn et al. (1994) estimated costs of illness in a rural province of the country, where households, particularly during rainy seasons, shift treatment choice from high-cost hospitals and pharmacy to low-cost alternatives such as home care and traditional healers, causing financial cost of illness to be lower compared to time costs.

This colossal cumulative financial burden of illness for farm households in the city has overarching impairments on households' investment portfolios in farm complementary inputs such as hired labour and chemicals and non-production activities. For instance, aggregate financial burden of transient diseases among farm households per month is estimated to be about 78 percent of seasonal total value of chemicals (9,773,750 FCFA) and 98 percent of total hired labour payments (7,769,900 FCFA) for the season in Ouagadougou, demonstrating the catastrophic level with which incidence and cost of transient diseases dissipate households' limited savings and other productive assets which could have rather been invested in the procurement of high-yielding and improved seeds, chemicals, and irrigation pumps to augment output and welfare of people.

4.5.1 Components of direct costs of illness

Households' monthly financial costs of illness is generally decomposed into care provision spending such as costs of drugs and medical care and non-health care costs such as travel costs and food costs. Households monthly spending on drugs – from hospital dispensaries, pharmacies, and traditional herbs – represents the largest share of overall monthly financial costs of illness, constituting 87 percent, followed by travel costs making up 7 percent, while food costs related to illness is the least important component of financial burden of illness in the city (see Figure 4.4). This consequently makes drugs the single most important healthcare utilization product for farm households in the capital, and therefore, their efficacy and prices may have profound impacts on the proliferation of diseases and households' capacity to build sustainable stock of health capital necessary for production and maximization of welfare. The predominance of drugs in households' health care kit is consistent with the findings of Bonfrer and Gustafsson-Wright (2016) in Kenya. Medical care provision cost is however unexpectedly and curiously lower compared to drugs and transportation costs as shown in Figure 4.4. This can be explained from two perspectives deducible from the results. First, because Ouagadougou is the capital city of the country, pharmacies have rapidly proliferated to match accelerated growth in demand for non-hospital health care services including the services of pharmacies by many households due to significantly high waiting time at the predominantly stateowned hospitals in the city. Results in figure 4.5 below show that the rate of visits to pharmacies by individuals in households who are ill is the highest, with a rate of 52 percent compared to a 44 percent hospital visit rate and 4 percent to traditional healers.

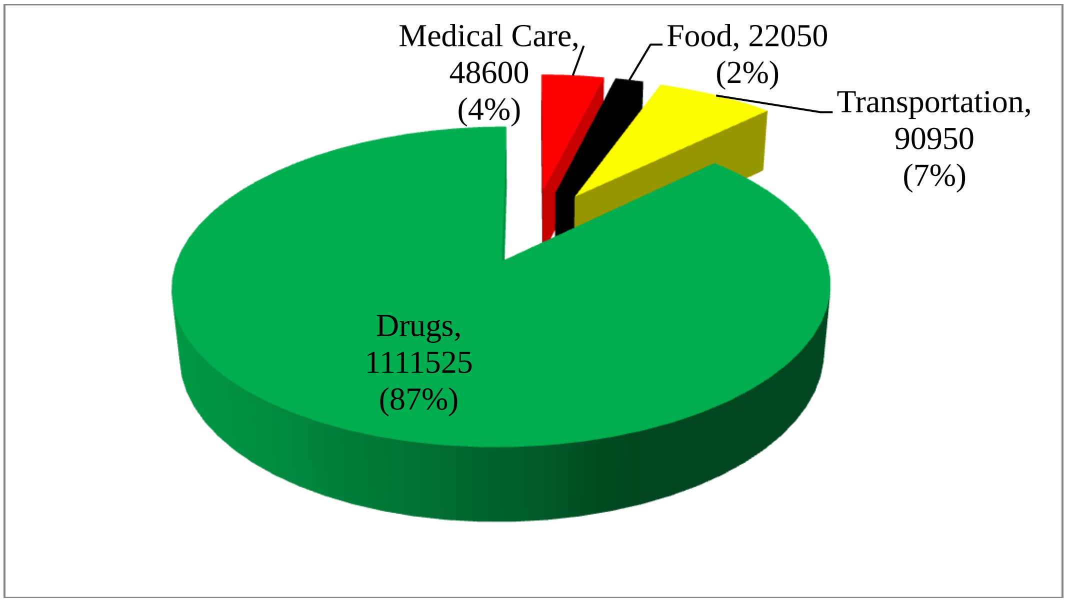


Figure 4.4: composition of direct costs of illness

Source: Field Data (2016)

This resultantly contributed to the higher household health payments on drugs relative to medical care and other services. Second, even among households that visited hospital for medical care, a large chunk of their health payments went to drugs since more than 90 percent of them were out-patients, while the rest of the payments went to medical care.

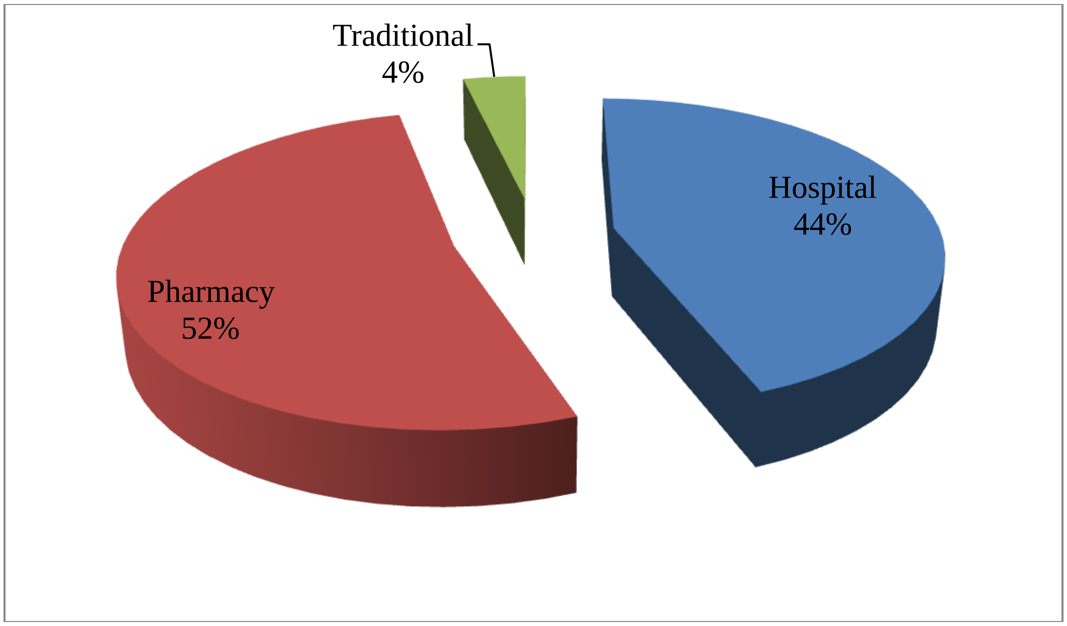


Figure 4.5: Healthcare utilization sources used by farm households in Ouagadougou

Source: Field Data (2016)

4.5.2 Components of indirect costs

Implicit costs of illness among farm households are divided into two major components viz self-reported perceived farm income loss due to illness-induced output dip and non-farm income loss including foregone wages and income from trading by the sick person and caretakers. Surprisingly, monthly illness episodes among farm households are reported to exert the greatest anti-productivity effect on the non-farm sector of the household, causing non-farm labourers to lose significant amount of wages and profits relative to perceived losses in farm income (Figure 4.6). This implies that non-chronic diseases heavily hit the non-farm household sector particularly wage labourers and traders harder than the farm sector, contrary to theoretical, conceptual, and empirical predictions and expectations. The estimated farm income loss is however significantly biased since the amounts were based on farmers' perception on whether or not illness affected their output negatively and hence their farm income. Results on an econometric estimation of the effect of illness on farm income are presented in Table 4.6d.

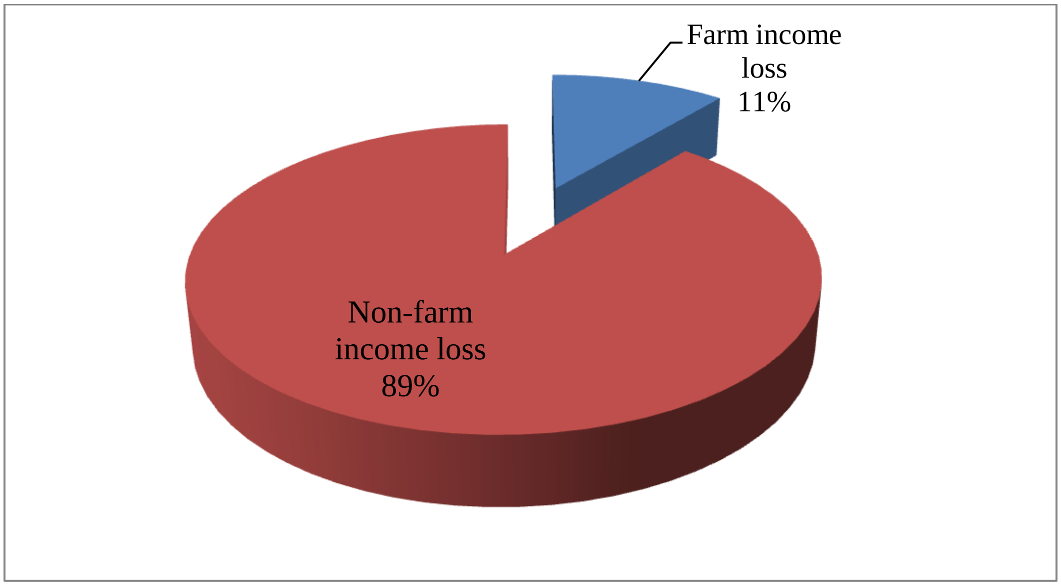


Figure 4.6: Composition of indirect costs of illness

Source: Field Data (2016)

4.5.3 The relationship between costs of illness and irrigation status

Figure 4.7 shows results that underscore a positive association between all the various components of households' monthly economic costs of illness and their adoption of irrigation farming system. Specifically, costs of drugs, medical care, transport, and food (direct costs of illness) as well as income losses are consistently higher among irrigating farm households compared to non-irrigating households, and this is justified based on earlier findings that significantly linked higher incidence of water-related illnesses to irrigating-households compared to non-irrigating households in Table 4.2. Interestingly, the gap in monthly financial burden of illness (direct costs) between irrigating households and rain-fed dependent households is quite lower as opposed to the difference in costs relating to productivity loss and foregone wages and sales income (indirect costs) between the two disparaging households. This implicitly implies that rain-fed dependent farm households incur a much lower opportunity costs of illness relating to drops in farm output and foregone wages and sales income compared to explicit costs of illness relating to drugs, care, travel and food. Therefore, irrigators in general suffer relatively high productivity and income losses compared to out-of-pocket payments for drugs, care provision, and travel costs during treatment of illnesses in the city.

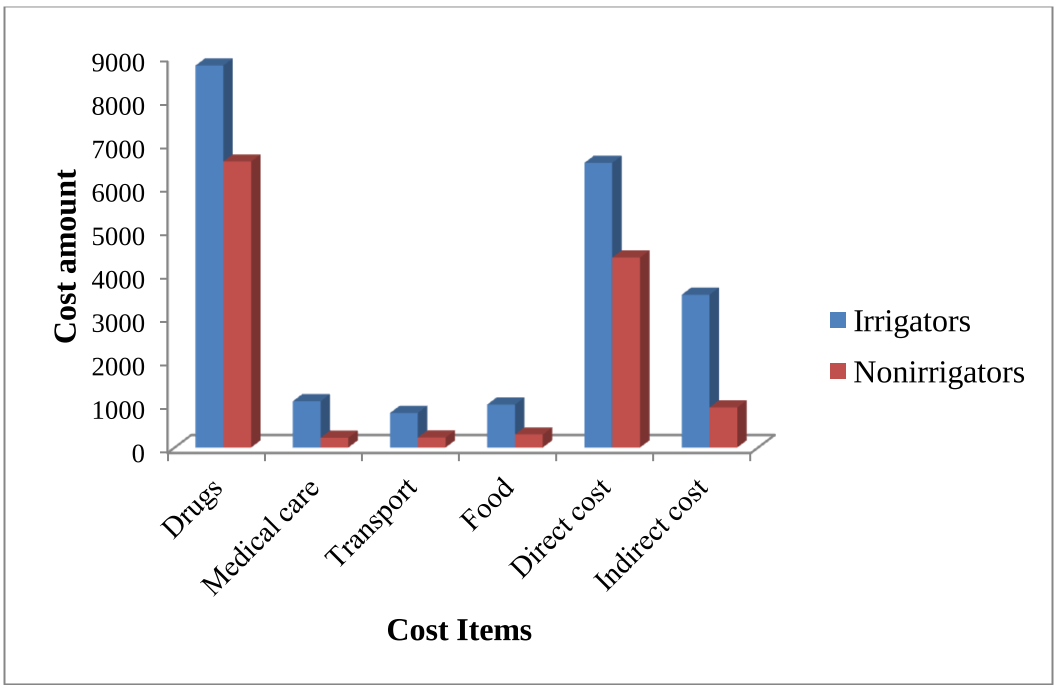


Figure 4.7: Economic costs of illness and irrigation status among farm households

Source: Field Data (2016)

4.5.4 The relationship between costs of illness and type of irrigation water

The positive correlation between irrigation and economic costs of illness shown in Figure 4.7 cannot be sustainably generalized to all households that practice irrigation since the quality of water used relevantly affects the incidence and costs of illness. Figure 4.8 therefore shows the correlation between monthly economic costs of illness and the type of water used for irrigation in terms of water quality. In contrast to results in Figure 4.6, Figure 4.7 reveals mixed relations between the various components of costs of illness among wastewater users and cleaner water users. On one hand, wastewater users incur relatively high monthly expenditures on medical care services and food costs related to illness compared to cleaner irrigation water users, whilst on the other hand, the former spent more on drugs and transportation to and from treatment centres compared to the latter. But at the aggregate level, monthly total financial burden of illness are relatively heavy on urban wastewater irrigators compared to well-water-dependent households, while the burden of output and income losses due to illness is lighter for the latter than the former. These may imply that households that irrigate with wastewater are highly predisposed to diseases that are highly likely to engender hospitalization and its concomitant incremental spending on care provision and sustenance. But those that rely on relatively clean well-water for irrigation spend highly on drugs and transportation because majority of the diseases caused by clean irrigation water are less severe so that such households recourse to pharmacies for drugs as the most cost-effective choice for disease treatment.

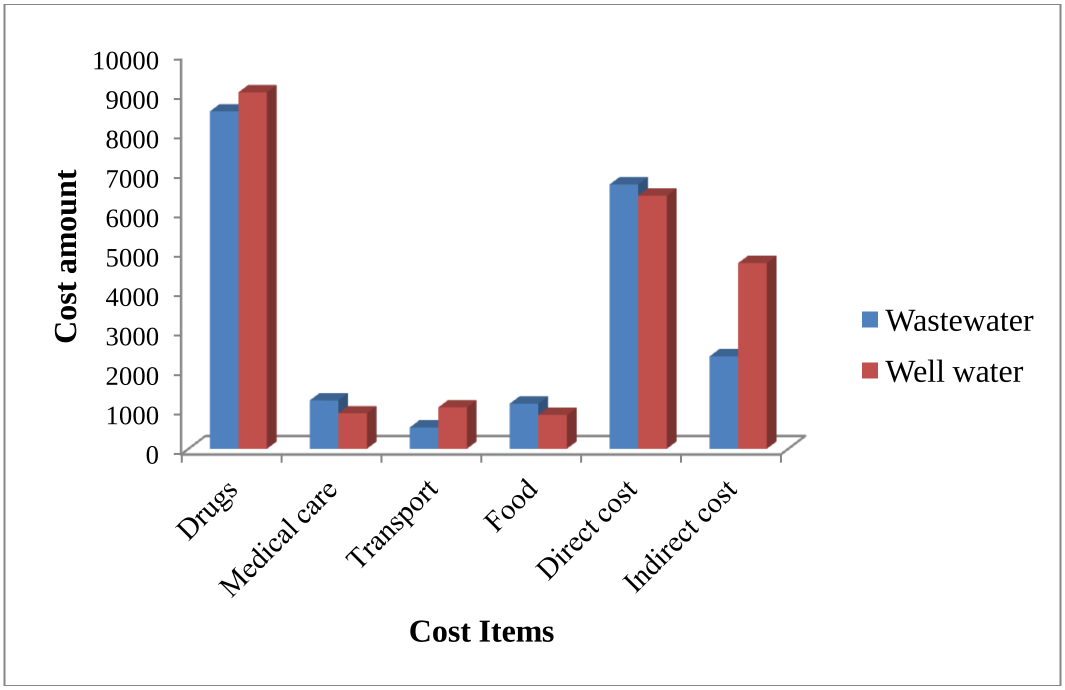


Figure 4.8: Economic costs of illness and type of irrigation water

Source: Field Data (2016)

4.6 Determinants of costs of illness among farm households

Table 4.5 presents the results of maximum likelihood estimation of Heckman sample selection equations for households' monthly incidence and financial burden of non-chronic illnesses.

The estimated coefficient of rho, which measures the correlation between the two disturbance stochastic terms is positive and statistically significant at 1 percent level, implying that there are unobserved variables which significantly increase both the probability of a household recording at least one incident of illness and the total direct financial costs of treating illness for households that are hit by at least one episode of a health shock. This is evidence of sample selection bias, and therefore the estimated Heckman sample selection model is more suitable for the data than OLS regression.

Table 4.5 Determinants of costs of transient illness among farm households (Heckman Sample Selection ML model)

Independent Variables	Selection (Illness status)		Outcome equation (Costs of illness)	
	Marginal[4] Effects	Robust S.E.	Marginal Effects	Robust S.E.
Dep	0.1140797***	0.0365694	170.4848	623.403
HHH_sex	-0.0174934	0.1078779	589.5523	1665.095
HHH_ed	0.0063298	0.0117889	53.82945	166.2029
Lit_adult	0.0372067*	0.0204136	840.6858***	322.4403
Nonfarm_inc			-32.9256*	19.51339
Wat_drink	-0.0007399	0.0449389		
Insect_app	-0.010254	0.0683003	-1343.082	1084.052
Farm-time	0.0535584**	0.0234587		
Mal_inc_4wk			5872.707***	1187.816
Nonmal_inc_4wk			622.5808	1116.963
Ill_day_4wk			113.9252	113.7909
Hosp_visit			2920.783***	761.518
Attend			1701.42*	945.9083
Trad_transp			-3616.657***	843.9323
Rho			2.443465***	0.442778
Constant			-6208.417***	2452.219
Wald χ^2 (12)				128.43
Prob > Chi^2				0.0000
Log Likelihood				-1315.274
N				185
Wald test of ind. Eqns. (rho = 0): Chi^2 (1)				30.45
Prob > Chi^2				0.0000

Significance level: ***1%; **5%; and *10%

Source: Field Data (2016)

More so, the Wald χ^2, which measures the overall explanatory power of the Heckman model, is 128.41, which is statistically significant at 1 percent level, implying that the model passed the goodness of fit test and that at least one of the

[4] See Appendix B for the corresponding coefficients of these marginal effects in a STATA output of regression results

regressors in both equations significantly explained changes in probability of monthly episode and financial costs of illness among farm households in the city.

The two exclusion restriction variables such as households' main source of drinking water and farm time have the expected negative and positive coefficients respectively, and have effectively contributed to eradicating sample selection bias in the estimates by overcoming the collinearity between the IMR and the covariates in the substantive equation. Farm time, which measures the number of months a farm household has been farming during the farming season, is shown in Table 4.5 to have a positive marginal effect, which is statistically significant at 5 percent. This implies that one additional month of farming during the rainy farming season significantly increases the probability of transient ill-health by about 5.35584 percent among farm households, holding all other covariates constant. This is underpinned by the fact that farmers who spend more time farming are exposed to high and intensive occupational hazards such as the vagaries of the weather, insect and other animal bites, stress, and body/waist pains, among others, thereby increasing the likelihood, and to some extent, the severity of transient illnesses among farm household workers and other individuals. In a similar vein, the variance inflation factors and correlation coefficients between all the independent variables were very low, showing evidence of no perfect multicolliniarity among the explanatory variables. However, hetroscedasticity was found to be present in both the selection and outcome equations, which made the estimates inefficient. Consequently, the robust hetroscedasticity-and-autocorrelation consistent standard errors estimator was used to estimate both equations, which eradicated the problem of heterocedasticity from the equations.

The type of irrigation water used and its effect on farm households' financial costs of illness was not estimated in the Heckman sample selection model. This is because given the relative importance this study places on the effect of irrigation water on incidence and costs of illness, the endogenous treatment effects model was used to estimate it due to possible self-selection and endogeneity problems that may have arisen if it was estimated in the Heckman model.

Beginning with the effects of socio-demographic and economic attributes of farm households on their costs of illness, the marginal effect of size of dependants (infants and the aged) is positive and statistically significant at 1 percent in the illness status equation, but insignificant in the costs of illness equation. This indicates that additional dependent member of a farm household was observed to have significantly increased the probability of recording at least one episode of a health shock condition by 11.40797 percent, *ceteris paribus.* This implies that increasing the size of dependant household members significantly increases the probability of ill-health without significantly affecting the financial costs associated with treatment of the illnesses recorded. This result reflects the higher vulnerability of both children under-five years and the aged adults above 60 years to transient epidemiological and age-related diseases. However, the model did not find any significant positive effect of dependant population on financial burden of illness because during field interactions, it revealed that all children under-five years and the aged receive free medical care and drugs under Government of

Burkina Faso limited pseudo health insurance scheme implemented at public hospitals in the country. This and other factors may have contributed significantly to why financial costs of treating illnesses did not respond significantly to changes in the size of dependant population in farm households. The positive significant effect of dependant population on probability of incidence of illness partly confirms both **Hypothesis 2B** of this study and Grossman (1972) theory of health capital that predicts a positive effect of age on the demand for health care services due to hastened rate of depreciation on stock of health capital over lifecycle as in equation [2.9] above. In addition, within the global framework of existing empirical literature, this result is consistent with results that linked rising incidence of illness to increasing proportion of elderly and infant household members (O'Donnell *et al*. 2005; Odoh and Nduka, 2014; Oyinpreye and Moses, 2014).

Literate adult population has a positive and statistically significant effect on both the likelihood of a household being stricken with an ill-health shock and the financial burden of illness, which is against the *a priori* expectation of this study. The result implies that an additional literate adult member in a farm household will cause, on average, the probability of households being infected with transient illnesses and the monthly financial burden of treating the illnesses to increase by 3.72067 percent and 840.6858 FCFA respectively. These findings sharply parallel both **Hypothesis 2A** and the theoretical predictions of Grossman (1972) that education contributes significantly to minimizing household financial costs of treating illnesses to the lowest possible level through optimal combination of bundles of health care services and efficient utilization of health and non-health services such as transportation, drugs, among others, during treatment of illnesses. It is also inconsistent with results of O'Donnell *et al*. (2005) who found strong inverse relationship between health expenditure and education of household members across all six Asian countries due to the contribution of education to efficiency in the use of modern medical care and production of gross investment in health capital stock. It is, however, worth-noting that apart from literate adult population, the sign on the marginal effect of educational level of household heads is also positive, thereby against the *a priori* expectation of this study and that of Grossman (1972) theory of health capital. Though the marginal effect of educational level of household heads is not statistically significant, the sign partly supports the relationship between literate adult population and probability of illness occurring in a household and the costs of treating the illness. However, the relationship can be explained in several ways. For instance, on the incidence of illness, it was observed on the field that a significant number of farm households with more literate individuals were located in the core-urban area, where large amount of industrial, institutional, and domestic wastes are generated juxtaposed against poor drainage and waste management systems typical of a capital city of developing countries compared with 'least literate' farm households largely located in urban periphery where less amount of wastes are generated, and traditional methods such as burning and burying of domestic solid wastes, and sometimes used as compost on farms. But for effect on costs of illness, though farm households with more literate members are expected to be more efficient in managing their stock of health capital, majority are more likely to choose hospitals for health care services with its concomitant other costs accessories such as transportation costs, registration fee, and costs relating to food compared with pharmacies and traditional healers. Similarly, it is possible that farm households with high number of literate people purchased highly efficacious and expensive drugs, which contributed to the positive relationship between literacy of household members and costs of treating illness.

The marginal effect of non-farm income is -32.9256 FCFA in the costs of illness equation, and it is marginally significant at 10 per cent level. This shows that when a farm household earns additional 1 FCFA from its non-farm income source, its monthly financial burden of treating transient illnesses recorded will decrease by 32.9256 FCFA, *ceteris paribus.* The negative marginal effect of income suggests that financial burden of treating illnesses recorded is heavier among farm households that are economically worse-off than those that are better-off. This result contradicts **Hypothesis 2C** of this study that income increases household financial spending on the treatment of illnesses recorded due to the choice of high-cost modern healthcare facilities. It is also inconsistent with the findings of Odoh and Nduka (2014) and Oyinpreye and Moses (2014) in Nigeria that households with higher incomes are more likely to make high out-of-pocket payments for healthcare which is considered a normal good and income inelastic. The negative effect, however, corroborates results of Mondal *et al*. (2010) in India that income significantly decreases the chances of households incurring catastrophic health payment. It further confirms results of Su *et al*.

(2006) in Nouna District in Burkina Faso that established that though higher income households report significantly higher number of illness episodes than poor households, yet the likelihood of the latter incurring catastrophic health care expenditure is significantly higher than the former in the District.

Other households' domestic attributes such as the sex of household head and the main source of drinking water were not found to have any significant effects on the probability of households being hit by illness shocks and financial costs of treating those illnesses.

Regarding epidemiological disease profile of households, monthly incidence of malaria disease is positive and statistically significant at 1 percent level, implying that an increase in the incidence of malaria by 1 episode will cause households' monthly financial costs of treatment to rise by about 5,872.707 FCFA ($9.70), holding all other covariates unchanged. In other words, any intervention that reduces malaria incidence among farm households by 1 episode will contribute to saving about 5,872 FCFA of households' financial reserves per month that otherwise would have been invested in the treatment of that episode of illness. Though the sign of the coefficient on incidence of non-malarial diseases is positive, the effect was not found to be statistically significant. This is a re-confirmation that the financial burden of malaria is significantly heavier on farm households compared to the incidence of all other observed transitory non-malarial conditions like skin infections, upper respiratory problems, and diarrhea among others. This result further confirms **Hypothesis 2D** that malaria exerts a positive pressure on household financial burden of treating illnesses. Besides, the depth of financial distress associated with incidence of malaria among relatively poor farm households in Ouagadougou is a trend for which some supportive evidence shows that aggregate public expenditures dedicated to malaria control in the country almost doubled from 18.7 million FCFA in 2006 to 37.2 million FCFA in 2009 (WHO, 2009).

The positive and significant marginal effect of farm households' hospital visit on financial costs of illness confirms the **Hypothesis 2D** of this study that increase in the intensity of hospital visits for utilization of services increases household monthly financial burden of treating ill members. This shows that a unit increase in households' hospital visit for treatment of sick members will increase household financial burden of treating illness by about 2,920.783 FCFA ($4.82) per month, holding all other regressors unchanged. Therefore, the financial burden of treating transient diseases is significantly sensitive to intensity of hospital service utilization among farm households in Ouagadougou. Note that hospital service utilization is closely linked to number of caretaker services provided during treatment of sick individual in household. As expected, the marginal effect of care-giving service provided to ailing individuals is significant and positive on the financial costs of illness (**Hypothesis 2D**). On average, one additional day of care-giving service for health-impaired household members significantly expands households' monthly out-of-pocket payments for treatment of and recuperation from reported illnesses by 1,701.42 FCFA, *ceteris paribus*. This implies that care-giving services generally heighten farm household financial commitments dedicated to curing of illnesses in the city. This strong positive response of households' financial load of treating illness to caretaking underscores the importance of care-giving service to the sick, particularly infants and the aged, and how it contributions to both transportation and sustenance bills of the household.

Another closely linked healthcare factor that generally determines farm households' financial costs of illness for the sick is the type of transportation facility that is used in the process of seeking healthcare. The marginal effect of traditional means of transport is negative and statistically significant at 1 percent level. By implication, when farm households increase the use intensity of traditional means of transport, including foot and bicycle, to and from health care service providers by 1 unit, their monthly financial payments for treatment of illness will reduce by 3,616.657 FCFA, *ceteris paribus*. Put differently, a unit increase in the use of traditional means of transport to and from health centres will contribute to increasing farm households' financial reserves by 3,616.657 FCFA per month which otherwise would have been invested in the treatment of reported sicknesses. Since traditional energy exhausting means of transport are largely patronized by relatively poor strata of society, increase in their use causes a significant increase in the amount of financial reserves hitherto earmarked for health care financing, which can be re-allocated into the acquisition of other productive inputs and non-health consumption goods and services to improve the welfare of individuals in the household. It is relevant to note that, holding all other factors unchanged, if farm households increase their hospital visit for healthcare services by 1 unit, the negative marginal health costs of 1 unit increase in the use of one of the traditional means of transport to the hospital will sufficiently offset the positive marginal health costs of the hospital use, and leave a surplus financial balance of about 695.874 FCFA in farm households' financial reserves that can be re-allocated into financing of other household activities. Hence, the use of traditional means of transport to and from care providers has a larger marginal effect on household's financial spending on treatment of sick members compared to hospital use and care-giving services in Ouagadougou.

Besides socio-demographic, economic and epidemiological factors that determine farm households' financial expenditures on health care, there are occupational-related factors that also affect incidence and costs of illness. One of such factors is pesticide application and its hazards on farmers' health. Though the coefficient of the mode of application of pesticide is negative and satisfies the *a priori* expectation, the model did not find its effect on probability of illness occurring and costs of treating the occurred illnesses to be statistically significant.

In sum, factors such as literate adult population, income, incidence of malaria, intensity of hospital service utilization, care-giving service, and traditional means of transport were found as significant determinants of farm households' monthly financial payments for health care services. Of all these factors, malaria had the largest effect on farm households' monthly financial expenditure on health care for ailing individuals, followed by use intensity of traditional means of transport and hospital service utilization in that order. Income however had the least marginal health costs for farm households.

4.7 The effect of type of irrigation water on direct costs of illness among farm households

Table 4.6 presents the results of endogenous treatment effects maximum likelihood model for households' choice between relatively clean-water and wastewater for irrigation and monthly financial burden of non-chronic illnesses.

The estimated coefficient of rho, which measures the correlation between the two disturbance stochastic terms is positive and statistically significant at 10 percent level, implying that there was self-selection among farm households regarding the use of wastewater or relatively clean-water. Therefore, the estimated endogenous treatment effects model is more suitable for the data than OLS regression. More so, the Wald χ^2, which measures the overall explanatory power of the model, is 259.92, which is statistically significant at 1 percent level, implying that the model passed the goodness fit test and that at least one of the regressors in both equations significantly explained changes in probability of clean-water use relative to wastewater use and financial costs of illness among farm households in the city.

Multicolliniarity was found to be low based on the variance inflation factors and correlation coefficient tests. In addition, the problem of hetroscedasticity was addressed in both the treatment and substantive equations using the robust hetroscedasticity-and-autocorrelation consistent standard errors estimator.

Table 4.6: Effect of type of irrigation water on financial cost of transient illness (Endogenous Treatment Effects Maximum Likelihood Model)

Independent Variables	Treatment equation (Irrigation water type)		Outcome equation (Costs of illness)	
	Coefficients[5]	**Robust S.E.**	**Coefficients**	**Robust S.E.**
Dep			-1417.554*	755.7398
HHH_sex	-0.761434	0.5062383	-249.0121	1882.778
HHH_ed	-0.0367028	0.0518995	-48.5511	200.8882
Lit_adult			50.94706	384.4544
Nonfarm_inc	0.0183897*	0.009611	5.156566	17.38505
Wat_drink			2136.822	1353.078
Irrig_wat			-4834.865***	1790.854
Insect_app			-1867.753	1547.093
Mal_inc_4wk			8304.906***	1081.504
Nonmal_inc_4wk			3442.925***	1136.601
Ill_day_4wk			283.0284*	147.1017
Attend			4495.285**	1960.596
Trad_transp			-5497.39***	784.9289
Ext_acc	0.8452389**	0.3420985		
Farm_type	-1.930561***	0.4155514		
Farm_loc	-1.340026***	0.3421846		
Wat_drink_cost	-0.0005145***	0.0001338		
Rho			0.3807494*	0.2247274
Constant	2.976728***	0.7055451	3772.761	2846.089
Wald χ^2 (13)				259.92
Prob > Chi^2				0.0000
Log Likelihood				-1116.2289
N				107
Wald test of ind. Eqns. (rho = 0): Chi^2 (1)				2.87
Prob > Chi^2				0.0902

Significance level: ***1%; **5%; and *10%

Source: Field Data (2016)

As expected, the coefficient of the type of irrigation water in the direct cost of illness equation is negative and statistically significant at 1 percent level, implying that farm households that used wastewater for irrigation of crops incurred

[5] The coefficients do not represent marginal effects. I could not find STATA commands to generate marginal effects for the treatment equation. However, since my foremost interest lies in the effect of irrigation water type on costs of illness, I decided to discuss the coefficients in both equations.

additional monthly financial costs of treating illness by 4,834.865 FCFA compared with those that use relatively clean-water, *ceteris paribus*. In other words, farm households that used relatively clean-water for irrigation were able to save about 4,834.865 FCFA of household meagre income that otherwise would have been invested in medical care, drugs, and transportation, among others, towards treating either additional wastewater-related illnesses or a more severe existing illnesses induced by contacts with micro-organisms in wastewater. The underlying reasoning explaining this relationship is that wastewater is reported to habour a large amount of coli-foam load and other microbial and pathological contaminations, which does not only precipitate increase in incidence of water-related diseases, but also exacerbate the severity of illnesses and the accompanied upward spiral effect on the monthly financial costs of illness for households that use wastewater compared with those that use relatively clean-water (FAO, 2012; Kpoda *et al.* 2015). This result unambiguously corroborates Grossman's modified theoretical predictions and **Hypothesis 2E** of this study that households' illness duration (severity) and demand for medical care (costs of illness) both increase with wastewater use (but reduce with clean-water) as stated in equations [2.14] and [2.16] in Chapter two. Also, the significant difference in direct costs of illness between clean-water and wastewater users confirms the predictions and conclusions of FAO (2012) and Kpoda *et al*. (2015) that by irrigating fields with wastewater, and spending more time near these wastewaters, farmers and their families are more likely to contract severe transient water-washed and water-based diseases such as ascaris and hookworms, diarrheal diseases, skin infections, nail problems, and occupational hazards, with their concomitant upward effect on the cost of treating the illnesses compared to irrigating with relatively clean-water. Many other studies have found similar findings that linked agriculture wastewater use to increased infections of common diseases such as cholera, skin diseases, and nail problems resulting from hookworm infections (Blumenthal and Peassey, 2000; Jiménez *et al*. 2010 and JIFSAN, 2010), and to increased economic and ecological costs to farm households (Kanyoka and Eshtawi, 2012). The World Bank's analytical framework concluded that though irrigation in general contributes to improving household farm productivity, income, and food security, among others, it equally creates congenial conditions for water-related vectors to thrive and increase the risks of households being stricken with water-washed illnesses and increase the financial burden of health care services (www.siteresources.worldbank.org). In sum, the choice between relatively clean-water and wastewater for irrigation of farm fields plays a phenomenal role in determining heterogeneity in financial burden of diseases among farm households that engage in irrigation farming in the city.

Regarding the effects of farm households' socio-economic characteristics on direct costs of illness, farm households' non-farm income was found to positively and significantly determine the choice of clean-water for irrigation over wastewater. By implication, increase in farm households' income by 1 FCFA will increase the likelihood of adopting relatively clean-water for irrigation of crops over wastewater. In other words, higher income farm households are less likely to adopt wastewater for irrigation relative to relatively clean-water. In effect, household income is a factor that significantly reduces the use of wastewater for irrigation of crops among urban farm households in the city. This result is consistent with **Hypothesis 2F** of this study and Havelaar *et al.* (2001) and Jiménez *et al.* (2010) who both attribute wastewater use to lack of adequate financial and physical resources to access clean water and treatment wastewater using expensive technologies. However, unlike in the Heckman sample selection model which showed a significant negative effect of income on farm households' direct costs of illness, this model found income to have a positive but insignificant effect on direct financial costs of illness.

Also, the size of dependants (infants and the aged) is negative and statistically significant at 10 percent level in the costs of illness equation, indicating that increases in the number of infants and elderly people in farm households will, on average, reduce farm households' monthly direct costs of illness by 1,417.554 FCFA, *ceteris paribus.* This implies that increasing the number of dependants in farm households significantly decreases the monthly financial burden of illness for farm households. The Heckman model of factors that determine direct costs of illness (Table 4.5) however did not find any significant relationship between dependant population and direct costs of illness. It rather found a strong positive effect of dependant population on incidence of illness. The negative effect of dependant population on direct costs of illness does not support the modified Grossman (1972) theory of health capital stock and the *a priori* expectation of this study. This can be attributed to observed free medical care and drugs enjoyed only by children under-five years and the aged under a pseudo health insurance scheme implemented at public hospitals in the country. Thus children under-five years and aged adults above 65 years enjoyed free medical services at public hospitals, which might partly explain the negative marginal effect of dependant population on direct costs of illness.

Unlike in the Heckman model of factors that determine farm households' direct cost of illness, the endogenous treatment effects model did not find household attributes such as literate adult population and nonfarm income to have any significant effects on farm households' monthly direct cost of illness. There is however some level of consensus in this study that the level of education and sex of household heads both do not have any significant relationship with farm households' direct costs of illness (see tables 4.5 and table 4.6).

Epidemiological and healthcare-related factors were also observed to have significant effects on farm households' monthly direct costs of illness. For example, monthly incidences of malaria and non-malaria (skin infections, diarrhoea, respiratory etc.) diseases are both positive and statistically significant at 1 percent level, implying that an increase in malaria and non-malaria illnesses by 1 episode will cause households' monthly direct financial costs of illness to rise by about 8, 304.906 FCFA ($13.71) and 2,369 FCFA ($5.68) respectively, holding all other covariates unchanged. By implication, monthly financial burden of one incremental episode of malaria is more than two-fold heavier on farm households compared with observed transitory non-malarial conditions like skin infections, upper respiratory problems, and diarrhoea among others. Unlike in the Heckman model, not only are monthly direct costs of illness significantly sensitive to changes in episodes of non-malaria diseases, its marginal sensitivity to variations in incidence of malaria is relatively high compared with the results in the Heckman model.

In a similar vein, duration of illness, caretaker service and the use of traditional means of transport to and from healthcare centre were all found to be significant determinants of farm households' monthly direct costs of illness. For instance, other factors remaining the same, whilst a unit increase in care-giving service and duration of illness will, on average, cause farm households' monthly financial burden of illness to rise by 4,495.285 FCFA and 283.284 FCFA respectively, a unit increase in the use of traditional means of transport to and from healthcare service providers will, on average, lead to a reduction in farm households' monthly financial costs of illness by 5,497.39 FCFA. What is, however, obvious with these results is that marginal costs of illness duration, caretaker service, and intensity of use of traditional means of transport for health services are higher compared to results in the Heckman sample selection model. Another striking difference is that average duration of illnesses has a strong effect on households' monthly direct costs of illness, implying that longevity of individuals' illnesses in farm households significantly and financially burdens farm households, and this is supported by results of Thavorncharoensap (2014) and Kallaru *et al*. (2015) that severity of illness in terms of illness duration plays significant role in increasing both direct and indirect costs of illness.

Table 4.6 further presented results on the factors that influence the farm households' choice between wastewater and relatively clean-water for irrigation of farm fields, which showed that extension access, type of farm, location of farm, and households' monthly cost of water for domestic activities were the significant determinants. For example, the coefficient on type of farm is negative and statistically significant at 1 percent level, implying that open space farming decreases the likelihood of farm households using relatively clean-water relative to wastewater compared with backyard farms. In other words, farm households that cultivate open space farms are higher users of wastewater for irrigation, whilst those that manage backyard farms are higher users of relatively clean-water users in the city. This result confirms the *a priori* expectation formulated in **Hypothesis 2G**. The positive influence of open space farms on the use of wastewater is fundamentally linked to their locational attributes, availability of relatively clean water and the stiff competition for clean-water, among others. For example, open space farms were observed to be situated at environments with water resources such as wells, rivers, streams, drains, and dugouts among others, whilst backyard farm fields were generally located at homes without necessarily considering their proximity to these water sources. However, due to competition for clean-water among farmers, industries, and institutions, open space farmers generally relied on polluted surface water sources for irrigation, whilst largely non-commercial backyard farmers generally irrigated their farms using household clean water sources. This confirms the argument of De Neergaard *et al*. (2009) that lack of access to cheaper, reliable and adequate clean water source in rapidly growing urban cities motivates the use of wastewater by urban farmers.

Another closely related factor is the location of the farm. Despite their closeness, multicollinearity test between the two variables have not reached problematic level since VIF test showed 1.19 and 1.15 VIF for location of farm and type of farm respectively. Location of farms was also found to have negative and significant effect on farm households' choice between relatively clean irrigation water and wastewater. By implication, the probability of farm households irrigating their farms with relatively clean-water declines significantly if the farm is located in the core-urban area but increases if it is located in a peri-urban area. In order words, farms located in urban core positively and significantly influence the use of wastewater for irrigation by farm households compared with farms located in the peri-urban areas in the city. This result is consistent with the *a priori* expectation of this study and that of Kanyoka, P. and Eshtawi (2012) that wastewater use increases with poor drainage and sanitation infrastructure in urban centres. One of the underlying factors that could explain the negative effect of farm location on choice of irrigation water is that the urban core serves as the industrial and commercial hub of the city where huge quantities of effluents are produced and discharged into open drains, which, due to poor drainage systems, end up polluting surface water bodies usually used for irrigation and drinking, thereby decreasing the use of relatively clean-water for irrigation, and rather increases wastewater use. On the other hand, the peri-urban areas are considered as the hub of urban agricultural production which receive disproportionally high investments from government, international development agencies, and NGOs in the provision of clean water resources and other agricultural support incentives, thereby influencing positively the use of clean well waters for irrigation, and decreases the use of wastewater.

Also, consistent with the *a priori* expectation, the coefficient on monthly costs of water for domestic activities is negative and statistically significant at 1 percent level, indicating that a 1 FCFA increase in farm households' monthly costs of water for domestic activities will decrease the likelihood of farm households using relatively clean-water for irrigation, and rather increase wastewater use for irrigation, *ceteris paribus.* Therefore, households' expenditure on the use of clean water for domestic activities generally and positively influences agricultural wastewater use quite significantly. This partly confirms the observation of Havelaar *et al.* (2001) that wastewater use in developing countries increased due to high costs of accessing commercial irrigation facilities using freshwater or treated water. Though majority of farm households in this study relied on unpaid polluted water resources for irrigation, one of the implications of this result is that quite a number of farm households who irrigate their farms with wastewater instead would have shared clean water at the household level between domestic activities and irrigation of the farm if expenditure and for that matter costs of the water had decreased significantly. Another possible reason is that if costs of consuming clean water at the household level were significantly decreased or lowered, then beyond backyard farmers, even open space farmers, who are generally higher users of wastewater, could have adopted small-scale drip irrigation systems that sourced water from pipe borne water or mechanized boreholes or wells.

Moreover, access to an extension officer (known as 'Inera') during the farming season was found to have a positive and significant effect on farm households' choice between relatively clean-water and wastewater for irrigation of farm fields. So that farm households that had at least one contact with an agricultural officer and received extension services are more likely to use relatively clean-water for irrigation relative to wastewater, *ceteris paribus.* Conversely, farm households that had no contact with any agricultural extension officer for extension service during the farming season are more likely to use wastewater for irrigation relative to clean-water. This result does not only confirm *a priori* expectation of this study, but also buttresses the conclusion of Asenso-Okyere *et al*. (2011) that the ability of farm households to adopt and appropriately and safely apply new technologies (including irrigation systems) depends largely on their access to extension services that are health focused.

In sum, the endogenous treatment effects model revealed, like the Heckman model did, that factors such as size of dependant population, type of irrigation water, incidence of malaria, incidence of non-malaria diseases, average duration of illness, number of days of care-giving service, and means of traditional transport such as walking and biking, have significant and varied effects on farm households' monthly financial burden of illness in Ouagadougou. Both models also converged in terms of their findings that incidence of malaria in farm households has the greatest financial implications for farm households, followed by the use of traditional means of transport and the type of irrigation water, in that order. The models, however, differed regarding the significance of income, duration of illness, and incidence of non-malarial diseases in determining farm households' financial burden of illness, and which of the significant factors has the least marginal costs of illness. In addition to these, this model analyzed the factors that influenced farm households' choice between relatively clean-water and wastewater for irrigation. Consequently, factors such as income, access to extension service, type of farm, farm location, and households' costs of clean water for domestic activities were found to generally determine the choice of farm households between the use of relatively clean-water and wastewater for irrigation of their farm fields in the city.

4.8 Effect of transient illnesses on agricultural productivity

After establishing the important positive effect agriculture wastewater use has on the probability of health shocks and increased financial burden of illness, it is important to estimate how the illnesses directly or indirectly related to agriculture wastewater use affects farmers' productivity and income. The effects of health shocks on household farm productivity is estimated 'simultaneously' using four equations including family labour, hired labour use, value of chemicals, and farm income. The results are presented in Table 4.7. The various effects are estimated firstly on family labour participation measured as the number of hours family members allocate to clearing, weeding, watering, chemical application, planting, and harvesting; secondly hired labour use measured as the total financial spending on non-family labour to undertake each of these farming activities; thirdly, value of chemicals (fertilizers and pesticides) used throughout the season; and finally on farm income.

The overall fitness of each of these four estimated models was tested using their respective R-squared and p-values. Covariates explained about 55.53 percent and 87.85 percent of variations in family labour and hired labour use respectively. The variables also accounted for 72.51 percent and 73.55 percent of changes in the value of chemicals and farm income respectively. Results on F-tests showed that the R-squared values of all the four regression equations are significant at 1 percent levels, indicating that at least, one of the regresors in each model significantly explained variations in the values of the respective dependent variables. Hence all the models have met the goodness of fit test.

Multicollinearity between the independent variables was tested using the Variance Inflation Factor. The results showed that intensity of using rivers, wells, and dugout were perfectly correlating with irrigation use variable, and as a result, these variables were dropped without any significant changes in the R-square values. Breusch-Pagan test of constant variance was rejected indicating the presence of heteroscedasticity in the estimates of all the equations except the farm income model. However, upon visual examination of the data set, it was realized that a large amount of outliers in the values of family labour hours, hired labour expenditures and values of chemical used were uncovered. The regression estimates of the equations were finally purged of the problem of heteroscedasticity by log-transforming the dependent variables.

4.8.1 Effect of illness on family and hired labour use in household farming activities

As expected, the effect of ill-health on hours worked on farm by household members is negative and highly significant at 1 per cent level. This implies that a day increase in the duration of transient illnesses reported in a farm household reduces the amount of hours family members are able to make available for farm work by 0.008 percent (Table 4.7). This result sufficiently satisfies both **Hypothesis 3A** theoretical expectation of Singh *et al*. (1986) agricultural household model of health and agricultural productivity as stated in equation [2.28]. Therefore, transient health shocks generally reduce family labour hours substantially (Larochelle and Dalton, 2006; Osei-Akoto *et al*. 2013) and the intensity of participation in farm work due to weakness and incapacitation (Asenso-Okyere *et al*. 2011). The negative partial elasticity of illness with respect to family labour use may stem either directly from incapacitation and weakness of economically active individuals in the household or indirectly from the time adult labourers spent caring for unhealthy infants and elderly members of the households or both (Larochelle and Dalton, 2006).

Since agricultural production activities are largely labour-intensive, the illness-induced reduction in family labour led to a corresponding increase in the use of hired labour to replace the lost family labour to ensure that final output is not severely affected. The coefficient for illness days in the hired labour equation is 0.054 and it is significant at 1 percent level, implying that a day increase in the duration of illness reported in a farm household significantly increases household purchase of outside labour by 0.054 percent. This is a confirmation of **Hypothesis 3B** and the theoretical prediction of Singh *et al*. (1986) that illness motivates a significant casual labour employment among farmers to replace lost family labour. The result shows a strong positive substitution of healthy hired labour for unhealthy family labour during the farming process by farm households (Osei-Akoto *et al*. 2013). It is significant to note that additional percentage of labour hours purchased due to illness far outweigh the percentage of family labour loss by 0.046 percent, suggesting that households spent 6.75 percent more on causal labour hours to replace 1 percent of family labour loss with the view to maintain uninterrupted farm activities[6]. Thus a percentage family labour lost due to illness is equivalent to 6.75 percent increase in hired labour expenditure in order to ensure that farm work is maintained and output is unaffected significantly. This result sharply parallels Osei-Akoto *et al*. (2013) and Larochelle and Dalton (2006) who both found negative balances in the replacement of family labour loss with healthy casual labour, causing overall labour use and output to decrease. It is significant to establish that the replacement of relatively smaller family labour loss with a much significant hired labour is a re-confirmation of the assumption of imperfect substitutability between unpaid family labour and outside commercial labour since the former has stronger incentive to work and produce relatively high output per hour to primarily ensure that household consumption needs are met and a surplus is generated to earn some income to satisfy other non-food needs compared to the latter. The substitution of relatively high number of paid

[6] The ratio of partial elasticities of casual labour to family labour gives 6.75

labourers for smaller number of illness-induced disabled family labourers due to discrepancies in work incentives and by extension productivity in favour of the latter also suggests a phenomenal support to the assumption of non-separability of production and consumption decisions in traditional agricultural households, an assumption strongly backed by Norton *et al*. (2010) and Larochelle and Dalton (2006).

It is worth noting that hired labour and family labour can be complementary to some extent since both have varied skills, competencies, and motives in the production process. The coefficients for economically active males and females are respectively 0.120 and 0.064 percent, implying that additional male and female members in the farm household who are economically active are significantly associated with an increase in family labour use by 0.120 percent and 0.064 percent respectively. However, additional economically active male and female members were not found to reduce hired labour significantly, indicating that even in the presence of economically active household members, hired labour is still engaged to undertake various activities for various reasons, including shocks and migration among household members. This is another reason why intra-family labour substitution is inadequate to maintain production in the face of health shocks to family labour (Larochelle and Dalton, 2006)

The contrasting effect of irrigation use on household family and hired labour use is also worth noting. Farm households that used irrigation significantly employed 0.677 percent more of family labour, but 2.416 percent less of hired labour relative to non-irrigating households throughout the farming season, thereby partly supporting **Hypothesis 3C** that irrigation increases both family and hired labour use. This implies that whereas irrigating farm households use family labour more intensively than rain-fed farm households, the latter use paid labour more intensively than the former. Therefore, irrigators use more family labour and less paid labour compared to non-irrigators, and this can be attributed to differences in landholdings and the relative contributions of farms to household livelihood and satisfaction of basic needs. It means that since irrigation farmers largely practice intensive farming on relatively smaller landholdings, in most cases, they traditionally rely more on household resources such as family labour for production than hired labour until such a time that the landholding is expanded or the household is hit by a health shock which makes family labour incapacitated so that hired labour is used to supplement or complement the work of the former. Another reason is that irrigation contributes significantly to crop yields and increased household income compared to non-irrigated farms (Ambrose-Oji, 2009; Jiménez *et al*. 2010), which therefore provides sufficient incentives for household members, including those engaged in non-farm sector, to increase their participation in the household farm enterprise. Besides, Burkina Faso has one growing season so that in order to accomplish activities such as land preparation, planting, among others, within time, the seasonal demand for hired labour by rain-fed farmers is less elastic compared with irrigators, whose activities are more flexible and do not require such urgency. Therefore, irrigation farmers are the biggest employers of family labour, whilst non-irrigating large-scale extensive farm households employ more of non-household resources including hired labour.

4.8.2 Transient illness and investment in fertilizer and agro-chemicals

The effect of illness on households' level of investment in the acquisition of soil fertility amendments such as animal manure, inorganic fertilizer, and agro-chemicals is estimated and presented in Table 4.7. Catastrophic financial payments for illness dissipate household savings and investible capital which otherwise would have been used to purchase fertilizers and agrochemicals, which are critical inputs for enhancing agricultural productivity and income. As expected, based on **Hypothesis 3D** and conceptual and theoretical discussions of Singh *et al*. (1986), the relationship between illness duration and total value of chemicals used during the season, including fertilizers and agro-chemicals, is negative, albeit it is not significant. The insignificant effect of illness on household investment in fertilizers and agro-chemicals may be attributed to government's distribution of hugely subsidized fertilizers and agro-chemicals to irrigation farmers through 'Inera', an agricultural extension organization in Ouagadougou in order to improve productivity. Therefore, even in the face of growing household payments for severe illness, farmers' access to fertilizers and agrochemicals was heavily subsidized by the Burkina Faso government particularly for organized farmers, which delinked households' expenditure on health care from their financial capacity to invest in soil fertility amendments. Besides, some farmers applied chemicals that were purchased in the last farming season, which indirectly cushioned them financially during this year's farming season, particularly against the unpredictable health care payments, which compete with farm inputs for households' meagre financial resources.

The estimated positive and significant effect of irrigation on the value of fertilizers and agro-chemicals farm households used has confirmed theoretical expectations and **Hypothesis 3E** of this study that irrigation has strong complementary effects on the efficacy and effectiveness of fertilizers and pesticides in improving crop productivity (Norton *et al*. 2010). Therefore, a farm household that irrigates increases its purchase and use of fertilizers and agro-chemicals by 12.062 percent more than a rain-dependent farm household, holding all other covariates unchanged. The relatively high spending on fertilizers and agro-chemicals among irrigators is responsible for multiple harvests per season and the significantly higher average farm income compared to non-irrigators. The result is a confirmation that urban irrigation farmers are predominantly smallholder intensive higher productivity farmers.

It is, however, against the *a priori* expectation that the estimated effect of non-farm income on the amount of fertilizers and agro-chemicals farm households used is negative. The result implies that on average, increase in non-farm income by 1000 FCFA significantly reduces household investment in fertilizer and agro-chemicals by about 0.040 percent, *ceteris paribus*. Therefore, non-farm income generally reduces consumption of soil fertility amendments among farm households in the city, a finding that is parallel to that of Knepper (2002) and Waithaka *et al*. (2007). The finding also may be indicative of households' level of investments and growth in the non-farm sector relative to the farm enterprise. Therefore, growth in non-farm income implies that households are investing higher proportion of their resources including both physical and human capital into non-farm production activities at the detriment of household farm enterprise. This might explain the negative effect of non-farm income on household investment in fertilizer and agro-chemical inputs[7].

Moreover, the coefficient of cultivated farm size is 0.031 and it is significant at 1 percent level, indicating that an increase in farm size by an additional bed raises the value of fertilizers and agro-chemicals used during the season by 0.03 percent, *ceteris paribus*. As expected, farm size significantly increases the intensity and amount of fertilizers and agro-chemicals that are used for soil fertility and crop productivity amendments. This result is confirmed by other supportive evidence uncovered elsewhere in Zambia (Knepper, 2002) and in Western Kenya (Waithaka *at al*. 2007). It is also worth mentioning that farm households that cultivated lettuce crop and male-headed households both have positive and significant effects on the volume and consumption of fertilizers and agro-chemicals for farming activities for the season. These findings are consistent with the *a priori* expectations of this study, and imply that male-headed households invest more into fertilizer and agro-chemicals, probably due to the large-scale nature of their farms and their relatively high access to farming resources such as credit and land space compared to female-headed ones (Knepper, 2002). Also, lettuce croppers used relatively more voluminous amounts of fertilizer and agro-chemicals compared with non-lettuce producers due to the large-scale production nature of the crop given that lettuce is the biggest cultivated vegetable in Ouagadougou. In sum, irrigation, farm size, lettuce, and male farmers are all

[7] This explanation assumes that the wage-food price ratio is constant.

highly intensive in application of soil fertility amendments such as fertilizers and agro-chemicals in Ouagadougou.

4.8.3 Transient illness and agricultural productivity among farm households

The final estimated model encapsulates the effects of illness, other endogenous variables such as family labour, hired labour, and value of chemicals, and exogenous control variables including farm size, irrigation use on the total value of output after controlling for prices of the various crops. The results are presented in Table 4.7. In this model, ill-health is expected to indirectly diminish farm income through its negative effects on production inputs such as family labour, hired labour, and fertilizers and agro-chemicals as stated in equation [2.34] in chapter two. Therefore, illness as an endogenous variable has a negative but insignificant effect on household farm income contrary to both theoretical predictions of Singh *et al*. (1986) and empirical results of Ajani and Ugwu (2008), Egbetokun *et al*. (2012), and Onuche *et al*. (2014) in Nigeria, Ulimwengu (2009) in Ethiopia, and Osei-Akoto *et al*. (2013) in Ghana.

It is important to establish that the fundamental reason why farm income is unaffected by ill-health is the more than sufficient substitution of sick family labour for physically and mentally capable hired labour by more than six-fold percentage points. Since illness is theoretically modelled to reduce output through its diminishing effect on family labour use, sufficient replacement of family labour hours lost with more than enough active hired labour as a coping mechanism partly contributes significantly to offsetting the downward effect of illness on output, a result consistent with the model of Singh *et al*. (1986) and findings of Conly (1975) but parallel to the famous conclusion of Audibert and Etard (1998) that ill-health actually increases family labour intensity significantly as a compensation for farm work lost due to illness, making final output unaffected. In some cases, weakly efficient family members such as women and children are re-allocated to replace sick and disabled men working on the farm as a coping mechanism against the effect of illness on farm output (Nur and Mahran, 1988).

In sum, ill-health does not significantly affect farm incomes of farm households in Ouagadougou. Rather, it actually increased hired labour use intensity to compensate for the lost family labour.

As expected, the coefficients for family labour and hired labour are both positive and significant at 5 percent level. Whilst an hour increase in family labour leads to 0.523 percent increase in farm income realized, an increase in spending on casual labour by 1 FCFA significantly translates into an increase in farm income by 0.022 percent, *ceteris paribus*, implying that both labour inputs generally determine the agricultural production, a result proven by copious previous studies (Ulimwengu, 2009; Osei-Akoto *et al*. 2013; Onuche *et al*. 2014; Bedemo *et al*. 2013b). It is relevant to establish that the productive contribution of family labour input to aggregate household agricultural production for the season is twenty-times greater than that of paid casual labour, and this boosts existing theoretical and empirical evidence in support of the assumption of non-separability of consumption and production decisions as well as the assumption that the two labour inputs are imperfect substitutes (Larochelle and Dalton, 2006; Norton *et al*.

2010). The disparity in marginal productivities of family labour and casual labour stems from strong economic and non-economic incentives encompassing, inter alia, household food and nutrition security, individual sense of social responsibility, need for income from surplus output to meet non-food needs, and other culturally motivating factors that significantly drive the former towards household farm work relative to the former being inspired mainly by the wage rate. A similar result was uncovered by Bedemo et al. (2013b) in rural Ethiopia where household unpaid labour had a larger impact on agricultural output than hired labour because of discrepancy in work incentives in favour of the former.

The coefficients for irrigation and seed value are positive and marginally significant at 10 percent and statistically significant at 1 percent levels respectively, implying that household farm income increased by 0.566 percent and 0.676 percent in response to the use of irrigation and 1000 FCFA increase in seed value used at the end of the season respectively, holding all other covariates constant. The wide gap in average farm income between irrigators and non-irrigators is consistent with theoretical, conceptual, and empirical discussions that households that irrigate their farm fields, regardless of the quality of water used (combination of waste and clean water) obtain higher cropping intensity, crop productivity, and crop output (Kanyoka and Eshtawi, 2012) as well as high average farm income per season (IWMI, 2006) than conventional rain-fed farm households. The disparity may also be influenced by the quantity of organic matter and diversity of nutrients that wastewater in particular recycles for optimal growth of crops, which is reported to outstrip what any commercial fertilizer can supply, thereby making irrigation farming highly cost-effective and more productive compared with rain-fed agriculture (Jiménez *et al*. 2010). In the case of farm size, the coefficient is positive and significant at 1 percent level such that additional bed cultivated by a farm household leads to 0.014 percent increase in farm income, *ceteris paribus*. Though intensive irrigation cropping was largely done on small landholdings of less than one acre by farm households in the city, the number of beds each farm household cultivated significantly increased quantities of variable inputs such as family labour hours and value of fertilizers and agro-chemicals used during the farming season, and invariably therefore influenced upwardly the amount of income a household generates from its farm business, confirming existing literature (Ulimwengu, 2009; Osei-Akoto *et al*. 2013; Bedemo *et al*. 2013b; Onuche *et al*. 2014).

However, the coefficient for value of chemicals is positive but not significant. Factors including wasteful over-application of chemicals due to government subsidy (above the prescribed quantity of fertilizer and agro-chemicals per bed), haphazard timing of application, and sub-optimal application methods among others may possibly be responsible for the weak impact of chemicals on household total farm income.

Table 4.7: Results of the 3SLS simultaneous estimation of family labour use, hired labour use, agricultural investment and household farm income

	MODELS							
Independent variables	**Familly labour use**		**Hired labour use**		**Fertilizer & agrochemicals**		**Household farm income**	
	Coefficient	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
Ill_day_sea	-0.007648***	0.0029041	0.054472***	0.0181493	-0.0033023	0.0227142	-0.0026243	0.0042996
EAL_male	0.120335***	0.029223	-0.2826785	0.1886925				
EAL_female	0.0642799*	0.033527	-0.1263645	0.2159929				
HHH_ed			-0.165797**	0.0732445			0.0049985	0.0183394
HHH_sex	0.2165955**	0.1102511	0.5944287	0.7110433	1.832995**	0.8319321	0.1895831	0.1818281
Lit_adults	0.0389281*	0.0227506	-0.1555926	0.1445378	0.0823441	0.177512		
Nonfarm_inc					-0.040245*	0.0215405		
Dep	-0.0036611	0.0436451	0.1762417	0.2789368				
Farm _acts			4.718059***	0.1714534				
Extension_cont					0.2633494	0.1856336	0.0235091	0.0382482
Credit amount					4.30E-06	9.97e-06	2.04E-06	2.04E-06
Insect_app	0.3007241**	0.1425082	1.013867	0.9192584				
FBO_memb	0.0744285	0.0836864			-0.3195653	0.7253106	0.2062123	0.1377676
Lettuce_cul	0.1326175	0.1177827	1.902255**	0.7524266	1.91591**	0.9690734		
Maize_cul					1.018374	0.8197184		
Burunbula_cul	0.1182027	0.0832252	0.2425346	0.5240363	0.1314548	0.6540216		
Rice_cul	0.2846107**	0.1152941	-1.076417	0.740133				
Farm size	0.0046728***	0.0012911	-0.0007498	0.0082228	0.03080***	0.0099183	0.01354***	0.0024663
Log(flab)							0.521905**	0.2573792
Log(hlab_exp)							0.0224953**	0.0098782
Log(che_val)							0.0067312	0.0261298
Seed value							0.676101***	0.1664011

Irrig_use	0.6966008***	0.1616859	-2.4162**	1.025306	12.0616***	1.142477	0.5655959*	0.3182877
Constant	5.572663***	0.1619402	-5.2017***	1.038638	-7.55711***	1.100774	6.99564***	1.651421
Model Diagnostics								
R-Squared	0.5553		0.8785		0.7251		0.7355	
Chi-squared	245.47		1388.24		507.42		528.05	
P-value (Chi-squared	0.000		0.000		0.000		0.000	
Number of observations	208		208		208		208	

Significance level: ***1%; **5%; and *10%

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Chapter outline

Findings and conclusions deduced from the analyses and discussions of results in the preceding chapters are summarized in this chapter. Based on these, relevant recommendations, involving policy, further research, and best practices are provided.

5.2 Summary

Urban farming contributes significantly to urban food security, job creation, and reduction in urban poverty particularly in developing countries. However, in Ouagadougou, due to rapid urbanization and its accompanied pressure on land and water resources, as well as environmental pollution, urban farmers, particularly those engaged in irrigation, mostly rely on polluted water for irrigation of farms, thereby predisposing such farmers to high incidence of water-related diseases and high financial burden of treating such illnesses. On the basis of this, this study sought to: analyze, empirically, the relationship between wastewater irrigation and incidence of water-related diseases; estimate household economic costs of illness and its relationship with wastewater irrigation; determine the factors that influence the use of wastewater for irrigation among farm households; estimate the effect of wastewater irrigation on financial costs of illness; and the effect of illness on household farm labour use, agricultural investment, and farm output.

Methodologically, data was collected from spatially randomly sampled farm households using a semi-structured questionnaire, from which results were produced using analytical methods such as the mean-comparison t-test, endogenous treatment effects, and the three-staged least squares (3SLS) simultaneous regression equations.

In an attempt to address the broad problem of agricultural wastewater use and its effect on farm households' cost of illness, copious number of important findings were established that addressed the specific research questions (objectives) of this study. On the question of incidence of transient diseases and their relationship with wastewater use, it was found that transient water-related diseases such as malaria, skin infections, and diarrhoea were endemically high compared with other non-related diseases including, upper respiratory infections, eye problems, and farm-related injuries among farm households. Of all the diseases reported, malaria had the highest incidence rate, followed by skin infections and diarrhea in that fashion, whereas occupational injuries had the least rate of incidence among farm households. In addition to this, wastewater use was found to have strong positive correlation with the incidence of malaria, skin infections, and diarrhoea in Ouagadougou.

Closely linked to the incidence of transient diseases is the economic cost of these diseases and their relationship with wastewater use by farm households. As a consequence, aggregate economic burden of transient health shock conditions, particularly malaria, skin infections, and diarrhoea, was found to be catastrophically higher for urban farm households compared with other household financial expenses such as agricultural investments, water consumption expenditure, and other food consumption expenditures in particular. Out of this total costs, direct financial costs of illness such as drugs, medical care, travel, and food costs, were found to have exerted a significantly heavier burden on farm households' meagre savings and other financial assets compared with time costs of illness such as productivity and wage income losses. Also, household spending on drugs made up the biggest share of total financial burden of illness, followed by travel costs and medical care, whilst food costs associated with hospitalization was the least share of total financial costs of illness. It was established, however, that the effect of direct financial costs of transient health shocks was harder on households that depended on wastewater for irrigation compared with those that irrigated using relatively clean water, whilst time costs of illness in terms of output and non-farm income losses were higher among the latter compared with the former. Hence, wastewater irrigation was positively and significantly associated with higher direct financial costs of illness but negatively correlated with time costs of illness.

Another important finding relates to the determinants of incidence and direct costs of illness among urban farm households in the city. Using Heckman Sample Selection and Endogenous Treatment Effects models, socio-demographic, and economic factors such as farm households' size of dependant population, number of educated adults, and income were found to have strongly determined farm households' financial burden of transient ill-health conditions. In addition to these factors, epidemiological profile and other disease treatment-related factors encompassing incidence of malaria and non-malarial diseases, duration of illness, care-giving service, hospital service utilization, and traditional means of transport were equally found as important factors that generally and significantly determined farm households' direct financial burden of illness in the city. Of all these factors, incidence of malaria was, however, shown to have the greatest effect on farm households' financial reserves, while illness duration had the least financial implications for the households. Similarly, incidence of transient illnesses among farm households was also found to have been influenced significantly by factors including size of dependant population, number of educated household adults, and period of farming.

Besides, the type of irrigation water was equally found to have generally determined farm households' direct costs of illness in the city. It was particularly revealed that urban agricultural wastewater use was found to have significantly increased farm households' direct financial costs of illness by about 4,834.865 FCFA ($7.98) per month compared with clean-water use. Thus the economic benefits of adopting relatively clean-water rather than wastewater for irrigation was estimated to be about 4,834.865 FCFA ($7.98) per month. On the other hand, farm households' choice between relatively clean-water and wastewater was generally and significantly influenced by socio-economic factors such as household income and expenditure on clean water for domestic activities, and farming-related characteristics, including, access to extension services, farm location, and the type of farm cultivated by a farm household.

Regarding, however, the effect of transient illnesses on households' labour use and farm income, ill-health conditions were found to have contributed significantly to determining the quantity and efficiency of households' family and casual labour use. For instance, family labour intensity in household farming activities reduced quite significantly due to ill-health, which led to a corresponding significant increase in hired labour to effectively compensate for the lost family labour supply. Hence, ill-health caused significant loss in family labour and a positive family-hired labour substitution to cope with the adverse effects of ill-health on outputs. Other factors that significantly influenced family and hired labour participation for agricultural production included number of economically active men and women, number of educated adults, irrigation of farms, rice and lettuce cultivation, and the land size cultivated. Although epidemiological conditions may have significant effects on the efficiency of labour (human capital) in agricultural production directly, and on output indirectly, they were not found to have any significant impact on the farm income of households in the city. This is partly due to the significant increase in the use intensity of more physically and mentally active hired labour in household farming activities as compensation for lost family labour. Nevertheless, factors such as family and hired labour inputs, cultivated land size, and seeds were shown to have significantly determined farm incomes of urban farm households.

5.3 Conclusions

There are important implications for formulation and implementation of policies, programmes and projects, as well as for research that are embedded in the major issues found to be addressing the specific problems of agricultural wastewater use and farm households' costs of illness at the end of this study. On the basis of these implications, the following important conclusions and recommendations have been reached.

In the first place, the problem of higher incidences of water-related diseases such as malaria, skin infections, and diarrhoea among farm households compared to other diseases in the city is closely associated with farmers' proximity and frequent contacts with irrigation water, particularly, wastewater, which creates a conducive environment for the breeding, thriving, and spreading of these diseases.

Similarly, the high and increasing financial burden of illness among farm households in the city is largely attributable to agricultural wastewater use for irrigation, high incidence of malaria and other non-malaria diseases, hospital service utilization, higher number of care-givers for sick individuals, and use of high-cost means of transport during treatment of illnesses, and high costs of drugs at pharmacies and hospitals.

Another important conclusion worth-noting is that the uncontrolled agricultural wastewater use for irrigation menace in the city largely stems from farmers' lack of access to extension services, high costs of clean-water that can be used for irrigation in addition to domestic activities, low non-farm household income, and the practice of open space farming as well as farming in the urban core where pollution is problematically high.

Epidemiological factors such as transient illnesses was greatly responsible for shortfalls in family labour input during household farming activities and the corresponding high household expenditure in employing hired labour to compensate the shortfalls. Other factors that contributed significantly to problems relating to availability of labour inputs in household farming activities are small urban landholdings for farmers, low labour force base, education of household heads, non-irrigation of farms, and non-cultivation of lettuce and rice.

However, low farm productivity and incomes of urban farm households in the city could not be traced to incidences of transient illnesses. Rather, farm households faced productivity and low income challenges due to inadequate access and use of family and hired labour, non-irrigation of some farms, lack of adequate access to improved seed varieties and agricultural lands.

5.4 Policy Recommendations

The following recommendations are proposed for address the major problems found in this study.

Firstly, government through MoH should implement short-term transient health shock policies such as intensification of the on-going distribution of insecticide mosquito nets particularly during the rainy season to prevent exposure to malaria. Also, the Ministry of Agriculture of Burkina Faso through extension officers should distribute protective clothing gadgets such as water-resistant boots, nose covers and hand gloves to farmers, particularly those susceptible to wastewater use, in order to prevent inhalation, ingestion, and physical contacts with wastewater during can-watering of crops in order to control the overall burden of diseases among farm households. Besides, wastewater-related diseases can be effectively controlled if safer and sustainable irrigation methods such as localized drip irrigation and use of small-scale wastewater filters are promoted effectively for urban farm households, particularly those located at the urban core and practice open space farming.

Moreover, the financial burden of illness for farm households can be significantly controlled and lessoned if government implement short-term costs of illness containment policies such as a downwardly reviewing the fees of health care services at public hospitals (like compulsory registration fee of 200 FCFA), promoting the adoption of clean-water for irrigation, intensifying the on-going implementation of malaria control programme, and limiting the number of family care-givers for the sick at hospitals, as well as making hospitals and clinics more physically accessible in terms of distance. Government can also consider a long-term health policy such as a comprehensive health insurance policy to replace the current limited free infant health care scheme implemented at government hospitals so that every citizen is covered at both public and private healthcare facilities, including pharmacies, in order to significantly cushion poor farm households against catastrophic out-of-pocket financial costs of illness, and address the negative effects of transient health shocks on farm households' expenditures and farm production.

Besides, government can effectively promote clean-water adoption for irrigation (and agricultural wastewater use de-promoted) among farm households, if the Ministry of Agriculture increase extension service delivery to farmers, particularly through periodic extension outreach programmes, and raising incomes of households, particularly by promoting and supporting off-farm business development. Equally significant recommendation is that clean-water resources such as mechanized pipe-borne water facilities, deep wells and concrete dams should be provided by the Ministry to help improve access to, and reduce costs of, clean-water for irrigation. Backyard farming should also be promoted using input, market, and other incentives, and a disproportionally high number of clean-water resources and other support schemes such as good drainage and sanitation systems should be provided for farmers located in the core-urban.

Furthermore, if government seeks to make family and hired labour inputs more accessible to farm households to increase household production, it is recommended that incidence of transient diseases, especially malaria and other water-related diseases, should be controlled as indicated above, and improve the labour force base of farm households, allocate adequate arable land spaces for urban farming, and promote irrigation farming through the provision of water resources, among others. Also, urban farming in the city can be more productive and economically rewarding than it currently does if the Ministry of Agriculture intensifies irrigation farming through the provision of additional clean water resources for farmers, allocates adequate protected arable lands to urban farmers, and invests in research and development to promote the availability of improved seeds for farmers, among others.

5.5 Recommendations for future studies

One of the major limitations of this study is linked to limited financial ability to have had hired independent health experts to professionally examine and confirm cases of illnesses of farm household members, and instead, relied on self-reported cases of illnesses which may have caused problems of bias and endogeneity in model estimation. This study therefore recommends that future study into the health effects of wastewater use should ensure that cases of illness of farmers are determined more accurately by employing the services of independent health experts to confirm cases of reported diseases.

Also, this study used a cross-sectional data, which therefore limited findings and conclusions relating to the problem of agricultural wastewater use and farm households' costs of illness to the past 2016 farming season. This study consequently recommends for future research to investigate the problem of wastewater use and incidence and costs of illness using a pooled-data study, involving multiple visits of farm households, that analyzes both economic and non-economic health effects of agricultural wastewater use simultaneously over time and across farm households. This will ensure that findings are more informative and insightful for better understanding of the difference in how wastewater contributes to incidence and costs of illness overtime across farm households for better policymaking and technological development. Such a study should also estimate the net benefit of agricultural wastewater use by comparing the marginal effects of wastewater on financial burden of illness and farm income.

5.6 Final Conclusion

While there is a great deal of theoretical and conceptual discussions on the impacts of agricultural wastewater use on the economic burden of transient health shock conditions among urban farmers in particular, there is relatively paucity of well-documented empirical evidence. This study has however uncovered that unlike the phenomenon of a well-controlled direct agricultural raw wastewater use which has received important attention from policy-makers and international development agencies, the predominant unplanned indirect agricultural wastewater use in terms of irrigating with polluted surface water sources contribute significantly not only to the transmission and prevalence of severe transient health shocks, but also to weighing heavy economic burden in terms of healthcare payments and costs of compensating for reduced human capital in farm production and other wage income losses. Therefore, preventive healthcare policy options to reduce disease density and transmission will need to include complementary well-targeted arrangements to effectively regulate the more proliferated poorly designed and unsafe irrigation systems to safeguard the possibility of water-related, water-washed, and water-borne health shocks among the relatively poor farmers in the city.

REFERENCES

Addo, K. A., (2010). Urban and Peri-urban Agriculture in Developing Countries: Studies using Remote Sensing and *IN Situ* Methods. *Remote Sensing*, 2: 498-501.

Africa Progress Panel (APP) (2010). Raising Agricultural Productivity in Africa: Options for Action, and the Role of Subsidies. APP Policy Brief. www.africaprogresspanel.org.

Ajani, O. I. Y., and W. M. Ashagidigbi, (2008). Effect of malaria on rural households' farm income in Oyo State, Nigeria. *African Journal of Biomedical Research*, 11: 262-264.

Ajani, O. I. Y., and P. C. Ugwu, (2008). Impact of adverse health on agricultural productivity of farmers in Kainji Basin North-Central Nigeria using a stochastic production frontier approach. *Trends in Agriculture Economics*, 1 (1): 5-6.

Ambrose-Oji, B., (2009). Urban food systems and African indigenous vegetables: defining the spaces and places for African indigenous vegetables in urban and peri-urban agriculture. In: Shackleton, C. M., M. W. Pasquini, and A. W. Drescher, (eds). African indigenous vegetables in urban agriculture. UK: Earthscan publishers: 1-25.

Anderson D. R., D. J. Sweeney, and T. A. Williams, (2011). Statistics for business and economics (11 ed). USA, South-Western Cengage Learning: 310-330.

Anim, F. D. K., (2011). Factors Affecting Rural Household Farm Labour Supply in Farming Communities of South Africa. *J Hum Ecol*, 34(1): 23-28.

Antle, J. M., D. C. Cole, and C. C. Crissman, (1998). Further evidence on pesticides, productivity and farmer health: Potato production in Ecuador. *Agricultural economics*, 18: 199-207.

Asenso-Okyere, K., C. Chiang, P. Thangata, K. Andam, and D. A. Mekonnen, (2011). Understanding the interaction between farm labour productivity, and health and nutrition: a survey of the evidence. *Journal of Development and Agricultural Economics,* 3 (3): 83-85.

Ashraf, M. A., M. J. Maah, I. Yusoff, and K. Mehmood, (2010). Effects of Polluted Water Irrigation on Environment and Health of people in Jamber, District Kasur, Pakistan. *International Journal of Basic and Applied Sciences IJBAS-IJENS,* 10 (03): 31-48.

Audibert, M. and Etard, J. F., (1998). Impact of Schistosomiasis on rice output and farm inputs in Mali. *Journal of African Economies,* 7 (2): 195-199.

Audibert, M., J. F. Brun, J. Mathonnat, and M. C. Henry, (2011). Malaria, production and income of the producers of coffee and cocoa: an analysis from survey data in Côte d'voire. Malaria, coffee and cocoa production and income. *HAL archives-ouvertes*, 00557214:11-19. www.halshs.archives.uvertes.fr/halshs-00557214.

Bagamba, F., K. Burger, and A. Kuyvenhoven, (2007). Determinants of Smallholder Farmer Labour Allocation Decisions in Uganda. Paper presented at the 10th Seminar of the EAAE: France: 8-12.

Bartlett II, J. E., J. W. Kotrlik, and C. C. Higgins, (2001). Organizational Research: Determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*, 19 (1): 45.

Bedemo, A., K. Getnet, and B. Kassa, (2013a). Determinants of Labour Market Participation Choice of Farm Households in Rural Ethiopia: Multinomial Logit Analysis. *Journal of Economics and Sustainable Development,* 4(1): 133-138.

Bedmo, A., K. Getnet, B. Kassa, (2013b). Determinants of Household Demand for and Supply of Farm Labour in Rural Ethiopia. *Australian Journal of Labour Economics,* 16(3):351-367.

Bellwood-Howard, I., V. Haring, H. Karg, R. Roessler, J. Schlesinger, and M. Shakya, (2015). Characteristics of Urban and Peri-urban Agriculture in West Africa: Results of an Exploratory Survey Conducted in Tamale, Ghana, and Ouagadougou, Burkina Faso. International Water Management Institute Working Paper 163: Colombo, Sri Lanka: 1-24.

Bonfrer, I. and Gustafsson-Wright, E., (2016). Health shocks, coping strategies and foregone healthcare among agricultural households in Kenya. Global Public Health. *An International Journal for Research, Policy and Practice,*: 9-16.

Bradford, A., R. Brook, and C. S. Hunshal, (2003). Wastewater Irrigation in Hubli-Dharwad, India: Implications for Health and Livelihoods. *Environment and Urbanization,*15 (2): 158-168.

Byford, S., D. J. Torgerson, J. Raftery, (2000). Economic Note: Cost of Illness Studies. *BMJ,* 320: 1335.

Cameron A. C. and Trivedi, P. K., (2009). Microeconometrics using STATA. Texas, USA: A STATA Press Publication: 541-546.

Centre for Ecogenetics and Environmental Health, (2013). Fast facts about health risks of pesticides in food. School of Public Health, University of Washington. marhair@uw.edu.

CIA (2016a) Burkina Faso economy 2016. www.theodora.com/wfbcurrent/burkina_faso .(Retrieved July 15, 2016).

CIA (2016b) Burkina Faso people 2016. www.theodora.com/wfbcurrent/burkina_faso_people. (Retrieved July 15, 2016).

Coelli, T. J., D. S. P. Rao, C.J. O'Donnell, and G.E. Battese, (2005). An Introduction to Efficiency and Productivity Analysis (5th ed). USA: Springer Science and Business Media, Inc:11-20.

Combary, O. S., (2016). Impacts of health services on agricultural labour productivity of rural households in Burkina Faso. African Growth and Development Policy (AGRODEP) working paper 0023: 6-17.

Conly, G. N., (1975). The impact of malaria on economic development: a case study. *Pan American Health Organization*, (297), scientific publication: Washington D. C.

Dayo, T., (2014). African economic outlook: Burkina Faso 2014. AfDB, OECD, and UNDP: 2 - 4. www.africaneconomicoutlook.org. (Retrieved from the internet July 10, 2016).

De Neergaard, A., A. W. Drescher, and C. Kouamė, (2009). Urban and Peri-Urban agriculture in African cities. In: Shackleton, C. M., M. W. Pasquini, and A. W. Drescher, (eds). African indigenous vegetables in urban agriculture. UK: Earthscan Publishers: 47-59.

Egbetokun, O. A., S. Ajijola, B. T. Omonona, and M. A. Omidele, (2012). Farmers' Health and Technical Efficiency Iin Osun State, Nigeria. *National Journal of Food and Nutrition Science*, 1(1): 22-24.

Fattal, B., P. Yekutiel, and H. I. Shuval, (1986). Cholera outbreak in Jerusalem 1970 revisited: the case for transmission by wastewater irrigated vegetables. In: Goldsmith J. R., and Raton, B., (eds). Environmental Epidemiology: Epidemiological Investigation of Community Environmental Disease. CRC Press.

Food and Agriculture Organization (2014). Country Fact Sheet on Food and Agriculture Policy Trends: Burkina Faso. www.fao.org/economic/fapda.

Food and Agriculture Organization (FAO) (2007). Profitability and Sustainability of Urban and Peri-urban Agriculture. Agricultural Management, Marketing and Finance Occasional Paper 19. Rome: Italy: 1-15.

Food and Agriculture Organization (FAO), (2012). On-farm practices for the safe use of wastewater in urban and peri-urban horticulture: a training handbook for farmer field schools. Office of Knowledge exchange, Research and Extension: Italy: 13-29.

Gleick, P. H., (2000). The world's water 2000-2001: the biennial report on freshwater resources. US: Island Press.

Greene, W. H., (2003). Econometric Analysis (5th ed). USA, New Jersey: Pearson Education, Inc, Upper Saddle River: 378-424.

Grossman, M., (1972). On the concept of health capital and the demand for health. *The Journal of Political Economy,* 80 (2): 223-255.

Havelaar, A., U. J. Blumenthal, M. Strauss, D. Kay, and J. Bartram, (2001). Guidelines: the current position. In: Fewtrell, L. and Bartram, J. (eds) World Health Organization (WHO) water quality: guidelines, standards and health. UK, London: IWA Publishing: 18-42.

Hawkes, C., and Ruel, M., (2006). The Links between Agriculture and Health: An Intersectoral Opportunity to Improve the Health and Livelihoods of the Poor. *Policy and Practice,* 84(12): 984-987.

Heckman, J. (1979). Sample selection bias as a specification error, *Econometrica,* 47: 153-161.

Heckman, J., (2014). Introduction to a Theory of the Allocation of Time by Gary Becker. The Institute for the Study of Labour (IZA) Discussion Paper, 8424: 1-8.

Humphreys, B. R. and Lee, Y. S., (2009). Statistical modeling of consumers' participation in gambling markets and frequency of gambling. *Alberta Gaming Research Institute*: 2-5.

Institute for Health Metrics and Evaluation (2010). GDB Profile: Burkina Faso. www.healthmetricsandevaluation.org. (Retrieved August 4, 2016).

International Monetary Fund (IMF), (2014). Burkina Faso: Selected Issues. IMF Country Report, 14/230, Washington D.C: IMF Publication Services: 3-10.

International Water Management Institute (IWMI) (2006). Recycling realities: managing health risks to make wastewater an asset. Water Policy Briefing: International Water Management Institute and Global Water Partnership (GWP): 1-6.

Jeong, H., H. Kim, and T. Jang, (2016). Irrigation water quality standards for indirect wastewater reuse in agriculture: a contribution toward sustainable wastewater reuse in South Korea. *Water*, 8 (169): 1-9. www.mdpi.com/journal/water.

Joint Institute for Food Safety and Applied Nutrition (JIFSAN), (2010). Improving the safety and quality of fresh fruits and vegetables: a training manual for trainers. University of Maryland: 1-23.

Jiménez, B., P., Drechsel, D., Koné, A.Bahri, L. Raschid-Sally, and M. Qadir, (2010). Wastewater, sludge, and excreta use in developing countries: an overview. In: Drechsel, P., C. A. Scott, L. Raschid-Sally, M. Redwood, and A. Bahri, (eds). Wastewater irrigation and health: assessing and mitigating risk in low-income countries. UK and USA, Earthscan Publishing: International Water Management Institute (IWMI) and International Development Research Center: 4 – 27.

Jones, A.M. (2000). Health econometrics in handbook of health economics, 1A, Cyler, A. and Newhouse, J.: 23-39.

Kallaru, H., V. R. Nagasubramanian, H. P. Balakrishnan, K. Gopal, and T. Palani, (2015). Impact of severity of the disease on cost of illness and quality of life of patients with chronic obstructive pulmonary diseases. *Journal of Young Pharmasists,* 7 (2): 108 – 111.

Kanyoka, P. and Eshtawi, T. (2012). Analyzing the trade-offs of wastewater reuse in agriculture: an analytical framework. Interdisciplinary term paper, ZEF Doctoral studies program, Centre for development Research: University of Bonn: 1-11 (Unpublished).

Kapteyn, A. and Fiebig, D. G. (1981). When are two-stage and three-stage least squares estimators identical? *Economics Letters*, 8, USA, North-Holland Publishing Company.

Keraita, B., Jiménez, B. and Drechsel, P. (2008). Extent and implications of agricultural reuse of untreated, partly treated and diluted wastewater in developing countries. *Agriculture, Veterinary Science, Nutrition and Natural Resources*, Vol. 3 (58), pp 15.

Kinané, M. L., A. Tougma, D. Ouedraogo, and M. Sonou, (2008). Urban Farmers’ Irrigation Practices in Burkina Faso. www.ruaf.org.

Knepper, E. T., (2002). Factors Affecting the Use of Fertilizer by Small and Medium-sized Farming Households in Zambia, 1997-2000. Michigan State University: 93-96.

Kpoda, N. W., A. Oueda, Y. S. C. Somė, G. Cissė, A. H. Maïga, and G. B. Kabrė (2015). Physicochemical and parasitological quality of vegetables irrigation water in Ouagadougou city, Burkina-Faso. *African Journal of Microbiology Research,* 9 (5): 307-317. www.academicjournals.org/AJMR.

Kumar, P., S. Mittal, and M. Hossain, (2008). Agricultural Growth Accounting and Total Factor Productivity in South Asia: A Review and Policy Implications. *Agricultural Economics Research Review,* 21: 145-172.

Larochelle, C., and Dalton, T. J., (2006). Transient Health Shocks and Agricultural Labour Demand in Ric-Producing Households in Mali. A paper presented at the International Association of Agricultural Economists Conference, Gold Coast Australia: 1-13.

Larson, B., S. Asuming-Brempong, D. Sarpong, H. Anim-Somuah, and S. Rosen, (2005). Household health and cocoa production: A baseline survey of smallholder farming households in Western Region of Ghana. Health and Development Discussion Paper, No. 6, Center for International Health and Development, Boston University School of Public Health: USA, pp. 18-24.

Maddala, G. S. (1983). Limited-dependent and qualitative variables in econometrics. Cambridge University Press: UK, pp149, 231-233.

Maumbe, B. M., and Swinton, S. M., (2002). Hidden Health Costs of Pesticide Use in Zimbabwe's Smallholder Cotton. Selected paper, American Agricultural Economics Association Annual Meeting:Long Beach: CA, PP 1-15.

Melgarejo, L. M. (2011) Determinants of health care expenditure: the Colombian case. *Apuntes del cenes,* 30 (52): 87-102.

Mondal, S., B. Kanjilal, D. H. Peters, and H. Lucas, (2010). Catastrophic out-of-pocket payment for health care and its impact on households:

experience from West Bengal, India. Future Health Systems: Innovations for equity: 1-20.

Naré, R. W. A., P. W. Savadogo, Z. Gnankambary, H. B. Nacro, and M. P. Sedogo, (2015). Analyzing Risks Related to the Use of Pesticides in Vegetable Gardens in Burkina Faso. *Agriculture, Forestry and Fisheries*, 4(4):165-172.

Nitiema, L. W., Boubacar, S., Dramane, Z., Kabore, A., Noel, P. J., Traore, A. S. and Dianou, D. (2013). Microbial quality of wastewater used in urban truck farming and health risks issues in developing countries: case study of Ouagadougou in Burkina Faso. *Journal of Environmental Protection:* 575-584.

Norton, G. W., J. Alwang, and W. A. Masters, (2010). Economics of agricultural development: World food systems and resource use, (2nd ed). Routledge Taylor and Francis Group: USA: 87-112.

Nur, E. T. and Mahran, H. A. (1988). The effect of health on agricultural labour supply: a theoretical and empirical investigation in economics, health and tropical diseases. School of Economics, Univerity of the Phillipines: Manila.

O'Donnell, O., E. Van Doorslaer, R. P. Rannan-Eliya, A. Somanathan, C. C. Garg, P. Hanvoravongchai, M. N. Huq, A. Karan, G. M. Leung, K. Tin, and C. Vasavid, (2005). Explaining the incidence of catastrophic expenditures on health care: comparative evidence from Asia. EQUITAP Project-Working Paper No. 5, pp. 1-25.

Odoh, V. T. and Nduka, E. K. (2014). Public healthcare expenditure in Nigeria: civilian versus military regimes. *Innovare Journal of Social Sciences*, 2 (3): 1-4.

Onadja, Y., S. Bignami, C. Rossier, and M.V. Zunzunegui, (2013). The Components of Self-rated Health among Adults in Ouagadougou, Burkina Faso. *Population Health Metrics,* Open Access: 1-12.

Onuche, U., H. I. Opaluwa, and M. H. Edoka, (2014). Ill-health and agricultural production: evidence from Kogi state of Nigeria. *African Scholarly*

Science Communications Trust, 14 (1), peer reviewed by African Journal of Food, Agriculture, Nutrition and Development (ajfand): 8497-8498.

Osei-Akoto, I., A. Clement, and O. R. Darko, (2013). The effect of health shocks on agricultural productivity evidence from Ghana. *International Journal of Agricultural Policy and Research*, 1 (3): 071-075.

Oyinpreye, A. T. and Moses, K. T. (2014). Determinants of out-of-pocket healthcare expenditure in the South-South geographical zone of Niegria. *International Journal of Economics, Finance and Management*, 3 (6): 2307-2466.

Reardon, T., V. Kelly, E. Crawford, T. Jayne, K. Savadogo, and D. Clay, (1997). Determinants of Farm Productivity in Africa: A Synthesis of Four Case Studies. Sustainable Development Publication Series, Technical Paper No. 75: AMEX International, Inc.: 1-8.

Rice, D. P., (1967). Estimating the Cost of Illness. *A.J.P.H.*, 57(3): 424-430.

Rossier, C., Soura, A., Baya, B., Compaoré, G., Dabiré, B., Dos Santos, S., Duthé, G., Gnoumou, B., Kobiané, J. F., Kouanda, S., Lankoandé, B., Legrand, T., Mbacke, C., Millogo, R., Mondain, N., Montgomery, M., Nikiema, A., Ouili, I, Pison, G., Randall, S., Sangli, G., Schoumaker, B. and Zourkaleini, Y. (2012) Profile: the Ouagadougou health and demographic surveillance system. *International Journal of Epidemiology*, Oxford University Press: 4.

Sauerborn, R., A. Nougtara, M. Hien, and H. J. Diesfeld, (1994). Why season matters: household costs of illness in Burkina Faso. Harvard Institute for International Development: Harvard University, Development Discussion Paper No. 494: 1 – 14.

Scicchitano, J., and Whitlock, R., (2002). Quantifying the Effects of HIV/AIDS on Agricultural Production: A Guide from Rural Burkina Faso. Danish International Development Agency Conference, Barcelona.

Shuval, H. I. (1990). Wastewater irrigation in developing countries: health effects and technical solutions. World Bank Technical Paper No. 51: UNDP-World Bank Water and Sanitation Program.

Simonsson, L., (2005). Vulnerability Profile of Burkina Faso. Stockholm Environment Institute (SEI): UK:1-13.

Singh, I., L. Squire, J. Strauss, (1986). The Basic Model: Theory, Empirical Results, and Policy Conclusions, in Singh, I., L. Squire, J. Strauss, (eds), Agricultural Household Models: Extensions, Applications, and Policy. A World Bank Research Publication: London: The John Hopkins University Press, pp1-25.

Suhrcke, M., Nugent, R. A., Stuckler, D. and Rocco, L. (2006). Chronic disease: an economic perspective. Oxford Health Alliance: London, pp 17-28.

Tarricone, R. (2006). Cost-of-illness analysis: what room in health economics? Health policy, *ELSEVIER*, *Science direct*: 51-61.

Thavorncharoensap, M. (2014). Assessing cost of illness related to tobacco. Health International and Technology Assessment Program (HITAP) and Mahidol University: Thailand, pp 21.

The two-way link between agriculture and health, www.siteresources.worldbank.org (Retrieved from the internet on July, 2016).

Todaro, M. P. and Smith, S. C. (2012). Economic development, (11th ed). Pearson Addison-Wesley publications: USA: 359-404, 416-465.

Traore, O., and Kone, D., (2009). Urban Agriculture as Alternative Livelihood Strategy in Burkina Faso. ENERA Features, Eth Zürich.

Traorė, O., O. Nyholm, A. Siitonen, I. J. O. Bonkoungou, A. S. Traorė, N. Barro, and K. Haukka, (2015). Prevalence and diversity of *Salmonella enterica* in water, fish, and lettuce in Ouagadougou, Burkina Faso. *BMC Microbiology*, pp 1-6.

Ulimwengu, J. M. (2009). Farmer's health status, agricultural efficiency, and poverty in rural Ethiopia: a stochastic production frontier approach. International Food Policy Research Institute (IFPRI) discussion paper 00868, Knowledge Capacity and Innovation Division, pp 7-22.

United Nations Development Programme (UNDP) (1996). Urban agriculture: food, jobs and sustainable cities. UNDP Publication series for Habitat II, vol. 1, New York.

Uyttendaele, M., L. A. Jaykus, P. Amoah, A. Chiodini, D. Cunlife, L. Jacxsens, K. Holvoet, L. Korsten, M. Lau, P. McClure, G. Medema, I. Sampers, and P. R. Jasti, (2015). Microbial hazards in irrigation water: standards, norms, and testing to manage use of water in fresh produce primary production. *Comprehensive Reviews in Food Science and Food Safety*, Vol. 14: Institute of Food Technologists, pp. 336 – 343.

Vance, C. and Buchheim, S. (2005). On the application of Heckman's sample selection model to travel survey data: some practical guidelines. Association for European Transport and Contributors: Germany, pp3-5.

Waithaka, M. M., P. K., Thornton, K. D. Shepherd, and N. N. Ndiwa, (2007). Factors Affecting the Use of Fertilizers and Manure by Smallholders: the case of Vihiga, Western Kenya. *Nutr Cyel Agroecosyst*, 78: 211-224.

Wooldridge, J. M. (2013). Introductory econometrics: a modern approach (5th Ed). USA: South-Western Cengage Learning: 603-608.

World Health Organization (WHO) (2001). Water quality: guidelines, standards, and health. Edited by Lorna Fewtrell and Jamie Bartram. IWA Publishing, London: UK: 22-25.

World Health Organization (WHO) (2006). WHO guidelines for the safe use of wastewater, excreta, and greywater. Vol. 2, Wastewater use in agriculture, WHO: Geneva.

World Health Organization (WHO) (2009). National health accounts: Burkina Faso. http://www.who.int/nha/country/bfa/en/.

World Health Organization (WHO) (2014). Non-communicable diseases country profile: Burkina Faso.

Appendix A (Questionnaire)

This information should be read to the interviewee:

Hello, my name is Abdulai Mohammed. I am a research student from the University for Development Studies in the Department of Agricultural and Resource Economics in Ghana. I am doing a research into the relationship between irrigation water and health of farmers. The research project is conducted as part of the projects of GlobE-UrbanFood^{Plus} (UFP), an interdisciplinary research partnership of African Universities, including University for Development Studies, and other West African, German and International Research Institutes such as International Water Management Institute (IWMI) to provide evidence-based solutions to sustainably manage water and land resources for food security, people's livelihoods, and the environment, and as well develop scalable agricultural water management solutions that have a tangible impact on poverty reduction and ecosystem heath in West African cities. This research is being conducted in Ouagadougou to compare its results with results already obtained of similar studies done in other partner West African countries such as Ghana, Ivory Coast, and Mali.

In the frame of this research project, I would ask questions relating to farmers' health and the costs related to the treatment of diseases. Your knowledge is key for understanding the situation. The conversation will last about one hour, and there are no 'right' or 'right' answers to the questions I would be asking you. The information you will provide would remain confidential, and your name will never be mentioned in any report or publications.

Your participation will help government and development partners to improve irrigation farming that will contribute to improving farmers' health situation and the financial burden associated with diseases.

I would like to know if you have questions to ask me.

Are you willing to participate? 1. Yes 2. No

Section A: GENERAL INFORMATION

GPS RECORD OF THE FARM ________________________/______________________/

Name of Interviewer: ____ Date of Interview_______

SOCIO-ECONOMIC AND DEMOGRAPHIC CHARACTERISTICS OF HOUSEHOLDS

1. **What is your name?** _
2. **What is your position in the household?** [ ] Household head [ ]Spouse [ ] Others specify _

3. Which ethnic group do you belong to?	
Peul	
Lobi	
Bobo	
Senofo	
Gurunsi	
Mossi	
Other…	

4. What is your religion?	
Traditional	
Christian	
Muslim	
Other…	

5. What is your marital status?	
Married	
Single	
Divorced	
Other…	

on B: Household Composition

With whom do you live together, take meals together and share financial resources within your household?

Name	Relationship to interviewee	Age	Sex M/F	Highest level of education	Education in years	Working on own farm (hrs./week)	Other income sources [code 3 + (hrs./week)]		

Code 2:
0=none
1= can read and write but never went to formal school
2=primary (1-6)
3=junior (7-10)
4=secondary (11-13)l
5=tertiary

Code 3:
1daily wage labourer
2=salaried employment
3= petty trading
4= craft (women/men (specify)
5=other (taxi driver, own shop etc.)
6=Transfer income (gov. grant or pension
7=student

Please estimate your family's farming season's cash income

Own Farm Product	No. of Harvests	Income per H	Income per season (CFA)
Total			

Daily wage labour	Earnings per	Days per week	Income per week (CFA)
Total			

Petty Trading	Earnings per day	Days per week	Income per week (CFA)
Total			

Source		Amount (CFA)	
salaried job			
Craft			
Other			
Remittance income			
Pension or gov. Grant			
Total			

3. Do you have other fields?	Yes	No
If yes, where else do you grow crops?	Tick	

Backyard	
Open space field	
Rural area	
Other…	

4. How many beds do you have on your field?	
How many beds do you have on your other fields?	
Total number of beds	

5. Do you sell more than 50 % of your yield?	Yes	No

Section C: Households living situation

1.		Rarely	Sometimes	Often	Never
1	In the last farming season, was there ever no food to eat of any kind in your household because of lack of resources?				
1.1	In the last farming season did you or any household member go to sleep at night hungry because there was not enough food?				
1.2	In the last farming season did you or any household member go a whole day and night without eating anything because there was not enough food?				

2. **What is your source of drinking water?**		
Piped water		
Shallow well		
Deep well		
Dugout		
Rainwater		
River/Lake		
Other…		
If well, is the water source covered?	Yes	No

3. Do you treat your drinking water?	Yes	No
If yes, how do you treat your drinking water?		
Filtration		
Boiling		
Other…		

4. What water source do you use for household activities like cleaning your dishes and to wash up?	
Piped water	
Shallow well	
Deep well	
Dugout	
Rainwater	
River/Lake	
Other…	

5. Do you always have enough water for these activities?	Yes	No
6. Please estimate your monthly water bill	**wet**	
	dry	

7. Do you and your family eat raw vegetables?	Yes	No
If yes, how do you clean your vegetables?	Tick	
Water only		
Salt Water		
Jarvel Water		
Vinegar Water		
Other…		

8. What toilet facilities are you and your household members using?

Toilet connected to sewage system

Pit Latrine

Public toilet

Other…

No toilet

9. Do you irrigate fields you and your household members work on?	**Yes**	**No**
If yes, please tell me your 3 most important sources of water for irrigation?	Tick	
Rainwater		
River		
Pipe water		
Pond		
Dugout		
Well		
Others		

10. Do you apply fertilizer on your fields?	**Yes**	**No**
If yes, which type(s) do you use and how much did you pay for it?	CFA *[Expenditure]*	
Chemical fertilizer		
Manure		
Pesticides		

11. Do you apply pesticides on your fields?	**Yes**	**No**
If yes, how do you apply them?	Tick	
Spraying machine (knapsack)		
Manual		
Others		

12. Do you hire people to work on your field?	**Yes**	**No**
If yes, how much do you pay them?	CFA *[Expenditure]*	
Planting		
Watering		
Harvesting		
Ploughing/weeding		

13. How much have you spent on seeds …………………………………….

Section D: general information on farming associations etc.

Do you belong to any famer-based organization (FBO)?	**Yes**	**No**

If yes, how do you benefit from the group?	
Facilitate access to credit	
Source of market (price) information	
Source of stronger bargaining power	
Source of extension services	
Facilitate new technology adoption	
Others	

Do you have access to credit anytime you need it?	**Yes**	**No**	
If yes, where do you apply the credit?	Tick		
Farm			
Household non-farm activities			
Which sources do you access credit?	Tick		Amount CFA
Family and friends			
Formal banks			
Money lenders			
Non-bank financial institutions			
Farmer-based organization (FBO)			
NGO			

Do you have access to extension services in the last farming season?	**Yes**	**No**
If yes, how many extension contacts did you have in the last farming season?		
Which sources do you access extension services?	Tick	
Colleague farmers		

Agric officers	
Farmer-based organizations (FBOs)	
Radio/television	
NGOs	
Others	

Do you have access to health information?	**Yes**	**No**
If yes, how many contacts did you have with health information personnel in the last farming season?		
Which sources do you access health information from?	Tick	
Hospitals/clinics		
Farmer-based organizations (FBOs)		
Radio/television		
NGOs		

Section E: general health costs

Do you pay for health insurance and your family	**Yes**	**No**
If yes, please specify the annual amount of money		

What measures do you and your household members take to prevent malaria?	**Tick the appropriate responses**
Sleeping regularly under mosquito nets	
Smelting mosquito repellent	
Use of mosquito coils	
Wearing of long dresses	
Others	
None of these	

Do you and your household members use protective clothes like boots while working on the field?	**Yes**	**No**
If yes, which ones are you using?		
Wearing of protective booths		
Wearing of gloves		
Wearing of protective cloths		
Wearing of protective mask		
Others		

Does anyone in your household need drugs for long-term therapy?	**Yes**	**No**

If yes, please specify the annual amount of money		

Have you or any of your household members been sick in the last four weeks?	**Yes**	**No**
If no, go to Section H (Last Section)		

	Section F: Direct Costs	**ID & Name**	**ID & Name**	**ID & Name**	**ID & Name**
	Which family members have been ill or injured in the last four weeks?				
	How many days in the last four weeks have/has (…) been ill?				
	How often has (…) been sick in the last four weeks?				
	Did you/(…) show symptoms like:				
	Fever				
	Skin irritation				
	Diarrhea				
	Nausea/Vomiting				
	Problems of the respiratory system				
	other …………….				
	Can you tell me the diagnosis of your/(…) disease?				
	Did you/(…) seek any treatment for this health problem including self treatment? (if no go to Section G)				
3	Did (….) go to the pharmacy for treatment? (if no ->4)				

Did (…) buy any drugs, herbs and/or bandages?				
How much did this cost?				
How did (…) reach the pharmacy?				
by foot				
Bicycle				
Taxi				
private vehicle				
other…….				

	Did (…) spend any money on travelling there?				
	Please tell me the amount				
	How did (…) get back home?				
	by foot				
	Bicycle				
	Taxi				
	private vehicle				
	other…….				
	Did this cost anything?				
	Can you specify the amount of money?				
3.6	Did (…) have additional travel expenses for an attendant?				

	Please tell me the amount of the Expenses				
	Did (….) visit a traditional healer for treatment? (if no->5)				
	How much did this/these visit(s) cost you altogether?				
	Did (…) pay for the consultation?				
	How much did this cost?				
	Did (….) spend any money on drugs, herbs and/or bandages?				
	How much did (…) spend for that purpose?				
	How did (…) reach the traditional healer?				
	by foot				
	Bicycle				
	Taxi				
	private vehicle				
	other…….				
	Did (….) spend any money for travelling there?				
	How much did this cost?				
4.6	How did (…) get home?				
	by foot				

	Bicycle				
	Taxi				
	private vehicle				
	other…….				
	Did (…) spend any money on travelling home?				
	How much did (…..) spend?				
	Did (….)have additional travel expenses for an attendant?				
	Please tell me the amount of the expenses				
	Did (…) visit a local doctor? (if no->6)				
	How much did this/these visit(s) cost you altogether?				
	Did (…) pay for the consultation?				
	How much did this cost?				
	Did (….) spend any money on diagnostic tests?				
	How much did this cost?				
5.4	Did (…) spend money on drugs and bandages?				
	How much did (…) spend for that purpose?				
5.5	How did (…) reach the doctor?				

	by foot				
	Bicycle				
	Taxi				
	private vehicle				
	other…….				
	Did (….) spend any money for travelling there?				
	How much did this cost?				
	How did (…) get home?				
	by foot				
	Bicycle				
	Taxi				
	private vehicle				
	other…….				
	Did (…) spend any money on travelling home?				
	How much did (…..) spend?				
	Did (….) have additional travel and other expenses for an attendant?				
	Please tell me the amount				
	Did any of you visit a hospital for treatment?(if no->7)				
6.1	How much did this/these visit(s) cost you altogether?				

Did you spend any money as a registration fee for the particular treatment center?				
How much money did you have to pay?				
Did you spend any money as a bed/ cabin rent for accommodation of that hospital?				
Please tell me the amount of money your family had to pay for that				
Did you have to pay for drugs and bandages etc. you/(…) received during this stay?				
Can you specify the amount of money you spend on drugs and bandages?				
Did you spend money on drugs for post treatment at home?				
How much did you spend?				
Did your family have to pay for food during the hospital stay?				
How much did this cost you?				

	How did (….) reach the hospital?				
	by foot				
	Bicycle				
	Taxi				
	private vehicle				
	other…….				
	Did you spend any money on travelling to the hospital?				
	How much did you pay for travelling purposes for (….)?				
	How did (….) get back home?				
	by foot				
	Bicycle				
	Taxi				
	private vehicle				
	other…….				
	Did (…..) spend any money on travelling home?				
	How much did (…..) spend?				
	Did (….) have additional travel expenses for an attendant?				
	How much did this cost you?				
7	Did a doctor, a healer or a nurse come to (…) for treatment?				
7.1	How much did this service cost?				

Did (…) buy any drugs, herbs and/or bandages?				
How much did (…) pay for that?				

	Section G: Indirect costs:				
	How many days has (…) been absent from work due to the illness?				
	Did he/she have any income loss from a paid job?				
	How much income did this person lose?				
	Did this illness prevent him/her from fulfilling his/her daily unpaid duties like fieldwork, household etc.?				
	Do you think the days he/she lost affected his/her harvest negatively? Yes ☐ No ☐				
	Did you lose earnings because of that?				
	Please estimate the loss of income				
	Did another family member take over?				
5	Did this person face any income loss due to that?				
	How much did this person lose?				

Has a household member been an attendant or caretaker for (….) during the illness?				
Did he/she face any income losses?				
How much did this person lose?				
Please estimate the overall costs of this/these illnesses				

on H: Illness for last farming season (6 months)

you or any of your household members sick in the last farming season? [last six hs]	**Yes**	**No**
, how many members have been sick?		
How many days has (…) been sick?	Days	Farm hours lost

APPENDIX B (STATA REGRESSION RESULTS)