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IMPACT OF IMPROVED COOK STOVES ADOPTION ON DEFORESTATION, SOCIO-ECONOMIC AND HEALTH STATUS OF SELECTED COMMUNITIES IN THE OTI AND VOLTA REGIONS OF GHANA.

THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL IN ENVIRONMENTAL SCIENCE DEGREE

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DECLARATION

I hereby declare that I have under supervision, undertaken this study herein submitted for the award of a Master of Philosophy in Environmental Science. This study is my own production and has not been presented anywhere for another degree whatsoever. The thesis report has been prepared and presented in accordance with academic rules and ethical conduct. I have fully cited, referenced and acknowledged all materials and results that are not original to this work.

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DEDICATION

I dedicate this work to my family and all the respondents from the various communities who took time off their busy schedules to take part in this research.

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ABSTRACT

To reduce deforestation along the Volta Lake and evapotranspiration of water in the Akosombo reservoir, the Volta River Authority (VRA) embarked on a reforestation project. However, the reforestation project was thwarted by the over reliance on trees for firewood usage in Traditional Three stone stoves (T3SS) in communities around the Volta Lake. The VRA then introduced Improved Cook stoves (ICS) which was believed to consume less firewood in communities along the Volta Lake in the Biakoye, South and North Dayi districts and Kpando municipality. This study sought to ascertain the benefits of the ICS and to understand why adoption of the ICS was still low after three years of introducing the ICS, thus, affecting the forest cover in the reforested areas. Using a mixed-method strategy to conduct a cross-sectional study with 184 respondents and twenty (20) stoves for Controlled Cooking Test (CCT) following Bailis (2007) guidelines, the study revealed through a Chi-square analysis of 0% likelihood of developing self-reported health issues when using the ICS and 87% likelihood of developing self-reported health issues when using the 'T3SS'. In addition, a T-test on CCT results revealed that the ICS reduced 58% of CO (M=0.75, SD=1.39) and 50% of $PM_{2.5}$ (M=0.57, SD =1.68) when compared to the 'T3SS' CO (M= 1.79, SD=1.55) and $PM_{2.5}$ (M= 1.13, SD= 1.89) and the result was statistically significant. Further, even though a T-test shows that the ICS saved 50g (0.05kg) of firewood during the CCT, it was not statistically significant. Also, duration of cooking 2604g (2.604kg) of "Banku" on the ICS took longer than cooking on the 'T3SS' with 30% of time saved by the 'T3SS'. Again, 59% of ICS users did not use their ICS exclusively (stove stacking), but rather complement it with 'T3SS' for commercial activities (smoking or frying fish, process oil or gari). In addition, analysis of GIS and remote sensing data revealed sparse vegetation growth of reforested area as the dependence on firewood for energy was still high. Through the lenses of theory of energy ladder and theory of diffusion, the study revealed that the cost of the ICS, other uses of T3SS and limitations associated with the ICS usage as barriers affecting adoption. It was recommended that the ICS should be reengineered to correct the limitations in using the ICS to accommodate the cultural practices in the study areas. Further, education and effective monitoring of the use of ICS should be increased. Finally, the provision of alternative sources of livelihood should also be considered to break the economic barrier influencing the adoption of ICS.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND ACRONYMS

CCT	Controlled Cooking Test
CDM	Clean Development Mechanism
CFU	Carbon Finance Unit (World Bank)
CO	Carbon Monoxide
CSIR	Council for Scientific and Industrial Research
ECOWAS	Economic Community of West African States
GACC	Global Alliance for Clean Cook Stoves
GHG	Green House Gases
GIS	Geographic Information Systems
GPS	Global Positioning System
GSS	Ghana Statistical Service
HEP	Hydro Electric Power
IAP	Indoor Air Pollution
ICS	Improved Cook stoves
ISO	International Organization Standards
PM	Particulate Matter
REDD+	Reducing emissions from deforestation and forest degradation
SE4ALL	United Nations Sustainable Energy for All
SNV	Netherlands Development Organization
T3SS	Traditional Three Stone Stove
VRA	Volta River Authority
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background

About half of the world's population relies on fuel from biomass to satisfy their energy needs for warming, cooking, boiling water and lighting (Martin *et al*., 2011). In sub-Saharan Africa, about 90% of individuals depend on biomass for their cooking needs (Rehfuess, *et al.*, 2014; International Energy Agency, 2010).

In Ghana, fuel from wood constitute two thirds of energy consumed (Energy Commission, 2013).Though the chunk of the firewood used is dead wood picked from forests, woodlots and farms (Hansen *et al.* 2009), it is estimated that 2.5 billion persons, particularly in rural areas depend on biomass to satisfy their energy requirements. These numbers of persons are likely to remain unchanged by 2030 according to International Energy Agency (2013) if no action is taken to address it. The high dependence on biomass for energy requirement contributes to deforestation, which in turn contributes to the primary sources of emitting greenhouse gases in several developing countries and increasing evaporation rates, in Sub-Saharan Africa (Hosonuma *et al.*, 2012). The cutting down of trees is hard to quantify, even with latest devices like remote sensing (Herold *et al.*, 2011). However, strategies to diminish wood consumption have the probability to concurrently mitigate climate change issues, conserve forests and improve the livelihoods of humans. Nevertheless, energy from wood is vital to sustain livelihoods in sub-Saharan countries because they are considered poor (Skutsch *et al.*, 2011).

In Ghana, biomass is commonly converted into heat energy in the Traditional Three Stone Stoves ('T3SS'). The 'T3SS' consists of three stones or bricks that are positioned around a fire in a triangular formation. A cooking pot is placed on the stones and firewood is added between the stones and lighted. It can be "*adjusted to fit any pot size and easily controlled by adjusting the firewood supply"* (Gill, 1987).

Burning of biomass fuels in T3SS produces great levels of chemicals that have damaging impacts on the environment and human health, largely through the emission of Particulate Matter (PM) and Carbon Monoxide (CO) in inefficient cook stoves (Fullerton *et al.*, 2008). These levels are beyond the United States Environmental Protection Agency's National Ambient Air Quality Standards (Environmental Protection Agency, 2005). Household air pollution is the key cause of 1.6 million premature deaths globally per year because of ineffective burning of biomass (Johnson *et al.*, 2010; Smith *et al.*, 2004). Women and children are highly vulnerable and affected because they are exposed to dangerous health pollutants, (carcinogenic compounds, CO and NOx) and fine particles in the process of performing their cooking activities (Naeher *et al.*, 2007; Díaz *et al.*, 2007). Children in particular are at the peril of paraffin poisoning (Clancy *et al*., 2013). Burns and scalding are some other health risk from the use of 'T3SS' that are inadequately reported. Puzollo *et al.* (2013) estimated that 'T3SS' and biomass fuels contributed to global carbon monoxide emission, black carbon and other pollutants, which contributes to global climate change. This increases evaporation rates of water bodies.

Due to the environmental and health hazards that the 'T3SS' creates, governments, multilateral donors, Non-Governmental Organizations and the private sector have advocated for the Improved Cook Stoves (Urmee &Gyamfi, 2014). Improved Cook Stove was highlighted in media when the then US Secretary of State, Hillary Clinton, pronounced the Global Alliance for Clean Cook Stoves in 2010 (Keese *et al.,* 2017). Improved Cook Stove is a cook stove that burns biomass, with improved heating, fuel-efficiency and reduced indoor air pollution (Urmee & Gyamfi, 2014).

Further emphasis was laid on the triple benefits from ICS on health, women and the environment in its operation. The ICS was intended to alleviate health status resulting from exposure to excessive CO, PM and other harmful gases from firewood burning and intensifies the effectiveness of cooking methods by reducing the quantity of firewood needed. It also helps in reducing household's expenditure on fuel wood. Studies have shown the link between firewood gathering and deforestation between areas (Arnold *et al.,* 2006). Likewise, efficient use of ICS may significantly decrease cutting down of tress in places that predominantly use firewood (Bensch & Peters, 2012). Research has proven the existence of a simultaneous use of land for logging, farming, and wood collection (Staton & Hardings, 1998). This makes it difficult to document the cause of deforestation due to uncertainty in the end use of the woods gathered by families.

According to Lewis & Pattanayak (2012), empirical (quantitative) studies on adoption of ICS remain narrow, scattered and barely comparable due to difference in ICS designs and fuel types (Chaigneau, 2013). Available research entirely focused on the interrelated health impacts (Smith-Sivertsen *et al.,* 2009). Some reports on Improved cook stoves were published on quality of indoor air in China (Mestl *et al.,* 2007), Zimbabwe (Rumchev *et al.,* 2007), Bangladesh (Dasgupta *et al.* 2006), and India (Balakrishnan *et al.* 2004). McKay & Aryeetey (2007) explored the role of social and environmental elements in modeling difference in contact to smoke from firewood in the Northern parts of Ghana. Existing statistics that relates the effect of firewood consumption to direct emission levels are scanty (Armah *et al.,* 2015). Further, some studies documented the use of ICS saves time spent on firewood collection and cooking (Critchley *et al,* 2015; Otieno *et al.,* 2014). However, this assumption is yet to be supported by empirical evidence from cook stove intervention in the selected communities.

This research is demand driven to help VRA attain its goal in reducing GHG emission, help communities protect the reforested areas along the Volta Lake while avoiding long-term respiratory diseases, increase number of trees to protect volume of water in the Volta Lake reservoir, which will ensure sustainable Hydropower generation and qualify for carbon credit payment on the global scale.

1.2 Problem Statement

Climate change is contributing to the reduced water levels in the Akosombo dam due to increasing evaporation and deforestation among other factors, thereby affecting the Akosombo reservoir and Hydropower generation (Gyau-Boakye, 2001). Big hydropower dams and their reservoirs themselves, emits substantial amount of greenhouse gases i.e. carbon dioxide, methane and nitrous oxide from decay of organic matter (International Rivers, 2013). No doubt, it was concluded in the study of International Rivers (2013), that tropical dams could be dirtier than fossil fuel in terms of releasing GHG emission. Due to the net GHG contribution of dams, the Volta River Authority (VRA) has initiated projects to minimize carbon and other GHG emissions to benefit from emission credits at the global level (VRA, 2018).

The VRA embarked on an intervention known as the reforestation project to increase number of trees around the Lake. The increase in vegetation was to reduce evapotranspiration and protect water volumes from the Lake especially the gorge area to ensure sustainable power generation.

Under this project, forest cover was established along the banks of the Volta Lake and some of its tributaries. Human activities such as (felling of trees, sand winning, drawdown farming, cattle grazing and charcoal burning within the catchment of the Lake were consequently outlawed (VRA, 2018). The ultimate purpose of the reforestation project is to increase the sinks for emissions from the Dam, reduce evapotranspiration and keep water volumes high for power generation. Further, all investments and activities were to safeguard optimization of social, economic and environmental effect to promote sustainable development.

However, the construction of Akosombo Dam for Hydro Electric Power generation in Ghana have had a long-term environmental, health, economic, social and physical impacts on the population living along the Volta Lake. Some of these impacts were however not envisaged and was felt in places quite remote from the immediate project site (Gyau-Boakye, 2001). Consequently, extreme poverty of households in the riparian communities along the Volta Lake created over reliance on trees for 'T3SS' for their cooking activities especially, as well as poorly maintained "Chorkor ovens" (ovens locally made from abandoned barrels) for fish smoking (Keese *et al.*, 2017). It is established that Traditional Three Stone Stove consumes a lot of firewood (VRA 2016), thus, encouraging higher levels of cutting trees and affecting the reforestation project.

To curb this menace and protect the reforested areas, the VRA collaborated with the Fisheries Commission in Asuogyaman Zonal Office, and gave out fuel-efficient and energy saving cook stoves known as "Climate Smart Stoves" (CSS) to 10 riparian communities along the Volta Lake (VRA, 2016). Several authors such as Keese *et al.* (2017); Bielecki & Wingenbach, (2014); Bensch & Peters, (2013) have referred to them as Improved Cook Stoves (ICS) hence ICS and CSS are used interchangeably in this research.

It is believed that ICS will reduce emission of greenhouse gases (GHGs) form the dam, mitigate climate change impacts and reduce forest degradation through reduced consumption of firewood as fuel for 'T3SS' (VRA, 2016). The Council for Scientific and Industrial Research (CSIR), Ghana evaluated the ICS in Adjena Dornor, a community in Akosombo and established that, it was more efficient than the 'T3SS' in terms of fuel saving and food processing rate as it also met the Energizing Development Programme requirement i.e. 40% fuel saving (CSIR, 2017). The

Energizing Development Programme is a multi-donor partnership that promotes sustainable access to modern energy for households in Africa, Asia and Latin America (Keese *et al.*, 2017; Bielecki & Wingenbach, 2014).

Three years after introducing Hundred (100) ICS, the VRA intends to deploy an additional two hundred pieces in order to reduce deforestation through the consumption of less biomass to gain carbon credit. However, reports have indicated slow rate of adoption of ICS and continuous use of 'T3SS' by the people, posing a danger to water conservation and climate change mitigation in the catchment area of the Lake.

This study examined the reasons behind the apparent slow rate of ICS adoption and its impact on deforestation. The study further assessed the emission rate of CO and $PM_{2.5}$ from ICS and 'T3SS' as a proxy to determine health impacts on the people, as well as the policies in place to ensure the sustainable use of ICS in riparian communities in the Biakoye, South and North Dayi, and Kpando Municipality (Oti and Volta Regions) of Ghana.

1.4 Research Questions

To establish the basis of assessment and achieve research goals, the following research questions were proposed.

1. What are the barriers influencing adoption of ICS in the study areas?
2. How do people perceive the ICS as an innovation that affects the health and environmental status?
3. Which factor (charcoal production, fuel wood use & farming) is the major cause of deforestation in the study area
4. Do ICSs actually reduce fuel consumption and emission of smoke (CO & $PM_{2.5}$)?

5. What is the density of vegetation growth of the reforested area?

1.3 Objectives

The general objective of this study was to determine and compare the impact of the use of Improved Cook Stoves and 'T3SS' on deforestation, health and socio-economic factors that influenced adoption of ICS by the people in the study area.

1.3.1 Specific Objectives

The following specific objectives were set to help achieve the main objectives:

1. Assess socio-economic factors that influence ICS adoption in the study areas
2. Assessed local perception of the ICS technology in the study areas.
3. Determined emission of Carbon Monoxide (CO) and Particulate matter ($PM_{2.5}$) from ICS and T3SS as a proxy for health status in the study areas.
4. Examined the major factors contributing to deforestation in the study areas.
5. Assess the type of awareness created by VRA to ensure sustainable use of ICS
6. Assessed the state of forest growth in reforested areas.

1.5 Research Hypotheses

The following hypotheses were proposed to help achieve the set objectives.

H_1 Socio-economic factors have significant influence on adoption of ICS.

H_2 Type of cook stove used has significant influence on self-reported health issues.

H_3 Type of stove used has significant influence on amount of firewood consumed.

H_4 Type of cook stove used significantly influenced the rate of CO and $PM_{2.5}$ emissions.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Global Biomass Fuel Consumption

Biomass fuel are materials from animals and plants deliberately burnt by human beings. More than three billion individuals on earth depend on "biomass fuels (wood, dung, and crop residues)" for energy use in the house (Bonjour *et al*., 2007). Almost half the global population use biomass to cook and heat.

About 2.8 billion people residing in developing countries use mostly firewood or charcoal for cooking with severe consequences on their well-being (International Energy Agency, 2014). According to the International Energy Agency, 2015), Asia, Sub-Saharan Africa and Latin America, have 1,900 million, 753 million and 65 million people respectively using biomass fuels.

In Ghana, more than 70% of households use mainly firewood and charcoal as the main "fuel" for food preparation. Biomass predominantly fire wood, recorded 40% as Ghana's total primary energy in 2015 (Energy Commission, 2016). Based on Ghana Statistical Service, (2014) report, firewood was noted as the core fuel for cooking in 41.3% households. Overall firewood usage in Ghana constituted 56% of the entire energy used in the country (Energy Commission, 2016). Further, in rural households in Ghana, almost eight out of ten families rely on firewood with inefficient stoves (GSS, 2014). More than 95% of rural Ghanaians are reliant on solid fuels for cooking.

Traditional use of firewood is associated with multiple adverse impacts on global, local environment, health and socio-economic development (Bailis et al., 2015). This presents a major concern for the world. However, population growth and slow pace of access to modern fuels, results in absolute population dependent on biomass fuels hence the use of biomass may not decline significantly in the future (Rehfuess, Mehta and Prüss-Üstün , 2006; International Energy Agency, 2011).

2.2 Impact of firewood usage in 'T3SS'

Firewood is usually used in cook stoves. The most common biomass stoves used in rural communities in Ghana are 'T3SS', tyre rim stoves, clay stoves and metal sheet stoves (Netherlands Development Organization, 2017). The 'T3SS' constitutes 51% of stoves used in Ghana. As such, this study focuses on the 'T3SS' and the ICS distributed by VRA.

The 'T3SS' consists of three stones or bricks that are positioned round a fire in a triangular form. Firewood is added from between the stones and a pot is placed on the stones. This type of stove is considered highly versatile and functional because, it can be adjusted to fit any pots size and can easily be regulated by adjusting the firewood supply (Gill, 1987). It is very functional thus performs other tasks apart from cooking of food. The heat from it can be used for heating, while its fire used for lighting and the smoke to repel insects in order to preserve food, timber and the thatch. Finally, the stove has a symbolic value as a "gathering place" (Gill, 1987).

Despite its versatility, consuming biomass through the 'T3SS' has several adverse impacts. The next sub-sections review the impact of fuel wood usage on forest resources, climate, general health and socio-economic activities.

2.2.1. Impact of fuel wood usage in 'T3SS' on Forest Resources

'T3SS' contributes to deforestation because it is inefficient. It cannot combust fuel wood completely (Naeher *et al.*, 2007). The low efficiency results in high usage of firewood and this creates the ambiance for more gathering of fuel wood. Household firewood use is reported as the major cause of deforestation in developing regions of the world in the 1970s (Bailis *et al.*, 2007).

Unsustainable harvest of firewood causes deforestation, influences the watershed function of an area and destroys wildlife habitat (Geist & Lambin, 2002).

Deforestation and forest degradation are enormous source of greenhouse gas (GHG) emissions (Corbera & Schroeder 2011). This fact gave green light for reducing emissions from deforestation and forest degradation (REDD+) to be launched by United Nations Framework Convention on Climate Change to tackle the menace of GHG emission through reducing deforestation and forest degradation (Puzollo *et al* , 2013).

A recent study recommended that the impact from household firewood use on deforestation was small as compared to other land use practices, such as mechanized agriculture, demand for timber and other infrastructure uses (Arnold *et al.*, 2003). However, it was estimated that, in 2009, the firewood harvested was done unsustainably, with higher rates in South Asia and East Africa (Bailis *et al.*, 2015).

Unsustainable harvesting of firewood presents a major concern from both local forest resource and global Carbon Dioxide (CO_2) cycle (Aung *et al*, 2016). Forest degradation in the form of logging, firewood harvest and bush fire is often a catalyst that leads to deforestation. In various schemes, degradation such as logging intensifies the possibility of additional emissions from fire, as revealed in the Amazon (Kissinger, 2010).

Firewood, as the leading fuel for cooking is not the key cause of forest cover loss globally based on an extensive analysis for more than two decades. The analysis indicated there might be few circumstances existing in particular areas on the continent (Arnold *et al.*, 2003). An East African Community research in 2006, found substantial reliance on "biomass" added to yearly rate of deforestation by "3-4% in Kenya, 2% in Tanzania and 2% in Uganda". A forestry survey conducted in the "Chalaco District in Peru", also pointed out that firewood gathering in preparedness for the wet time of year is intensely correlated to cutting trees from forest areas (Ektvedt, 2011). The survey again indicated that in "forests with steep" slopes where farming is barely viable, wood removal could be the most important reason for forest "degradation and deforestation" (Ektvedt, 2011).

Daily firewood collection according to Staton & Hardings (1998), deforests an area slowly. Statistics regarding what land was considered "deforested" are often unclear. However, it is certain, that in Africa, most of the wood harvested goes to meet local energy needs.

2.2.2 Impact of fuel wood use in 'T3SS' on Climate

'T3SS' discharges "gassy products" with complex "global warming" ability (Bailis *et al.*, 2015). Studies have found out that pollutants emitted from the burning of firewood in 'T3SS' include "carbon monoxide, nitrogen dioxide, particulate matter, transition metals, fluorine, and polycyclic aromatic hydrocarbons, volatile organic compounds such as benzene and formaldehyde and free radicals" (Fullerton *et al.*, 2008). Studies estimated that biomass combustion from household cook stoves make up 20 - 50% of global greenhouse gas (GHG) emissions (Bond, Venkataraman & Masera, 2004).

Additionally, formation of black carbon, an intoxicating greenhouse agent is formed due to "incomplete burning of fuel wood. Black Carbon is the second most significant climate-warming gas after CO_2 (Bond *et al.*, 2013; Bailis *et al.*, 2015). This indicates emission of greenhouse gases and black carbon influences air quality on a local and global scale. Kissinger (2010) posited that there is a relationship between climate and forests. This means, as Forest changes precipitation, temperature and other climate change effects also changes.

In addition, the consumption of biomass for food preparation is accountable for substantial percentage of gases emitted into the atmosphere (Martin *et al.,* 2011). Precisely, the unsuitable burning of firewood adds up a change in climate through the emissions of methane and carbon dioxide (Bailis *et al.,* 2015). Degradation of natural forests can lead to biodiversity loss, influence ecosystem services and economic livelihoods. Burning of non-renewable firewood is believed to contribute to net CO_2 emissions (Johnson *et al.*, 2010). The harvesting of biomass fuels in many locations also results in net loss of forested area, which have consequences on ecosystems services and economic livelihoods of the people who depend on tropical forests for survival (Foley *et al.*, 2005).

2.2.3 Impact of fire wood usage on health through pollutants

Exposure to smoke from biomass has been connected to pain in the eyes, headache, acute respiratory, infections, chronic obstructive pulmonary disease, lung cancer, asthma, cancer of the nasopharynx and larynx and tuberculosis (Ezzati & Kammen, 2002). High levels of health-damaging pollutants were released from 'T3SS' during cooking and heating activities. Biomass combustion is also a major contributor to pollution of outdoor air (Chafe *et al*., 2014; Liu *et al*., 2016). High levels of household air pollution including carbon monoxide (CO) and changeable sizes of particulate matter (PM), toxics like benzene and Polycyclic Aromatic Hydrocarbons (Naeher *et al*. 2007) were generated because of incomplete combustion. PM and CO are two of the most frequently measured household air contaminants. Their association with health outcomes have been well documented (World Health Organization, 2014). The World Health Organizations' Global Household Air Pollution database compiled from 154 studies in developing countries showed households burning biomass greatly beyond the guidelines for ambient air quality of World Health Organization. Household Air Pollution also contributes to degradation of ambient and regional air quality, with a variety of adverse consequences (Jeuland *et al.*, 2014). The proportion of ambient $PM_{2.5}$ pollution attributable to residential solid fuel use was estimated to be over 10% in low-income countries, with higher levels in southern Sub-Saharan Africa of 37% and South Asia constituting 26% (Chafe *et al.*, 2014). According to Rehfuess *et al.* (2006), 85% of all global particulate exposure occurs indoors.

Even though these pollutants affect humans, women and young children have the highest exposures. This is because of women's traditional role of food preparation, and children who spend much of their time with their mothers (WHO, 2006; Smith *et al.*, 2014). Indoor Air Pollution constituted a great portion of the Burden of Diseases in Sub-Saharan Africa, Oceania and other Asian countries (Rehfuess *et al.*, 2014). Exposure to Indoor Air Pollution is ranked the "fourth highest risk factor" for mortality. Meanwhile three billion individuals on the earth rely on firewood for cooking. Exposure of individuals to Household Air Pollution constitutes to almost four million deaths annually (Lim *et al.*, 2012).

Research by Boadi & Kuitunen, (2006) revealed that indoor pollution due to the use of firewood in Ghana is in serious problem. Millions of deaths and disability-adjusted life as effects of Indoor air pollution (Global Burden of Disease, 2013; WHO, 2014). Some cross-sectional epidemiologic studies have found associations among biomass-derived air pollution and cardiovascular related diseases, like "blood pressure" (Neupane *et al*., 2015; Norris *et al*., 2016). Several literature shows that acute lower respiratory infection in childhood can be caused by smoke from biofuels (Fullerton *et al.*, 2008; WHO 2006; Smith *et al.*, 2004).

In addition, lower weight of births and stillbirths are connected to pollution of "indoor air from biomass use" (Pope *et al.*, 2010). A survey by Dherani *et al.* (2008) pointed out that 1.6 million deaths occurring yearly is caused by indoor air contamination. This emanates from burning biomass for food preparation. Most countries in Sub-Saharan Africa including Ghana where about 96% of the Ghanaian populace still depend extensively on unprocessed solid cooking fuels using ‘T3SS’, have many people exposed to harmful emissions (Armah *et al.*, 2015). The traditional method of energy usage for food preparation is less efficient and harmful, although the use of recent energy for food preparation is efficient (Malla *et al.*, 2014).

2.2.4 Impacts of firewood use on socio –economic activities

Reports from World Health Organization (WHO) indicates that, about three billion people across the world are found in the lower levels of energy ladder. This forces them to rely on firewood, crop waste, leaves and coal to satisfy their energy requirements. A huge population constituting 95% each in Africa, Asia , Afghanistan and Chad, 87% in Ghana, 82% in India, 80% in China (Duflo *et al.*, 2008), on all forms of biomass. Families receiving lesser levels of income are likely to be within the lower part of “the energy ladder”. This is because the fuels and stoves listed in the lower part of the energy ladder is cheap and locally available but not efficient (Duflo *et al.*, 2008).

‘T3SS’s are associated with poor heat transfer capacity where energy and heat is wasted to the surroundings instead of directed at the pot, which can lead to high fuel consumption and prolong cooking duration (Bentson & Li 2015). This translates to increased time and energy burden for rural women who are often responsible for cooking and collecting firewood. It is believed that longer hours and energy spent in cooking and firewood collection may take time away from engaging in activities that build skills or generate income to improve rural livelihoods (WHO, 2006).

The World Bank survey in India found that over 9 hours spent on household production activities (cooking, collecting firewood, food processing, cleaning dishes and house, child care, and fetching water) daily leave just 2 hours for pursuing income-earning activities (World Bank, 2004). Rural women desire to reduce the burden of cooking and fuel collection; interviews with women in Nepal, India, and Bangladesh revealed their motivation for adopting improved stoves was because they believed it would reduce firewood use and cooking time (Chowdhury *et al.*, 2011).

A survey in Zimbabwe, Ethiopia and India found women spent on average 40 minutes to over 2.5 hours a day cooking (Horrell *et al.*, 2008). In India, the World Bank survey of 5,000 rural women from 180 villages across six states found that on a daily basis, women spent around 3 hours cooking and 40 minutes collecting firewood (World Bank, 2004).

2.3 Improved Cook Stoves

Improved cook stoves (ICSs) are cookers with advanced effectiveness and cleaner burning. They offer a likelihood for improving health related issues and decreasing greenhouse gas emissions (Grieshop *et al.,* 2011). ICS's are made to consume traditional fuels in a more effective mode in an attempt to reduce large costs on poor households. They were designed to eradicate toxins from the kitchen via a chimney attached to the stoves. Duflo *et al.* (2008) stated that unlike the traditional cooking stove, reports proclaim ICS produce less "soot on the walls" surrounding the cooking area.

The recent wave of improved stove agendas aiming at efficiency of energy consumption, commenced in the 1970s after the gigantic "rise in oil prices". Higher rates of oil prices increased the cutting down of trees for fuel, leading to an imminent "firewood crisis." This prompted governments, donors and nongovernmental organizations to commit finances in developing stove programmes (Barnes *et al.,* 1994).

The efforts to encourage adoption of ICS in Ghana, begun over two decades. The initiatives begun in 1990s by the Ghanaian Government through the then Ministry of Mines and Energy in their pursuit to promote efficient cook stove (Atakora & Hammond, 1999). The premier ICS made for "charcoal stove" was "Ahibenso stove". It was estimated that by 1993 the programme had disseminated approximately 40,000 cook stoves. Another stove was rolled-out by Enterprise Works, a division of Relief International called Gyapa in 2002 (Owusu *et al.,* 2015).

By 2006, the Gyapa stove became a favorite stove in Ghanaian households with 200,000 units of the stove sold out (Kemasour *et al.,* 2011). Other initiatives included the Council for Scientific and Industrial Research (CSIR) ICS for woodstove project and the Volta River Authority's climate stove initiative", which led to introduction of improved firewood stoves in communities along the Volta Lake (Netherlands Development Organization, 2017). Currently, Ghana is home to different improved cook stove producers where each of them produced tens of thousands units of cook stove annually (GACC, 2012). However, they are more concentrated on charcoal cook stoves in urban areas than fuel wood cook stoves in rural areas.

The ICS provided by Volta River Authority (VRA) was built from clay with small quantity of sand (0.5% of total volume) and water. The stove has an elevated chimney of diameter 100 mm fitted behind to remove the smoke from the cooking area. It has a long inner firepot of (L x H) 920 x 310 mm for front loading of wood fuel (VRA, 2016). The stove can accommodate two (2) cooking pots (Size 3 and Size 1½) weighing 1.711kg and 1.132 kg respectively) simultaneously. The gap between the pots base to the floor of the firepot is 300 mm. The walls of the combustion chamber are 220 mm thick without lining and has an overall dimension (L x W x H) of 950 x720 x 330 mm (VRA, 2016). Pilot study to the field in August 2018 showed that shape, height and number for chambers is based on adopters' preference.

Chandar &Tandon (2004) proclaimed that the cleaner the biomass cook stove technologies, the more expensive they become. Modern fuels like liquefied petroleum gas and electric stoves that are prevalent in high-income, urban households has been deployed in rural households Chandar &Tandon (2004) but on a limited scale. Access to these modern fuels is limited by high cost and physical access, particularly in rural remote parts of the world (Foell *et al.*, 2011). Hence, the majority of cook stove technologies distributed has been in more basic biomass cook stoves category (GACC, 2015; Akbar *et al.*, 2011).

2.4 Benefits of adopting and Using ICS

Different types of ICSs have been developed since the 1980s and their usage has been improved by subsidizing their production by Government or Non-Governmental Organizations. Numerous empirical studies and experiments done in several developing countries attest to the benefits of improved cook stoves in sectors of health, environment and socio-economic aspects of the lives of users of ICS.

2.4.1 Health

A study in Guatemala involving over five hundred (500) distributed plancha stoves (constructed on site with bricks, concrete blocks and a chimney), found out that there was reduction in Indoor Air Pollution and personal exposures to pollutants in homes using the intervention stoves (Smith *et al.*, 2011; Smith-Sivertsen *et al.*, 2009) . Locally made stoves showed reduced Indoor Air Pollution and firewood decline when tested in the lab (Hanna *et al.* 2016) or field (Burwen & Levine, 2012).

A study in Kenya by Otieno *et al.* (2014), proclaimed individuals have realized reduction in smoke emitted and improved safety. Similar reports were recorded in rural Mexico (Masera *et al.*, 2007) and Guatemala; (Diaz *et al.*, 2007). A reduction in eye infections and headaches were observed. Some ICS reduced particulates and carbon monoxide by 90 % in a test conducted at the laboratory. Stoves well fitted with chimney and regularly maintained by cleaning can drastically reduce Indoor

Air Pollution (Diaz *et al.*, 2007). Akbar *et al.* (2011) noted that increased awareness of health impacts led to interventions that were focused on reducing exposure to air pollutants in the late 1980s and 1990s.

More recently, increased awareness of the scale of health, climate and socio-developmental impacts (Aung *et al* 2016) has made ICS a popular policy prescription. One of the first health focused randomized controlled trials was in Guatemala where chimney mud stoves (plancha) that vented smoke outdoor were distributed to assess the effect on personal exposures and health outcomes (Smith-Sivertsen *et al.*, 2004). Other large-scale interventions in China under the National Improved Stove programmes also focused on fuel efficiency and indoor smoke removal through chimneys (Smith & Keyun, 2010).

ICS has revealed potentials for alleviating the undesirable health impacts of food preparation with biomass. This was seen in the Randomized Exposure Study of Pollution Indoors and Respiratory Effects study in Guatemala. The study found substantial decline in contact with Indoor Air Pollution and degrees of respiratory diseases within the populations using ICS (Smith, 2009; Diaz, 2007). Current evaluations of various designs of ICS on the field exhibits declines in exposure (20-50%) to PM and CO when compared to 'T3SS' (Bailis *et al*, 2007; Masera *et al*, 2007). Further, a meta-analysis of studies on respiratory illness in youngsters recommends that ICS' are connected with respiratory health issues (Dherani *et al.*, 2008). Despite the fact that ICS was designed to improved health impacts, scholars have argued that there is less evidence to support it. According to GACC (2011), the absence of universally accepted ICS standards and restricted country capability resulting in health claim makes it unclear as to how much emission must be reduced to provide substantial health benefits.

2.4.2 Climate

The reduction of indoor emissions varies significantly. According to Omar (2007), successful adoption of ICS in urban Zanzibar resulted in an incredible drop in firewood consumption in urban sectors. Burwen & Levine (2012) first presented theory of change in the context of a cook stove intervention with ultimate goals of reducing deforestation, lowering GHG emissions and improving health.

A detailed analysis showed how different cook stove technologies and fuels provide variable benefits as well as drawbacks on different co-benefits (Grieshop *et al*., 2011). At the domestic level, users testified to less smoke, minimized risk of burning, better taste of the food, saving of fuel and money (Dresen *et al.*, 2014).

Bensch & Peters (2013), in their study in Senegal revealed that ICS dissemination led to reduction in the use of charcoal in the area. This increases the density of trees and forests. A survey in China established that uptake and use of ICS lowered fire wood utilization by 40.1%, time spent gathering by 38.2% and tree felling by 23.7% (DeWan *et al.*, 2013). A life cycle analysis by Afrane & Ntiamoah (2012) revealed firewood consumption in Ghanaian homes for food preparation has a yearly environmental cost at US$36497 per household. ICS saves firewood use and reduces pressure on tress (Urmee & Gyamfi, 2014). Again, the outcomes display a degree of firewood saving through the usage of "improved charcoal" cookers as compared to traditional stoves. It was estimated the use of improved charcoal stoves might lower the dependence on firewood to stop rural deforestation (Omar, 2007). Sponsors of the initial group of ICS was to aid slow the rate of deforestation by reducing the quantity of fuel needed for cooking activities.

The earliest set of ICS was driven by deforestation apprehensions. They were manufactured to improve heat transfer, which will lead to energy efficiency. Recent anxieties about health of humans increased the zeal to champion manufacture and use of efficient stoves. Efficient combustion stoves provides positive impact for environment, which further affects the changes in climate and as well as good human health (Barnes *et al.*, 1994).

2.4.3 Economics

A life cycle analysis by Afrane & Ntiamoah (2012) revealed firewood consumption in Ghanaian homes for food preparation has a yearly harm to the environmental costed at "US$36497 per household". Economically, the use of ICS was reported to reduce the length of time spent in cooking, the amount of fuel used and the convenience in cooking (Otieno *et al.*, 2014). The few studies that evaluated this outcome have relied on self-reported or recall methods on time use or timesaving, and assumed that the saved time is used for livelihood improvements such as earning income (García-Frapolli *et al*., 2010; Malla *et al*., 2014). Although the indoor air quality of cookhouses did not appear to change as the result of conversion to ICS, women appeared to benefit by spending less money for extra fuel and less time in wood collection a report from a study in Kenya (Critchley *et al*, 2015).

2.4.4 Physical Burden

Studies have established that women suffer long-term physical damage from strenuous work without sufficient recovery with 'T3SS' (WHO, 2006). In developing countries, firewood collection is the sole responsibility of women and children, which takes long distances and time. Since the introduction of ICS, women and children felt a change in fuel wood collection. Lewis & Pattanayak (2012), realized time spent in collecting firewood in Uttah Pradesh reduced among ICS users. Brooks (2014) supports this finding, using Heckman two-step estimator and realized time spent collecting firewood in India reduced by 23% among ICS users. In Guatemala the 'Plancha' ICS reduced firewood usage by 39%, lowered time spent for wood gathering and reduced Indoor

Air Pollution (Bielecki & Wingenbach, 2014). Time saved through increased efficiency cook stoves would bring greater freedom and opportunities to the cook stove user (GACC, 2015).

2.5 Factors influencing adoption of ICS

Adoption is the procedure by which modification takes place in the arrangement and existence of a social system (Omar, 2007). It is a form of social change. When novel ideas are developed, they can be adopted or rejected. This phenomenon may lead to certain concerns causing social change.

The slow adoption of improved cook stoves all over the world (Fitzgerald *et al*., 2012) has generated widespread interest in research globally. The issue of adoption is an unsettled debate in the empirical literature. It was noted that several projects worldwide have suffered lower rates of ICS uptake. (Lewis & Pattanayak, 2012).

2.5.1 Socio – cultural factors

Consumers might not be willing to invest in an ICS, when they do not know the value of it (Pattanayak & Pfaff, 2009). Based on the principle of "perceived attributes" Rogers (2003), adopters of an innovation (ICS) will base their decision on five features of innovation; thus trialability, observability, relative advantage, complexity and compatibility. This means an invention can record an augmented frequency of distribution if users perceive the innovation to be simple and compatible. Rogers continued to state that, management support was also a factor that influences adoption of ICS.

According to Rehfuess *et al.* (2014), positive results from adoption of ICS can only be realized if all above factors are well integrated. This means for an innovation to be adopted, the innovation must be compatible with existing practices; it must not be complex, have relative advantage over the old technology and coordination between policy makers and institutions to help adopters. Omar

(2007), in his framework on adoption of ICS and deforestation in Zanzibar stated access to information, economic status and educational level as a determinant factor for adoption and diffusion of improved charcoal stoves.

A study by Jan in rural Pakistan, revealed education and household income as the utmost substantial factors that affected adoption of ICS in 100 randomly selected households (Jan , 2012). Another study by Beyene & Koch (2013) in Ethiopia also discovered increased in adoption of *Mirte* stoves in urban towns were dependent on price and household wealth. Puzollo *et al* (2013) have pointed out several socio economic factors such as household composition and institutional factors that influence adoption of ICS. Malla *et al.* (2014) supported this report in their study when they realized respondents with higher economic status adopted ICS more than respondents with lower income did.

ICS adoption has a significant positive link with higher socio-economic status, income, education, higher firewood price and large household size. Negative adoption is associated with socially marginalized status and age of head of the household (Lewis & Pattanayak, 2012). A study in Ghana, in Ejisu-Juaben Municipality also revealed adoption was positively influenced by composition of adult females in the households (Owusu *et al*., 2015). Field observations reveal that in many cases the ICS is not exclusively used, but in addition to other stoves, a term known as stove ‘stacking’ (Burwen & Levine, 2012). Increasingly, the presence of multiple cooking devices is recognized as a normal practice in developing countries households (Ruiz-Mercado *et al.*, 2011).

2.5.2 Health

Countries, institutions and organizations are steadily promoting adoption of ICS as a means of decreasing cooking induced illnesses, death and environmental degradation. Nevertheless, in current times the focus is now on the negative health effects of solid fuel usage (Bailis *et al.,* 2009). Projects that claim higher rates of adoption are uncertain about the extent of health issues and fuel consumption of the beneficiaries (Hanna *et al.*, 2016). In addition, adoption of ICS could advance achievement of Sustainable Development Goals on child mortality, maternal health care, gender equality, eradication of poverty and environmental sustainability (Cordes, 2011).

2.5.3 Deforestation

At the international level, countless interventions have been employed to increase utilization of improved cook stoves to mitigate deforestation, domestic pollution and ultimately improve quality of life (Vahlne & Ahlgren, 2014). Most ICS programmes these days highlight their health benefits however, households initially responded to ICS based on its ability to save fuel, cooking fast, convenience and compatibility with local food preparation (Ruiz-Mercado *et al*., 2011).

2.5.4 Physical features

Kshirsagar & Kalamkar (2014), noted about 160 cook stove programmes going on across the world, but the stoves distributed differ in size, scope, design and financial mechanism. Some of the programmes were sponsored through Clean Development Mechanism (CDM) and the Gold Standard (Ruiz-Mercado *et al*. 2011) and others self-financed by governments and institutions.

According to Barnes *et al* (1994), "*no matter how efficient or cheap the stove, individual households have proved reluctant to adopt it if it is difficult to install and maintain or less convenient and less adaptable to local preferences than its traditional counterpart".*

2.6 Guidelines in place to ensure the use of ICS

In the 1970s and 1980s, unsustainable cutting down of trees for food preparation was considered a major environmental alarm especially in third world countries. Several, plans and procedures designed to ease "tropical deforestation" is a priority on the political agenda (Gabriela *et al.,* 2018).

Internationally, the "Global Alliance for Clean Cook stoves" was established in 2010 under the leadership of the "United Nations Foundation", with an explicit mission to "protect lives, develop livelihoods, empower women and protect the environment" (GACC, 2013)**.**

To avert the dangers of fire wood usage on health and the environment, Ghana ascribed to global conventions and programmes such as United Nations Sustainable Energy for All (SE4ALL) and the Sustainable Development Goals. Others were Economic Community of West African States (ECOWAS) white paper on Energy, ECOWAS Renewable Energy and Energy Efficiency Policies, all with the interest of promoting the use of ICS (Netherlands Development Organization, 2017).

Ghana, for the past years has put in place controls and strategies to inspire the adoption of efficient stoves for cooking activities. The policies in relation to wood fuel stove market development include "Strategic National Energy Plan, Energy for Poverty Reduction Action Plan, National Energy Policy, Sustainable Energy for All Action Plan, Renewable Energy Act, Ghana Forest and Wildlife Policy, Forestry Development Masterplan, Bioenergy Policy (draft), and the Renewable Energy Masterplan" (Netherlands Development Organization, 2017) . The strategies pointed out are targeted at endorsing sustainable firewood usage. This aided woodlot growth, promoting ICS manufacturing and usage, lowering cutting of tress, and education to promote study in the energy sector. One of the accomplishments till now, is the reduction of "biomass portion in the national final energy mix (Energy Commission, 2016).

Today, there are new financing mechanisms, such as carbon financing, that is poised to transform rural household energy sector. Carbon financing is a term applied to resources provided to a project or activities generating GHG (carbon) emission reductions, usually in developing countries, and allowing for trading of those emissions reductions (Kossoy & Ambrosi, 2010). Carbon financing is another way to transfer investment and cleaner technologies to promote sustainable development in developing countries (World Bank Carbon Finance Unit, 2016). According to WHO (2014), complete displacement of traditional stoves with high performing stoves or clean fuels would be needed to attain the WHO annual interim Target 1 for achieving health benefits (Johnson & Chiang, 2015).

In spite of several policies in the sector, implementation has been a problem while achievements have been minimal. Achieving sustainable energy development in Ghana will require applications of energy efficiency and renewable energy, coupled with efficient legislative and regulatory system.

5.7 Conceptual framework

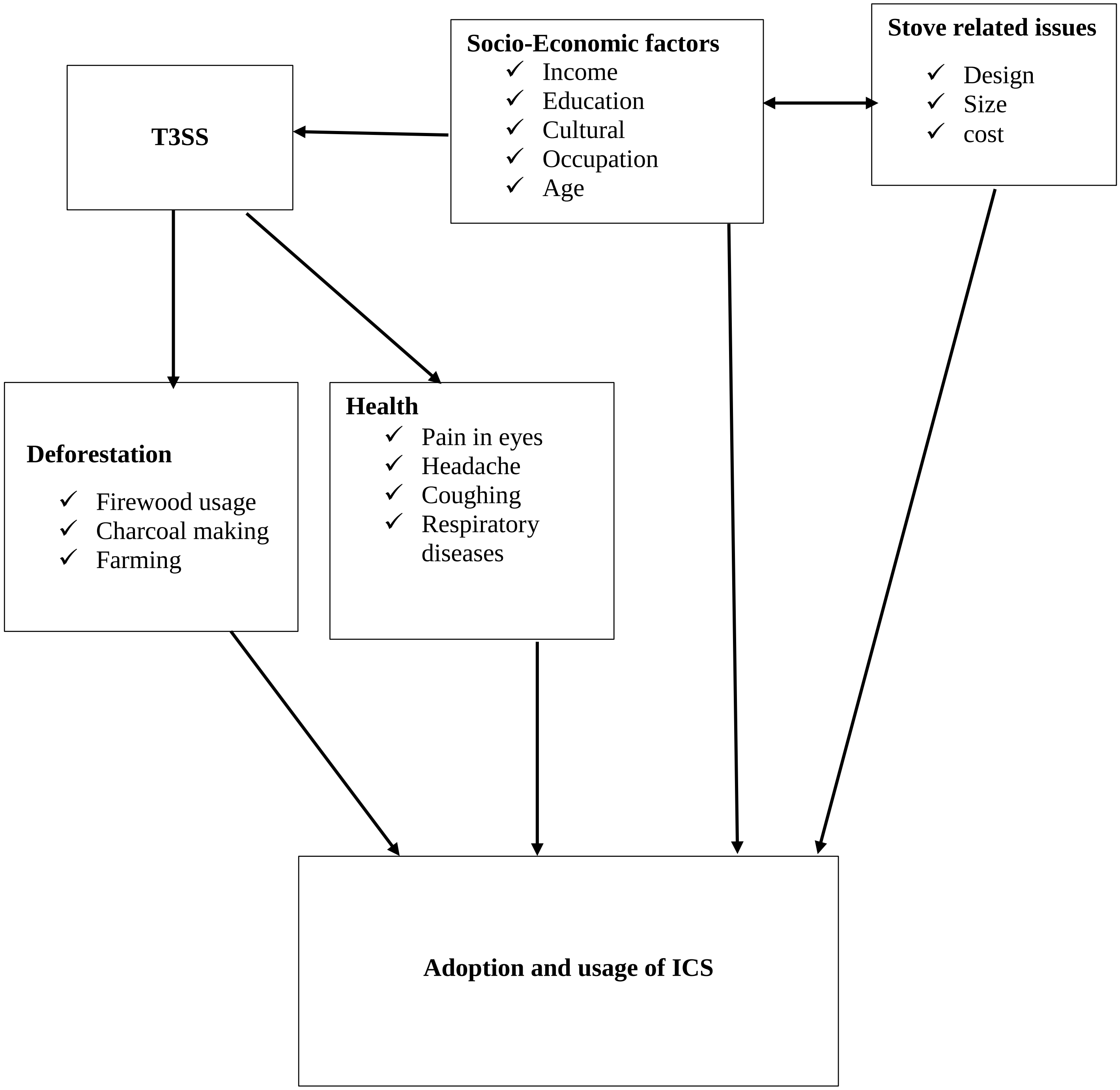


Figure 2.1: Conceptual framework on T3SS and ICS use and their impacts

Legend: Socio-economic factors influence the adoption and usage of ICS and the T3SS. For example, people who are educated and or have higher income may adopt and use ICS while low-income earners or less informed people may continue to use the T3SS. However, the continuous use of the 'T3SS' could lead to health hazards through the release of PM and CO and increase the rate of deforestation because of its higher consumption of firewood. In the long- run when people realize the harmful environmental and health impacts of the use of T3SS, they may adopt and use ICS. Again, there is a recursive relationship between socio-economic factors and stove related issue, which in turn, influences the adoption and usage of ICS. For instance, the cost of ICS may be cheaper to a high-income earner, which could encourage adoption. Besides, the design of the ICS could influence and be influenced by local cultural practices to encourage or inhibit the adoption of ICS.

CHAPTER THREE

MATERIALS AND RESEARCH METHODOLOGY

This chapter presents the profile of the study area and the methodology employed in the study. The profile of the study area includes demographic, socio-economic and physical features. With regard to the methodology, the chapter presents the type of research design, method of sampling, the sample size, form and sources of data, the techniques of collecting data, how the data is processed, analyzed and reported.

3.1 The Study Areas

Four districts in the Volta and Oti region were used for the study; namely, Biakoye, Kpando, North and South Dayi district assemblies. This is because the households who have benefited or adopted the ICS were found in the communities of these districts.

The details of these districts are presented below.

3.1.1 Location and Size

The Biakoye District is found in the Southern part of the newly created Oti Region in Ghana and lies within latitude 60° 45' N and 70° 15' N and longitude 00° 15' E and 00° 45' E. The Oti region is boarded on the north by the Northern Region, to the south by the Volta Region, and to the west by the Volta Lake as shown in Figure 3.1 (GSS, 2013). The Kpando District lies between Latitude 6° 20' N and 7° 05' N, and Longitude 0° 17' E. It shares boundaries with Biakoye District to the North, Afajato South District to the East and North Dayi District to the South, while the Volta Lake defines its Western boundary (GSS, 2013). The Figure 3.1 shows the map of the study areas.

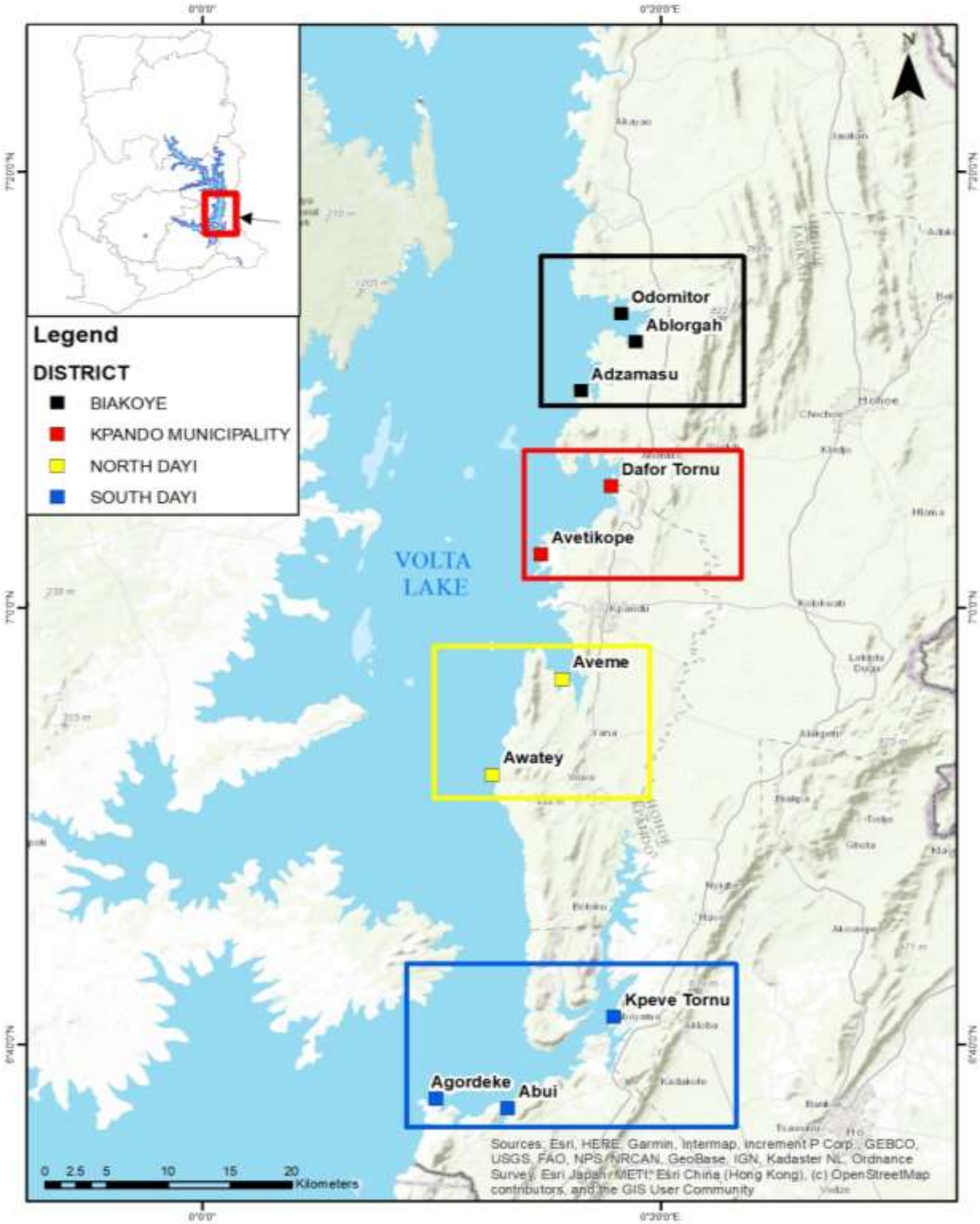


Figure 3.1: Map of the study areas

The Kpando municipality covers an approximate land area of 314.1 km^2, which represents 1.5% of total land extent of the Volta Region of Ghana. The South Dayi District lies within Latitudes 30° 20'N and 35° 05'N and on Longitude 00° 17 and 00° 27'E" (GSS, 2013). It shares borders with North Dayi and Afadzato South to the north, Ho West to the east and Asuogyaman District to the south, with the Volta Lake delineating its western boundary. The District covers a total land area of 358.3 km^2, of which 1.7% of land area within the Volta Region, and about 20% covered by the Volta Lake (GSS, 2013).

3.1.2 Population Size, Structure and Composition

The 2010 Population and Housing Census estimated 65,901, as the total population of Biakoye District with about 33.9% of the population being rural. The Kpando municipality has an estimated population of 53,736 of which 55% of the population, reside in urban localities. South Dayi district is predominantly rural with 46,661 people in the district (GSS, 2013). Youthful populations characterize all three areas, which displays a wide base "population pyramid" and rises off with a low number of the elderly aged 60 years and above. Males in all study areas constitute 40% to 45 % of the population with females representing 60% to 55%. Dependency ratio is very high in all districts (GSS, 2013).

3.1.3 Economic activities in the municipality and districts

The predominant economic activities in the study areas are farming and fishing constituting 60%. Artisanship and associated trades workers constitute 15%, service and sales workers make up 14% and 11% are engaged as managers, professionals and technicians (GSS, 2013).The economically active people are within the ages of 15 and above (77%). However, those working make up (98 %) while 2% were jobless. For those who were not economically active, a larger proportion of them were students i.e. 49.3% and 6.5% are incapacitated (GSS, 2013).

3.1.4 Climate

All the study areas falls within the tropical Equatorial Zone and experiences a bimodal rainfall regime, with the major rainfall occurring between middle of April to early July, whereas the minor season starts in September and ends in November. This is affected by the Monsoon winds blowing from South Atlantic Ocean and the dry Harmattan winds from the Sahara (GSS, 2013).

Approximately 1,500 mm of rainfall is noted as the mean annual rainfall (GSS, 2013). All districts experience dry season, characterized with cool-dry air from North East Trade Winds from December to March each year. The average relative humidity during the rainy season is 80%. This climatic condition is favorable for agricultural activities in the districts (GSS, 2013).

3.1.5 Vegetation

The Biakoye, Kpando Municipality and South Dayi Districts are located within the Forest-Savanna Transitional Ecological Zone and mix of Guinea Savannah Woodland Forest of Ghana; the vegetative cover is made up of timber resources such as Millicia excels (Odum), Swietenia (Mahogany), Afzelia africana (Papao), Mansonia altissima (Aprono), Triplochiton Scleroxylon (Wawa), Tectona grandis (Teak) among others. The savannah woodland comprise of grass with dispersed plants like Acacia and Bamboo as well as Oil palm are located along the Volta Lake areas (GSS, 2013).

3.1.6 Relief and Drainage

The topography of the study areas is generally undulating, hilly at the eastern part but has lowlands along the Volta River on the west. As such, some sections closely located to the Volta Lake are prone to flooding. There are several hills and ridges scattered throughout the study areas, which has resulted in the undulating topography thereby, making it a potential tourism feature (GSS, 2013). The areas are well drained with several rivers and streams including Konsu, Bompa, Kabo, Ufuo and Asukawkaw, empty into the Volta Lake (GSS, 2013).

3.1.7 Housing Types

The major construction materials for houses in the study areas are cement (29.8%) and mud brick (62.6%) and bamboo (0.2%). The key material used for roofing is thatch or palm leaves or raffia with few houses roofed with metal sheets (GSS, 2013).

3.1.8 Energy for Cooking

The key fuels for cooking comprise of firewood and charcoal, accounting for 80% and 20% respectively and mostly collected from farms, around houses or along the Volta Lake (GSS, 2013).

3.2 Research Design

This research adopted a cross-sectional study design because it is an observational and descriptive study expected to enquire about phenomenon or features of current occurrences, in a particular population and requiring relatively large sample sizes in a one-time survey, according to Saksena *et al.*, (2007). This study involved huge sample cross-sectional studies with high degree of change in cook stove study measurements. When combined with simple equipment and protocols, cross-sectional studies are more rapid and cost-effective than longitudinal studies (Neuman, 2007).

The study also adopted a mixed method procedure, which is becoming popular due to its usefulness in showing various stages of analysis, expanding the significance of discoveries as well as offering a holistic illustration of data (Rudestam and Newton, 2007; Creswell, 2011). Qualitative data communicates stories and provides evidence in areas that cannot be provided by quantitative data. The qualitative data collected assisted in gaining in-depth knowledge on reasons for slow and nonadoption of Improved Cook stoves (ICS), stoppage in usage of ICS, respondents' perception on ICS and how these issues influenced deforestation and health of individuals.

3.3 Target Population

This study-targeted communities in the Biakoye District (Ablonga, Odormitor, Adzamasu), North Dayi (Awatey, Aveme) , South Dayi (Abui, Agordeke, Kpeve-Tornu) Districts and Kpando Municipality (Dafor –Tornu and Dzigbe –Avertikope) who used Improved Cook Stove (ICS) or Traditional Three Stone Stove (T3SS) for cooking. It also involved field officials of the Environment and Sustainable Development Department of VRA and Key informants like Opinion leaders, political leaders or Chiefs.

3.4 Sampling Procedure and Sample Size

The total sample of the study was 184 participants even though 220 participants were targeted. The study purposely selected 73 ICSs users from Ablonga, Odormitor, Adzamasu, Awatey, Aveme, Dzigbe-Avertikope, Kpeve Tornu, Dafor-Tornu, Abui, Agordeke). In addition, 20 key informants were purposively sampled; two (2) from each community who were leaders of the communities to provide more insight into their socioeconomic issues and two (2) from field officials from the Environment and Sustainable Development Department. However, users of 'T3SS' were randomly selected from each community as the control until a sample size of 89 was attained. Individuals constituting 10 from all the communities who had stopped using the ICS were added to 'T3SS' users to provide answers to why they stopped using the ICS. On a whole, 184 participants took part in this study made up of ICS users (73), former ICS users (10) 'T3SS' users (79) and 22 key informants.

A pilot survey in August 2018 and aspects of the study was tested in one of the study areas Agordeke (South Dayi District), to observe cooking activities on ICS and 'T3SS', sources and types of firewood. The researcher also interacted with some members of the community and informed them of the research that will take place in that pilot.

Information gathered for this pilot study was from primary and secondary sources, which were then used to update that of the main study.

3.5 Data Sources

3.5.1 Primary data

The primary data was collected from Improved Cook Stoves (ICS) and Traditional Three Stone Stoves (T3SS) users, leaders of various communities, as well as field officials of Environment and Sustainable Development Department (VRA).

3.5.2 Secondary data

Secondary data was collected from existing published and unpublished sources such as journals, books, government official reports, publications and documents from the VRA and related institutions who undertook a similar research. Secondary data provided information on Energy situation in the country, health implications from biomass use, ICS technology, adoption levels, and policies to promote ICS technology. It also provided the basis to develop research objectives and hypothesis.

3.6 Data Collection Instruments

3.6.1 Questionnaire

A household questionnaire administration method was designed to include both close and open-ended questions, and was divided into sections based on the research objectives. The questionnaires were administered face to face by the researcher in the selected households in ‘Ewe’, the local language at different times. The questions included information on socio-economic issues like education, household size, income, age, tradition, and perception about ICS in the study areas. Information on smoke to deduce health issues, firewood usage and sources to infer impact of deforestation. Issues related to ICS adoption and sustainable stove usage, as well as the extent of vegetation depletion on reforested areas.

The questions were read out to respondents and answer options on the questionnaire that corresponded with answers provided by the respondents were selected. Answers not corresponding with any of the options provided on the questionnaire were written down and later coded for analysis. Questionnaires were also used to determine health issues such as headache, painful eyes, coughing and respiratory ailments. Likert scale was used to assess the general perception of the respondents about ICS, problems in using ICS and comments to improve the stove. Administration of each questionnaire lasted between twenty (20) and forty –five (45) minutes on the average.

3.6.2 Focus Group Discussion (FGD)

A group of respondents known to have much knowledge on the use of ICS and ‘T3SS’ because, they have used these stoves for more than ten years were purposely selected to represent the general opinions. A focus group discussion (FGD) was held to evaluate the perception of the people regarding acceptability and impact of ICS on users and reasons behind slow adoption of ICS. Two (2) FGD events were held in each community i.e. one set for ICS users and the other for ‘T3SS’ users. A total of 16 FGD events were held for both ICS & ‘T3SS’ users, (2 per community) in 8 communities.

Focus Group Discussions (FGD) included five (5) to ten (10) members both males and females. Members selected for the FGD were those who have resided in the community for not less than eight (8) years, users of ICS or ‘T3SS’, participated in the ICS educational programme and were between the ages of twenty–one (21) to seventy (70). A guide was prepared to explore health, cultural, economic issues, adoption levels and general issues on deforestation by users of ICS and 'T3SS'.

3.6.3 Key Informant Interview

Chiefs and leaders of women groups with adequate knowledge on sources of energy and frequency of usage and smoke from the use of ICS and 'T3SS'as well as factors influencing adoption of ICS were interviewed using semi-structured questions that lasted 40 minutes on average. Two key interviews were conducted in each community. In addition, information on policies and programmes available for adoption and sustainable use of ICS was collected from two field officials of Environmental and Sustainable Development Department of VRA.

3.64 Observations and Photographs

This method was used to get first-hand and detailed information on activities undertaken throughout the cooking process. Direct observations of how stoves were handled were also documented. Pictures helped document the cooking environment as well as activities not captured in questionnaires or interviews.

3.7 Controlled Cooking Test (CCT)

The Controlled Cooking Test is a test conducted on the field, to measure stove performance in comparison to traditional cooking methods when a cook prepares a pre-determined local meal.

The CCT was conducted to assess stove performance in a controlled setting using local fuels, pots and practices to assess actual impacts on household firewood consumption using locally available fuels. It revealed what is possible in households under controlled conditions (Kshirsagar & Kalamkar, 2014). Even though performed on the field, they still offer a limited understanding of the stoves' true effects when used in households on daily basis (Global Alliance for Clean Cook

Stoves, 2012). Tests conducted in controlled settings, such as the CCT, does not allow for variations in cooking styles of different cooks and their behavior in the community, which may affect the operation of the stove and subsequent outcome on emissions (Aung *et al.*, 2016).

This test was also to measure amount of fuel saved to help determine ICS's impact on deforestation, the CCT measures the amount of fuel used per unit of standardized meal cooked per day (Burwen & Levine., 2012 ; Grimm & Peters., 2015).

A total of 20 stoves made up of 10 ICS & 10 'T3SS' were tested from five selected communities (Aveme, Awatey, Ablonga, Odormitor and Dafor-Tornu) because some ICSs in other communities were abandoned, while others were not willing to undertake the test. However, for a CCT to represent total number of stoves distributed, 10% of stoves were required to be tested. 10% of 73 was seven (7) for ICS and nine (9) for 'T3SS'. However, 10 of each stoves were tested because 10 respondents expressed their willingness to take part in the CCT. The CCT lasted 6 weeks in enclosed cook areas, which were purposely selected for the cooking test so that air did not affect the concentration of $PM_{2.5}$ and CO. These were bamboo structures roofed with thatch, Mud/clay building roofed with thatch and cement building roofed with aluminum as shown in plate 3.1 and 3.2.

Plate 3.1: Mud kitchen with thatch roof

Plate 3.2: Cement kitchen with zinc roof

3.7.1. Fuel and Ingredients used in Controlled Cooking Test

Firewood, corn and cassava dough were provided for the Cooks using ICS and 'T3SS' to prepare "Banku" a traditional meal in all communities. Based on the procedures of CCT, each test consists of preparing three sets of the same meal, three different bundles of firewood averaging the result, three different bowl of water of same weight and three sets of ingredients to prepare the meal (Bailis, 2007). All the measurements and observations of the study were recorded on a CCT data sheet shown in appendix 7.

Senna siamea specie locally known as cassia were provided for use as firewood, considering that it was the common firewood used in the study communities. The average length and diameter of firewood were determined with a tape measure by measuring three different woods from a bundle of firewood prepared for cooking. Moisture levels of the firewood were taken using Voltcraft FM-300 (Conrad Electronics SE, Hirschau) on three different points of a wood in a bundle and the result recorded in dry basics.

Plates 3. 1: Weighing of an empty pot

Plates 3. 2: Weighing of Corn dough

Plates 3. 3: Education of participants on CCT

Plates 3. 4: Weighing a bundle of firewood

3.7.2 Cooking

Before every cooking test, explanation of the procedures were given to the volunteeres and observers. Three different pots of the same size (size 2) , three seperate quantities of corn and cassava dough, three bundles of firewood and separate bowls of water were weighed on Constant electronic Digital scale (ISO certified) with a maximun allowable weight of 600 kg before given to the Cooks. The mixed ingredients were placed on the fire and timer started for cooking. Each cook test lasted between 10 and 45 minutes. Cooking process was allowed to proceed per the traditional way of cooking, without any interference. Specific events during cokking processes were observed and recorded.

The readiness of the "Banku" was checked using a yellowish change in colour and the "Banku" not sticking on the hands of the Cooks. Once the "Banku" was done, the time was noted but monitors were stopped after 5 minutes. The pot containing the food was weighed. The firewood left was brushed against each other to remove any char and weighed. The char remaining in the stove after cooking was collected into a metal tray using a spatula and weighed, after which it was discarded. The "Banku" was packaged, cooking area cleared by the Cook and other participants who were observing and new setup for the next Cook was made. All weights were recorded in kilograms and converted into grams because the formula used for the calculation was in grams (Bailis, 2007).

3.7. 3 Indoor Air Monitoring

Haz-Dust Environmental Particulate Air Monitor Model -7500 was used to measure indoor Particulate Matter ($PM_{2.5}$) and Aeroqual S500 V6.5 gas monitor (Aeroqual Limited; Auckland, New Zealand) used to measure CO in mg/m^3. The two equipment were placed on a table measuring 1 meter above the floor and 1 meter away from the stove as shown in plates 3.5 and 3.6. These distances were chosen for the equipment to get direct contact with the smoke from the stoves. Though the equipment's can be placed anywhere according to manufacturer specification (Ghazali *et al.*, 2012), the distance and height were enough to prevent the equipment from excessive heat as this can damage it. These instruments were chosen because of their portability and reliability in setup. Each equipment was warmed up for 3 minutes to burn off any contaminants before its use and was put on standby mode when not in use to prevent buildup of contaminants. The gas monitors were programmed to log at every 1-minute interval during the cooking period. The equipment's also recorded humidity and temperature of the cooking areas. The sampling period depended on the cooking time of each test. Logged data from the monitors were downloaded onto a laptop computer using Aeroqual S500 gas monitor software, version S.500V6.4 for analysis. The gas monitored, sensor type, sensor range and minimum detection limits is presented in Table 3.1.

Table 3. 1: Sensor Specification for Aeroqual ambient sensors

Gas	Sensor Type	Sensor Range (mg/m^3)	Minimum detection Limit (mg/m^3)
CO	GSE	0 – 123	0.25

GSE: Gas Sensitive Electrochemical

Plates 3. 5: Indoor Air Pollution monitoring on ICS

Plates 3. 6: Indoor Air Pollution monitoring on 'T3SS'

3.8 Geographic Information Systems (GIS) and Remote Sensing

Global Positioning System (Garmin etrex 20) was used to record points of eight (8) reforested areas and the locations of households where the CCT was conducted. Reforestation in two (2) communities was not possible because of land issues hence no GPS point was obtained. The GPS points of reforested areas were taken between 40 to 50 meters away from the Lake with 2 to 3 meters margin of error. The GPS Points were downloaded using DNR GPS software and saved as ESRI shape files, which were loaded into Arc GIS/Arc Map software version 10.6.

Attributes of the shape files were opened in Arc GIS/Arc Map software. Vector layer was created to extract land use classes from the Rasta layer. These points were converted into polygons. The polygons were generated using outlines of buildings, farmlands, Volta Lake and reforestation. The polygons were saved as shape files, categorized into various classes and different colors assigned to them. Geo-Eye satellite imagery uploaded from Arc GIS online on October 2018 was used because it had 1-meter resolution range. A change detection was not carried out because the duration of reforestation project was not long enough as a period of at least Five (5) years is most appropriate.

3.9 Data Analysis and Presentation

Data (questionnaire) was processed by removing uncompleted questionnaires, organized, coded and entered into SPSS 25.0. Data were presented using descriptive (frequencies, charts, tables and graphs) and inferential statistics (Chi-square, T-test, Binary Logistic Regression, One-way ANOVA and Pearson correlation). Data from key informants and focus group discussion was translated from the local dialect (Ewe) to English, transcribed and analyzed using intensive textual analysis.

This study adopted a Binary Logistic Regression model to statistically test socio-economic factors influencing adoption of ICS in the study area. Logistic regression is the statistical technique used to predict the relationship between predictors (independent variable) and predicted variable (the dependent variable) where the dependent variable is binary. This method was used because it does not require any strict adherence to the expectations of normality, linearity, equal variance and covariance of error terms (Hair *et al.*, 2006).

Binary logistic regression (BLR) was used to analyze the socio-economic factors affecting the adoption of ICS. The BLR was used to explain the effects of independent variables (age, education, occupation, income, knowledge about ICS and cultural practices) on the dependent variable (stove) at 95% confidence level. The regression model used is

Ln (P/1-P) $\beta_1 X_1$

Where

Ln (P/1-P) = the dependent variable thus the Probability of adopting ICS

B_0 = intercept / constant of the dependent variable

B_1= intercept or constant of the independent variable (socio economic factor)

X_1 = independent variable socio-economic factor

Pearson and Spearman correlation were used to measure the strength of association between type of stove and socio-economic variables stated in this study. Chi-square was used to test the relationship between type of stove and health issues, which were categorical. T. test was used to analyze significant difference between the means of fire wood consumption and emissions of (CO and $PM_{2.5}$) from ICS and 'T3SS' in the CCT. Further differences in fuel consumption and emission from ICS and 'T3SS' from various communities was obtained using Onaway Anova with Post Hoc analysis. All statistical tests were conducted at 5% significance level. These statistical tests provided basis for accepting or rejecting the hypothesis in this study. Base maps of reforested areas was presented using Remote Sensing and GIS imagery.

The CCT protocol and formulae applied to calculate the performance indicators of the stoves were derived from the testing protocol developed by Bailis (2007).

- **Total weight of food cooked (g) (W_f) = $\sum_{j=1}^{3} (P_{jf} - P_j)$**

  Where:

  J = Index of empty cooking pot (3)

  Pj_f = Weight of Pot after cooking

  Pj = Weight of Pot before cooking

- **Weight of char remaining after cooking (g)** $\Delta C_C = Cc - k$

  Where:

  Cc = Weight of Char container and Charcoal (g)

  K = Weight of Pot After cooking (g)

- **Equivalent dry wood consumed** $(f_d) = (f_f - f_i) * \{1 - (1.12 * m)\} - 1.5 * \Delta Cc$

  f_f = Final weight of fuelwood (g)

  f_i = Initial weight of fuelwood (g)

  m = Wood moisture content (% - wet basis)

  Δ**Cc** = Weight of Char remaining after cooking

- **Total cooking time (Mins)** $\Delta t = t_f - t_i$

Where t_i = Initial cooking time (Mins)

  t_f = finial cooking time (Mins)

  Wf = Total weight of food cooked

- **Specific fuel consumption: (g/kg)** **SC** = fd / (Wf*1000)

3.10 Ethical Consideration

The Ethics Committee for Basic and Applied Sciences (ECBAS), University of Ghana, Legon granted ethical clearance for this research.

The purpose of the study, as presented for ethical clearance, was to know if the improved cookstoves that was given to respondents by VRA were reducing the use of trees for fuel along the Volta Lake and enquire reasons behind low adoption of ICS was explained to respondents. The participants were notified on length of time of the study, their roles in the study and use of their pictures for academic purposes.

3.10.1 Study Precautions

Risk of the study included burns from open fires and stomachaches but participants were assured of first Aid from health personnel from VRA health department and transfer to hospital when necessary.

Participants were assured of confidentiality of information provided and information was solely used for academic purposes. Participation in this research was voluntary hence; participants had the freewill to withdraw from the study without any penalties.

3.11 Limitations

The study was limited to cover households that use firewood for cooking activities and those using their ICS. The sample size of 220 intended for the study was not achieved because some of the respondents were not willing to participate in the study. Availability of respondents for interviews and questionnaire filling was difficult since some of the respondents were busy attending to their economic activities.

CHAPTER FOUR

RESULTS

This chapter presents the results of the study that focused on socio-economic determinants of Improved Cook Stoves (ICS) adoption, cause of deforestation, perception of ICS from households, benefits and problems of using ICS and Traditional Three Sone Stoves (T3SS) are presented.

4.1 Demographic features of household respondents

A total of 162 respondents from ten (10) communities in three (3) districts namely; Biakoye (Odormitor, Adzamasu and Ablonga), North and South Dayi (Awatey, Aveme, Abui, Agordeke and Kpeve Tornu) and Kpando Municipality (Dafor Tornu, and Dzigbe-Avertikope) were engaged for questionnaire administration in this study. Table 4.1 illustrates the distribution of respondents and number of stoves in study areas.

Table 4. 1: Number of communities and Stoves used for questionnaire administration.

	Stoves		
Oti region (Biakoye district)	**ICS**	**'T3SS'**	**Total**
Ablonga	19	12	31
Adzamasu	4	11	15
Odormitor	5	7	12
Volta (Kpando Municipality)			
Dafor –Tornu	6	11	17
Dzigbe Avertikope	6	9	15
Volta (North Dayi)			
Awatey	8	10	18
Aveme	10	9	19
Volta (South Dayi)			
Abui	3	10	13
Agordeke	4	7	11
Kpeve Tornu	8	3	11
Total	**73**	**89**	**162**

Majority of the respondents for the study were women constituting 92% with males constituting 8%. This is not surprising because societal roles place women at the center of household chores. The males who were using the stoves were single, divorced or widowed as at the time of the study.

The study involved 73% users of ICS and 83% users of 'T3SS'. In addition, 75% of users of both stoves were married, 9% divorced, 5% single and 12% widowed. About 44% of the respondents using ICS and 'T3SS' had household size in the range of 6-8 person at the time of the study.

Most cook areas were thatch shed (34%), closed mud building with thatch roofing (33%) for ICS users and 'T3SS' users mainly had their cook areas in thatch shed (39%) and the rest in cement building with aluminum roofing or semi closed mud building with thatch roofing as shown in Plate 3.1 and 3.2 in Chapter 3.

About 36% of respondents were within the age groups (20-29), age groups 30-39 constituted 33.3%, 23.5% represented age groups 40-49 and 6.2% of respondents within the age group 50-59 at the time of the study. This meant most of the respondents were within the age groups 20 to 39 making quite a young cohort. Pearson's correlation between age and adoption of ICS shows that the coefficient of correlation (r) is -.488 at p-value 0.000 i.e. $p<0.05$ as shown in Table 4.3. This meant age was negatively associated with stove adoption and statistically significant.

The study revealed that 36% of stove users received Junior High School Education with 26% who had attended primary level of schooling whereas 2% had attained secondary education but 36% of the respondents have had no formal education. Pearson's correlation between educational level and adoption of ICS showed that the coefficient of correlation (r) is -.095 at p-value 0.228 thus p>

0.05 as shown in Table 4.3. This indicated education is negatively associated adoption of ICS but statistically insignificant. The table 4.2 presents all the demographic features of the study areas.

Table 4. 2: Demographic data of respondents in the study.

Variable	**Category**	**Frequency**	**Percent**
Sex of Respondents	Male	13	8.0
	Female	149	92.0
	Total	162	100.0
Age of Respondents	20-39	58	35.8
	30-39	54	33.3
	40-49	38	23.5
	50-59	10	6.2
	60-69	2	1.2
	Total	162	100.0
Marital Status of Respondents	Single	8	4.9
	Married	121	74.7
	Divorced	14	8.6
	Widowed	19	11.7
	Total	162	100.0
Educational Level of Respondents	No formal education	58	35.8
	Primary	42	25.9
	Junior high school	59	36.4
	Secondary	3	1.9
	Total	162	100.0
Occupation of Respondents	Farming	58	35.8
	Fishing	4	2.5
	smoke/fry fish/cook to sell	64	39.5

	Trader	22	13.6
	gari /oil processing	5	3.1
	civil/public servant	2	1.2
	Craft	7	4.3
	Total	162	100.0
Monthly Income of respondents	100 & below	60	37.0
	101-200	64	39.5
	201-300	22	13.6
	301-400	12	7.4
	401-500	3	1.9
	above 500	1	.6
	Total	162	100.0
Household size	below 3	11	6.8
	3-5	44	27.2
	6-8	71	43.8
	above 8	36	22.2
	Total	162	100

Occupations of households included farming, fishing, smoking or frying fish, cooking in bulk to sell and gari or oil processing. Fish smokers and fryers made up 40% of the occupations observed whereas farming recorded 36%. Traders, gari or oil processors, civil servants and artisans recorded 14%, 3.1%, 1.2% and 4.3% respectively. Pearson's correlation between occupations and adoption of ICS shown in Table 4.3 indicated that the coefficient of correlation (r) was .037 at p-value 0.637 indicating $p>0.05$. This meant occupation associated with the adoption of ICS.

In addition, 37% of the respondents had monthly incomes <100 to 100 Cedis and 39.5% had monthly income between 101 to 200 Cedis. Spearman's rho correlation between income and adoption of ICS shown in Table 4.3 showed that the coefficient of correlation (r) was -.144 at p-value 0.067 i.e. p>0.05. This meant that income level is negatively associated with the adoption of ICS but not statistically significant.

Table 4. 3: Correlation results for strength of association between socio- economic variables and stove adoption

		Age	knowledge about ICS	cultural practices	health issues	monthly income	Occupation	Stove user education
type of stove	Pearson Correlation	-.488**	.178*	-.475**	-.873**	-.137	.037	-.095
	Sig. (2-tailed)	.000	.024	.000	.000	.081	.637	.228
	N	162	162	162	162	162	162	162

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.2 Fuel use

4.2.1 Type of fuel used for cooking

The study discovered that firewood usage contributed 51.9% of the main source of fuel for cooking, which is not surprising because most of the households used ‘T3SS’ and ICS to prepare their meals. About 37% of the firewood used for cooking activities were collected, whereas 33.3% of the respondents solely purchased firewood. Those who collected and bought firewood at the same time constituted 30.9%.

4.2.2 Source of firewood

Those who collect firewood obtained them from various sources ranging from the farm, picking dead wood around or from the bush. A Focus Group Discussion (FGD) revealed that people, who collected firewood from farms, harvested the trees from their own farms for firewood, charcoal burning for domestic use or sometimes sold to supplement their income.

A respondent indicated; *"most often, people cut trees from their own farms. Farm labourers can also harvest firewood from their employers' farm. Those of us who don't own farms just gather firewood around or buy it"*.

4.2.3 Time spent collecting firewood

Members of the various communities walk long distances in search of firewood for cooking activities. About 42% of the respondents thus walk over an hour in search of firewood. Those who use between 50 to 60 minutes to collect firewood constituted 15.9%. Most the firewood gathered after the long search is not fully mature as shown in Plate 4.1. The study showed that, only a few of the respondents walked between 20 to 50 minutes to gather their firewood.

An informant in an interview revealed that, "*These days we spend lots of time searching for firewood because there are no trees around. You have to walk long distances to get a few and they are not matured enough, but you have to cut and use it like that because it is expensive to purchase".*

Plate 4. 1: Pile of young trees gathered for firewood in a household.

4.2.4 Amount spent on firewood and frequency of purchase

A greater proportion of households who purchased firewood spent about six (6) to twenty-five (25) Cedis twice per week. Other respondents' spent 50 to 250 Cedis every day or two times in a week or monthly. These respondents' are those involved in frying/smoking fish for sale, processing gari, oil or cooking in bulk to sell. These occupations require large amounts of firewood. However, data indicates that, a few households who fried /smoked fish in small quantities bought more firewood as well. Most respondents, who bought firewood, got them in huge quantities. Table 4.4 shows a summary on fuel usage in the study areas.

Table 4. 4: Summary of fuel usage in the study areas.

Variable	**Category**	**Frequency**	**Percent**
Fuel for cooking	Firewood	84	51.9
	Charcoal	2	1.2
	Firewood & charcoal	76	46.9
How fuel was obtained	Collected	58	35.8
	Bought	54	33.3
	Collected & bought	50	30.9
Where fuel was collected	Farm	22	36.1
	Bush	24	39.3
	Pick around	1	1.6
	By Lake	14	23
Time spent collecting fuel	<20	4	3.7
	20-30	23	21.5
	31-40	11	10.3
	41-50	7	6.5
	51-60	17	15.9
	> 60	45	42.1
Amount spent on buying fuel	<5	9	8.5
	6-10	24	22.6
	11-15	10	9.4
	16-20	16	15.1
	21-25	16	15.1
	26-30	7	6.6
	50 -250	24	22.6

4.3 Knowledge about ICS

The study delved into knowledge about ICS, and revealed that 96.3% constituting both stove users were aware of ICS commonly known as "VRA stove" as presented Table 4.5. Respondents attested to the fact that field officers from VRA educated them about the ICS before giving it to benefactors. The education highlighted the reasons why they should use ICS and benefits associated with its use.

An interview with the VRA field officer revealed that, *"we educated all the members in the various communities before introducing the stoves. They are all aware of why VRA wants them to use the stoves and the benefits in using ICS to them and to the whole country"*.

Table 4. 5: Stove users and their knowledge on ICS

Type of stove	**Knowledge about ICS**		
	Yes	**No**	**Total**
ICS	73	0	73
'T3SS'	83	6	89
Total	**156**	**6**	**162**

At the time of the study, only six respondents indicated that they had no knowledge about ICS (Table 4.5) in their various communities. This is ascribed to the fact that they did not attend the educational seminar held in their communities by the VRA field officials. Even though most of the respondents knew about the benefits from the use of ICS, they were reluctant to adopt the ICS. Based on information gathered, some respondents said they could not part ways with the use of 'T3SS' because they have some cultural significance (preparing medicine and repelling insects) use of the 'T3SS', which ICS cannot provide for them.

Pearson's correlation between knowledge about ICS and ICS adoption shows that the coefficient of correlation (r) is 0.178 at p-value 0.024 (Table 4.3). This indicates a weak correlation; the relationship is however significant.

4.4 Factors limiting the adoption of ICS

4.4.1. Cost of ICS

The Environment and Sustainable Development Department of VRA indicated ICS was molded freely for ten (10) lucky participants who balloted (Yes) at the end of the ICS education in all communities. This was confirmed when all the ICS users stated they were given the ICS at no cost. Those who were not lucky were asked to request for the ICS by paying some amount, for the materials like chimney, iron-rod and the pot area designer. The cost of getting an ICS ranged from 50 to 420 Cedis where the cost of commercial ICS was higher than domestic one.

FGD of 'T3SS' users revealed paying for ICS was a factor affecting its adoption. A FGD member lamented, "*I do not understand why they did it for some people freely and they want the rest of us to pay, even if I want to pay, I cannot pay anything more than thirty (30) Cedis. That is even too much for a stove".*

From the FGD, some 'T3SS' users were willing to get some of the materials by themselves for the cost to reduce but they had not been able to communicate with the VRA officials at the time of the study. The study also found out the prices were different in the communities of the study area.

A FGD Discussant stated, "We *want the ICS but they told us to pay for the iron rod and chimney, some of us can get the iron rod so we want them to reduce the cost".*

All 'T3SS' users indicated they want the ICS made for them at no cost. Majority, 78.7% of them are willing to use the ICS if made for them at no cost. Some of the respondents who were still using 'T3SS' have no interest in ICS because they cooked in an open space. If they have to adopt ICS, they need to build kitchen or at least make a shed but they are financially constraint, hence, they are comfortable with the 'T3SS' because it is very easy to repair if destroyed.

4.4.2. Other uses of 'T3SS' limiting the adoption and of ICS

The study also indicated that households using 'T3SS' used it for other activities apart from cooking. Majority of the respondents constituting 71.4% used the smoke from 'T3SS' as post-harvest safeguard to repels insects from destroying their harvested maize, 62.9% of the respondents said they used 'T3SS' to warm themselves in the evening when was cold and 20% of households reported they used 'T3SS' to provide light (mainly at Odormitor) for the evening. Pearson's correlation between other uses of 'T3SS' and adoption of ICS showed a coefficient of correlation (r) of -.475 at p-value 0.000 thus $p<0.05$ (Table 4.3). Thus, cultural practice was negatively correlated to adoption of the ICS and was statistically significant.

Key informant revealed, "*We prefer 'T3SS' because we set fire in the 'T3SS' and used the smoke to preserve our harvested maize".* The Figure 4.1 shows the reasons limiting the adoption of ICS because of other uses for 'T3SS'.

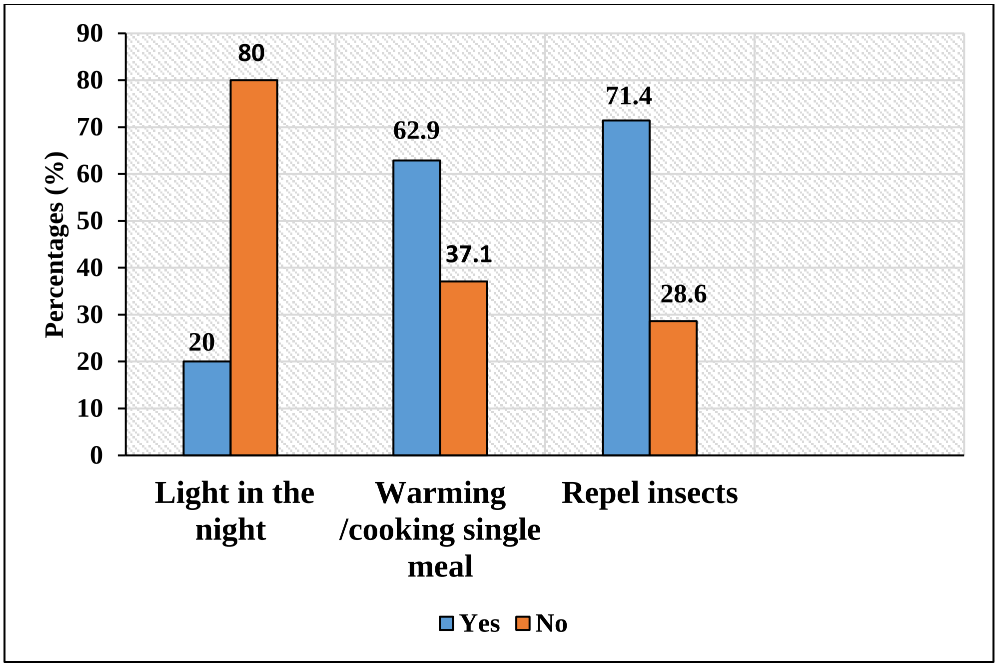


Figure 4. 1: Other uses of 'T3SS' limiting adoption of ICS

4.4.3. Limitations associated with the use of ICS

The major problem found out from the study was the inability of ICS to carry large cooking pots for large scale cooking, frying, and smoking of fish. The other problem indicated was the chimney. The respondents indicated the chimney could get excessively hot and sometimes become dangerous as it burns when touched. Others also complained that the chimney was not long enough to pass through the thatch roofing, hence, causing smoke and fine particles from the stove to burn their thatch instead of the smoke going out. Another issue with the chimney was the top cover, which was too small, thus, allowing rainwater to drip over the stems into the kitchen and melts the ICS, since it was made from clay.

For some communities like Adzamasu, their challenge with the ICS was the clay used in molding the stove. The members of the communities believed the physical components of the clay in that community was not malleable, causing all the stoves to crack within a short period.

In addition, some of the respondents blamed the VRA field officials for rushing the molding of the stove. According to them, the clay must be kneaded, left down for some days to increase its malleability before use. However, because the stoves were molded immediately after the education about the ICS, the clay was not malleable enough but was used to mold the stove and this resulted in cracking of most of the stoves hence, they abandonment of the ICSs by some.

A discussant in the FGD revealed that, *"VRA did not tell us they were coming to construct stoves for us. We need to mix the clay down before we use. We suffered with the stove because they cracked and we had to reconstruct it. It was very time consuming. The clay must be kneaded and left for a minimum of 3 days. Those who could not repair theirs abandoned them".*

In addition, a few users constituting 3.6% lamented about the inability to cook "Banku" on the ICS because it was uncomfortable and causing frequent cracks in ICS as indicated in Figure 4.2, Plate 4.2 and Plate 4.3.

A discussant stated, "*I cook in bulk to sell using a big saucepan, The VRA stove is small for my saucepan. That is why it does not really interest me to get it"*. The factors limiting the use of ICS and affecting its adoption in the study areas are presented in the Figure 4.2.

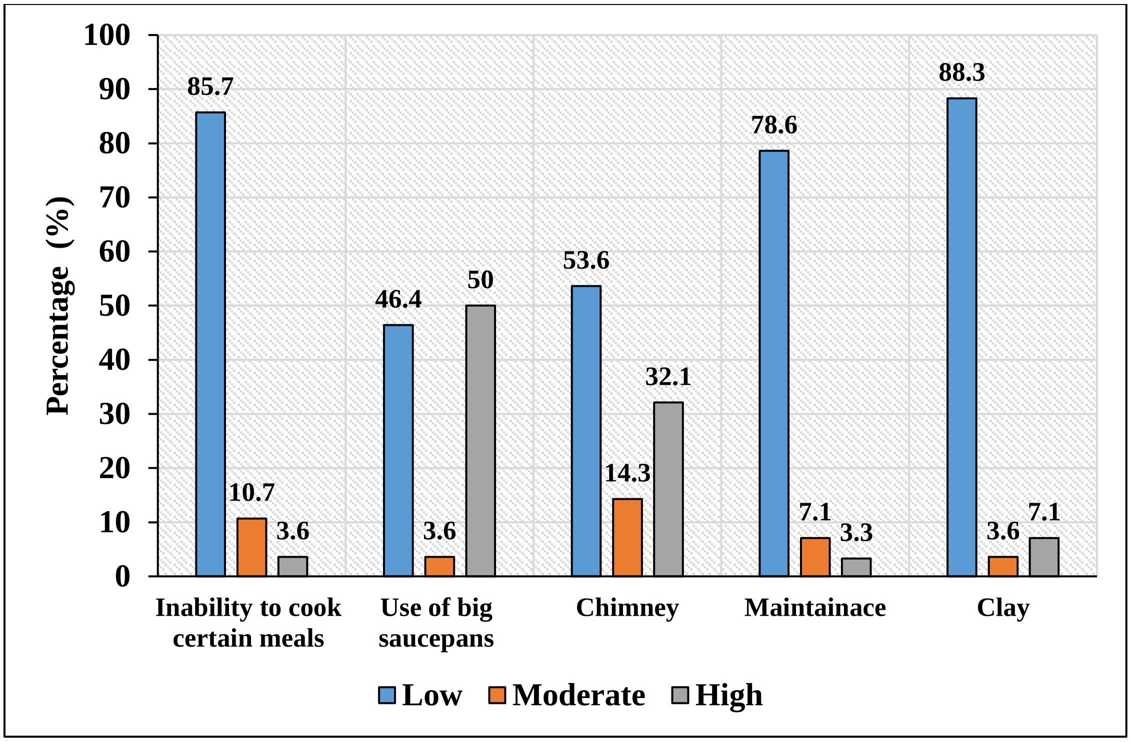


Figure 4. 2: Limitations associated with the use of ICS

Plates 4. 2: Cracked ICS

Plates 4. 3: Perforated chimney of an ICS

4.4.4 Analysis to assess socio-economic factors influencing adoption of ICS

Socio-economic variables selected included age, education, occupation, income, knowledge about the ICS and other uses of 'T3SS'. At least one or more of these variables are assumed to influence the adoption of ICS. Independent variables (socio- economic factors) were described under the demographic information. These descriptions were further tested to validate the claims made by respondents. Using Binary Logistic Regression, age was the only statistically significant variable affecting adoption of ICS with a p-value of 0.000 i.e. $p < 0.05$, whereas knowledge about ICS and other uses of "T3SS recorded p-values of 0.099 and 0.097 respectively (> 0.05) at a confidence level of 95% (Table 4.14). This indicated that, the adoption of ICS was likely to increase, as people grew older.

4.5 Perception of ICS as an innovation and benefits to health and the environmental

Users of ICS generally perceived the ICS to be an innovation or an improvement in their lives. They also believe those who were using it were very concerned about their health (Figure 4.3). About 33% users indicated that using ICS helped protects the environment (Figure 4.3). However, 74% of 'T3SS' users did not perceive ICS as a status symbol or special; the remaining 26% saw ICS as an improvement in lives and having clean kitchens, clean utensils and non-smelly clothes.

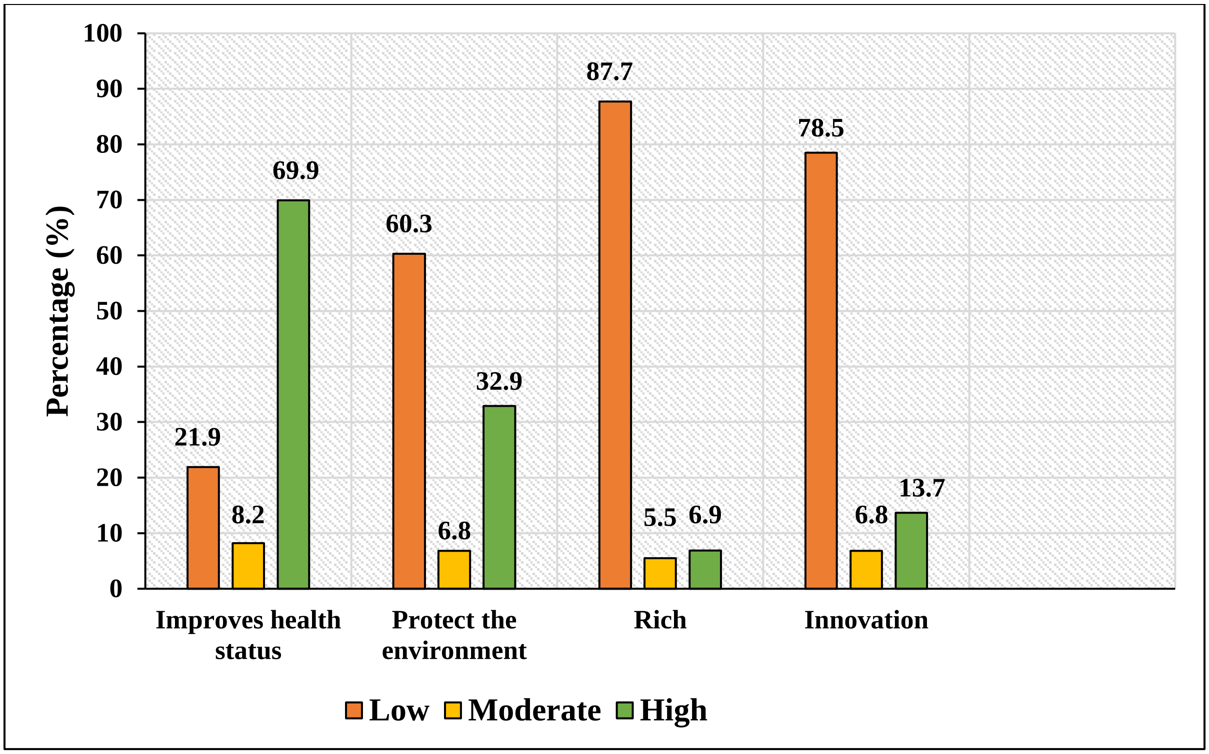


Figure 4.3: Perception of respondents about ICS as an innovation and its impacts on environment and health

4.6 Stove use and self-reported health status

Data gathered on the rating of ICS by its users showed absence of smoke in the kitchen, which was rated highly at 78.1%. Some 'T3SS' users have shown interest in adopting the ICS because 87.6% believe 'T3SS' has an effect on their health.

A discussant confirmed by stating *"the 'T3SS' is what we always use. We feel it is simple but it gives a lot of smoke, which affects our eyes; our utensils are always black and our dress smells of smoke anytime we cook. We also use lots of fuel as compared to the ICS users".*

About 62% of 'T3SS' users believe, it affected their health but only visited the hospital when they were sick or have checkups by mobile clinics organized by Non-Governmental Organizations in the area. Yet, others did not report to the hospital or clinic because they felt the smoke out of the 'T3SS' was normal and visiting the hospital was a waste of time and expensive. They rather relied on herbalist and painkillers. The study showed most households constituting 98.8% were affected by smoke, which made them, felt extreme pain in their eyes, headache, coughing, heat stress and triggered respiratory diseases like asthma (Figure 4.4).

Pearson's correlation between health and adoption of ICS showed that a coefficient correlation (r) of -.873 at p-value 0.000 thus $p<0.05$ (Table 4.3). This meant that health issues are strongly and negatively associated with the adoption of ICS; the relationship is statistically significant. Most of the health issues are caused by the smoke released from burning of firewood in the 'T3SS' as shown in plate 4.4. The higher the adoption of ICS, the lower people suffer from smoke.

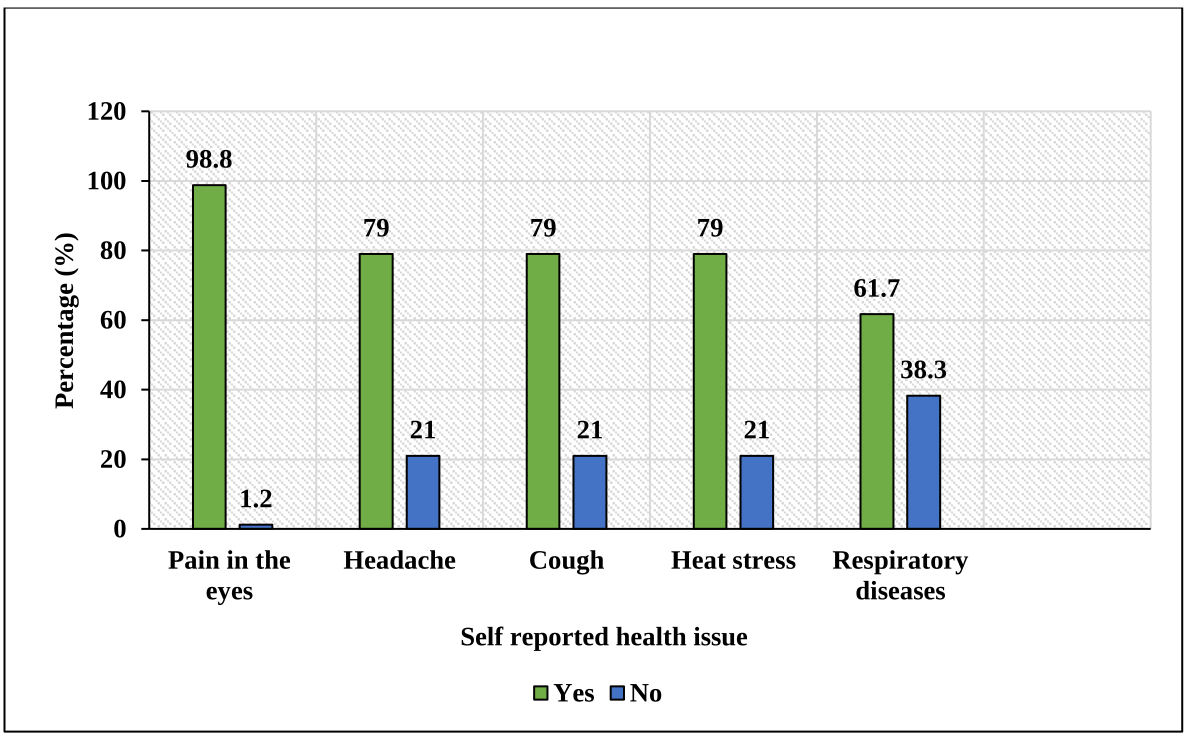


Figure 4. 3: Self-reported health problems faced by 'T3SS' users.

Plates 4.4: Release of smoke from 'T3SS' during a cooking activity

4.6.1 Statistical Analysis

Health Issues

Using Chi-square, the odds of developing self-reported health issues when using ICS was 0% (yes/no) i.e. (0/73), while the odds of developing self-reported health issues 'T3SS' was 7.09% (yes/no) i.e. (78/11). Health issues were dependent on type of stove used (Table 4.15).

A discussant in FGD revealed, "*the heat that comes out of 'T3SS' is a lot, my skin used to burn and become black; sleeping was very difficult for me, because my eyes itch every night but now I sleep soundly".*

For respiratory diseases most of the ICS users attested that, coughing and attacks on asthmatic patients' had reduced even though there was no hospital data to prove their claims.

Controlled Cooking Test (CCT)

An independent t. test analysis on CCT showed ICS emitted lower concentration rates of CO (M=0.77, SD=1.39) and PM $_{2.5}$ (M=0.57, SD =1.68) when compared to emission rates from 'T3SS' CO (M= 1.79, SD=1.55) and PM $_{2.5}$ (M= 1.13, SD= 1.89) 60 minutes; the difference for each parameter was statistically significant at 95% (Table 4.21). To show where the variations occurred for emissions of CO and $PM_{2.5}$ in communities, a one- way Anova with Post hoc (Turkey) was run on the data sets (see appendices 5 and 6). Generally, the variations in recordings of CO and $PM_{2.5}$ for ICS within the communities were hugely different (p - value = 0.00). However, specific variations at 95% confidence interval was noted between Aveme, Odormitor and Darfor- Tornu, Awatey and Odormitor, Ablonga, Odormitor and Darfo Tornu, Odormitor and Darfo-Tornu as presented in appendix 5 and 6. The one-way Anova was also conducted on emissions from 'T3SS' to identify communities with significant variation. Specific variations at 95 % confidence level existed between Aveme, Awatey, Ablonga, Odormitor and Darfo Tornu), Ablonga and Aveme, Odormitor and Dafor Tornu.

A discussant in FGD revealed, "When *I was pregnant with my first child, I use to visit the hospital frequently, but with my second pregnancy when, I was using the ICS, I never fell ill until I gave birth. I think the old stove was hurting us but we did not know especially the smoke."*

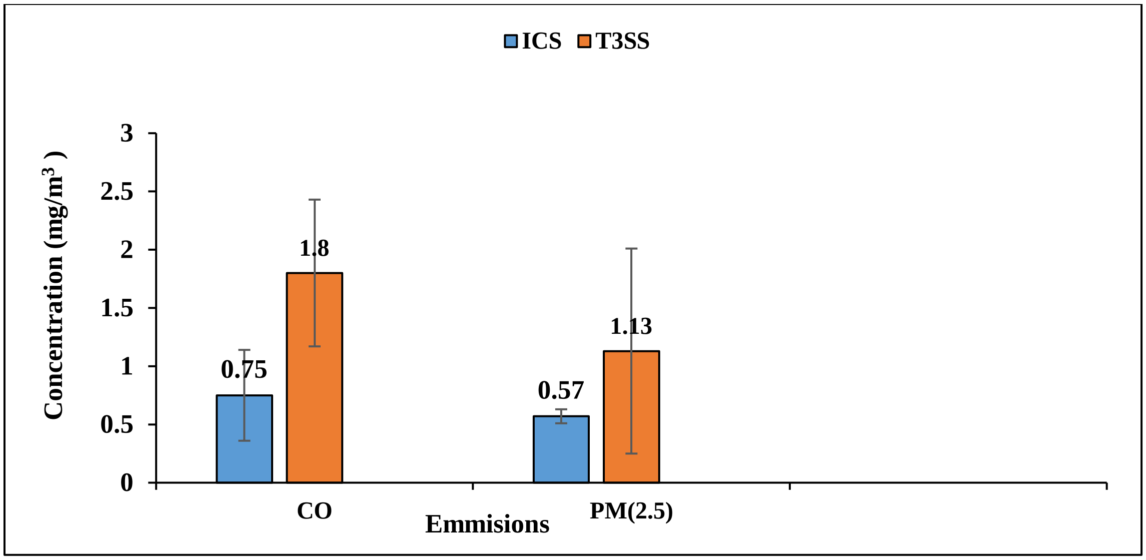


Figure 4. 4: Compared means of emissions from ICS and 'T3SS'

The study further looked at respondent's exposure to Indoor Air Pollution (CO and $PM_{2.5}$) based on communities. Indoor Air Pollution levels were higher from users of ICS in Odormitor and Aveme. The 'T3SS' users in Darfor recorded higher level as illustrated in Figure 4.6.

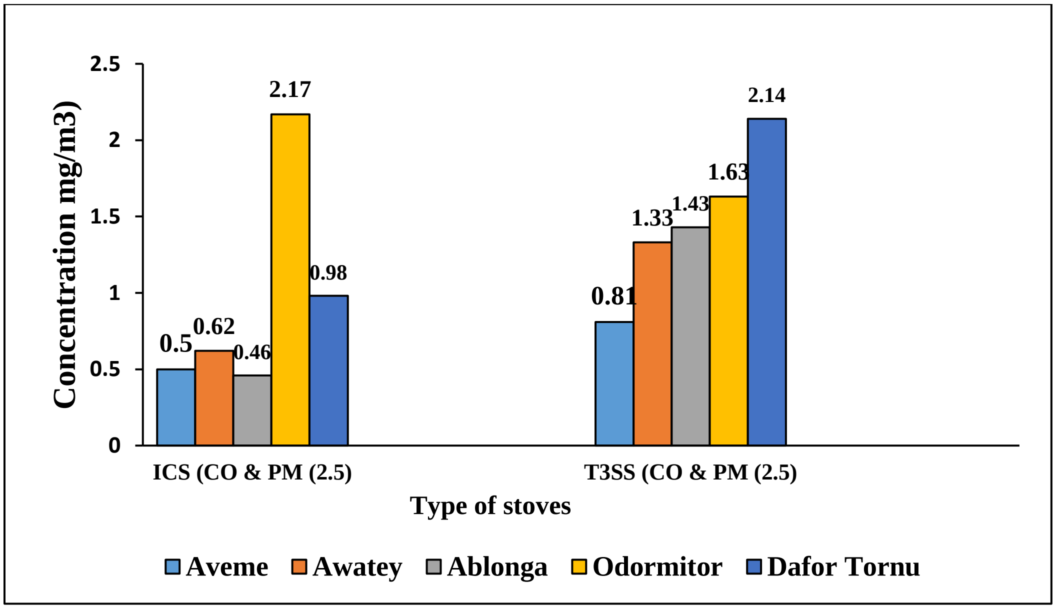


Figure 4.6: Levels of Indoor Air Pollution recorded in kitchens of the study communities

4.7 Major cause of deforestation

Respondents from all communities agreed that most of the trees were cut down for firewood or were burned as charcoal. These two activities recorded 43.8% each as the main cause of deforestation in the study areas. About 13% of the respondents claimed removal of trees was to make way for farming. Bush fire and the cutting of trees to lay traps for fishes in the Volta River (Atidzah) was not a significant cause of deforestation. The causes of deforestation by respondents are shown in Figure 4.7.

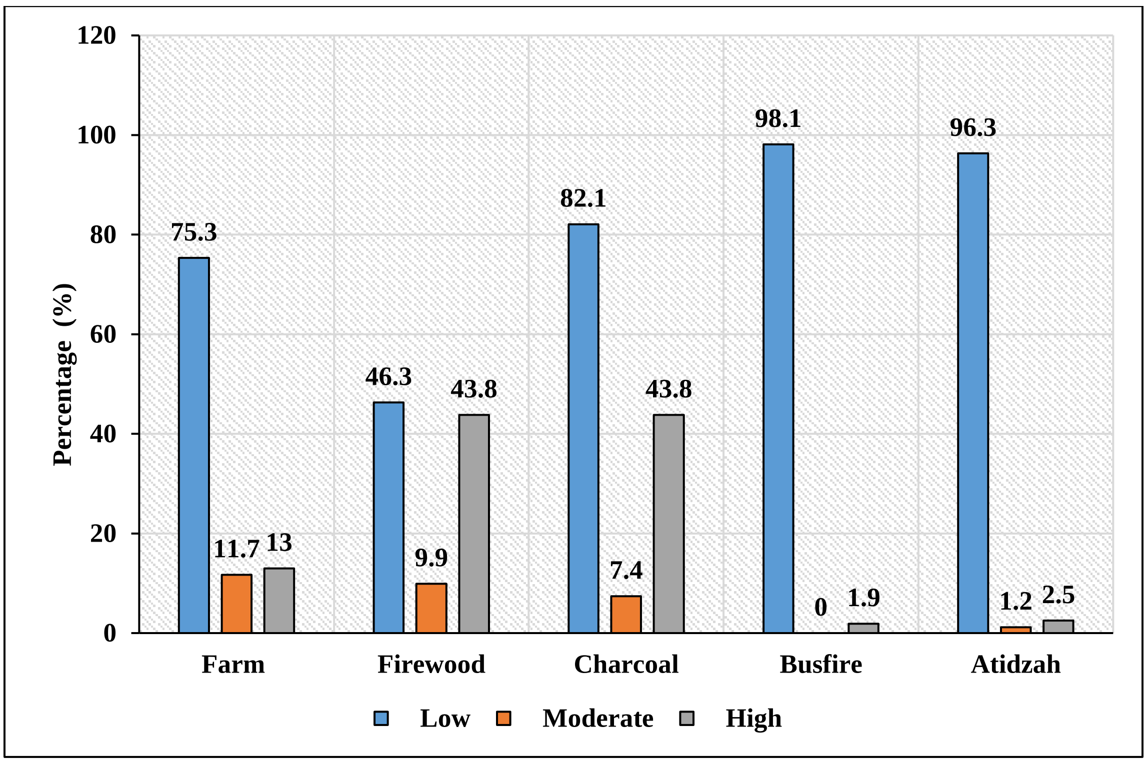


Figure 4.7: Major cause of deforestation

About 41% of respondents using ICS confirmed that, the use of ICS reduces the rate of cutting down trees whereas 42.5% indicated cutting down of trees has not reduced that much. However, 16.4% said the stove has not reduced the rate of tree harvesting (Figure 4.8).

A key informant revealed, *"cutting of trees and buying of firewood has reduced for those of us using ICS, hence to an extent, deforestation has reduced but we are just 10 out of about 350 people. The rest using 'T3SS' are still cutting down more trees; I believe cutting down of trees will reduce totally if we all adopt the ICS and our trees will live longer"*.

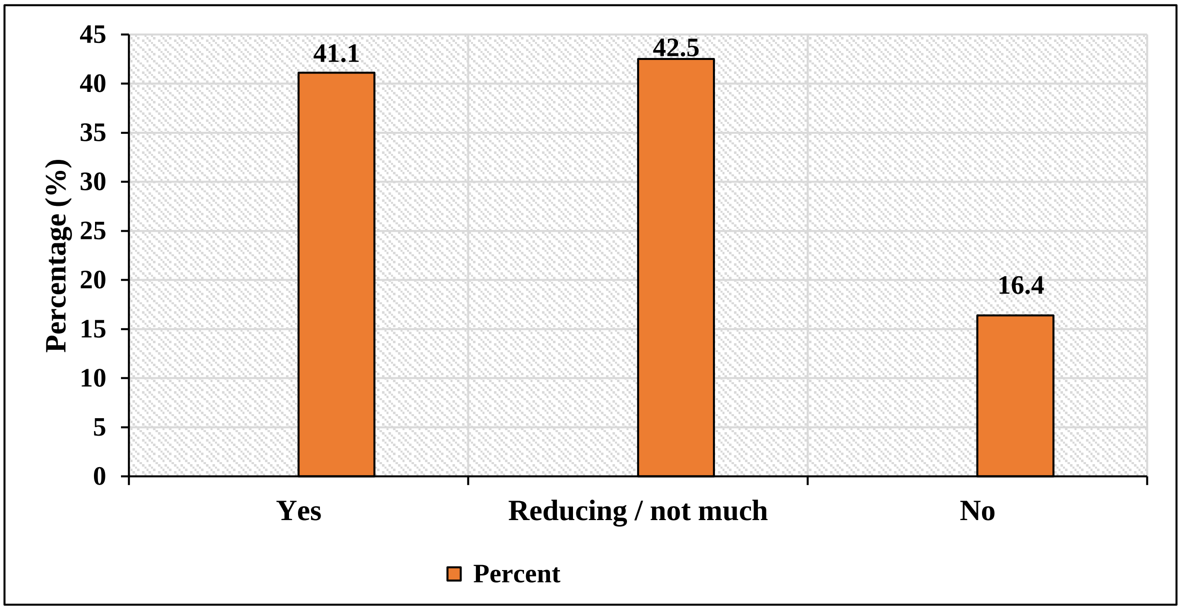


Figure 4.8: State of deforestation in the study areas

The continuous harvesting of trees by commercial operators like lumbers, charcoal and firewood sellers as shown in Plate 4.5 is not reducing deforestation. The respondents alluded to the fact that, most lumbers get their wood from the farms, bush or around the Lake.

A discussant in FGD revealed, *"people who make firewood here get the trees from the bush; there is an embargo on cutting but madam, We are not to smuggle goods but people do, once you cross the border you are fine. It is same as this; once you cut and you are not caught, you make money"*.

An interview with a key informant stated, "*VRA should get people to monitor the place and pay them. I guard the reforested area but I am a farmer, once I leave for the farm, people go there to harvest the trees. The VRA should get a trained guard to monitor the reforested area."*

Plates 4.5: Tree harvesting in the reforested area.

4.7.1 Fuel consumption of ICS compared to 'T3SS'

Seventy-five percent (75%) of ICS users indicated that they spent lower amount of money on the purchase of firewood because they used less. They also claimed they walked fewer distances to collect firewood because a little amount can cater for cooking needs as confirmed by respondent stating that, *"The stove does not produce any smoke and the firewood we use now is small. Formerly we spend lot of hours looking for firewood but now, we spend less time because few pieces of firewood can cook for days".*

4.7.2 Statistical analysis of Controlled Cooking Test (CCT) results

Statistically, the ICS saved 50g (0.05kg) of firewood in the preparation of 2604g (2.604kg) of "Banku". However, t. test showed that the difference was not statistically significant because t (0.693), df (43) and p = (0.492) thus $p > 0.05$ (Table 4.18).

4.8 Awareness creation to ensure sustainable use of ICS

The guidelines put in place by Volta River Authority to ensure the adoption and sustainable use of ICS is education and awareness creation. In assessing the education structure, the study found that education took place once, to introduce the ICS to the people, reasons behind the introduction of the ICS and the benefits from using the ICS. However, during the education and awareness creation, children were not actively involved. A lot of the concentration was on older women and men. In addition, Focus Group Discussions revealed that there was no follow-up to assess if others who were not at the meeting also got the information. The respondents again revealed that the education was conducted in English, translated into 'Ewe', the local language and the respondents found it difficult to fully comprehend the discussions.

A discussant recommended "*VRA should also try to get people who can speak our language 'Ewe'; sometimes the translation is not clear. The language is very important. The education should also be frequent and should be done by women".*

4.9 Benefits of using ICS

Comparatively, all the users of the ICS constituting 100% reported that the ICS has reduced their health issues, which they attributed to the chimney attached to ICS, which directs the smoke out of the cook area. They also indicated that the absence of open fire has also reduced their exposure to heat stress and burns while cooking.

FGD discussant, *"I love the stove because, when I am cooking, the smoke goes straight in to the sky. I do not feel any heat and I am so comfortable. It does not take lots of firewood. ICS is very good".*

Data gathered from the ICS users, showed a generally better performance of ICS compared to 'T3SS' as shown in Figure 4.9.

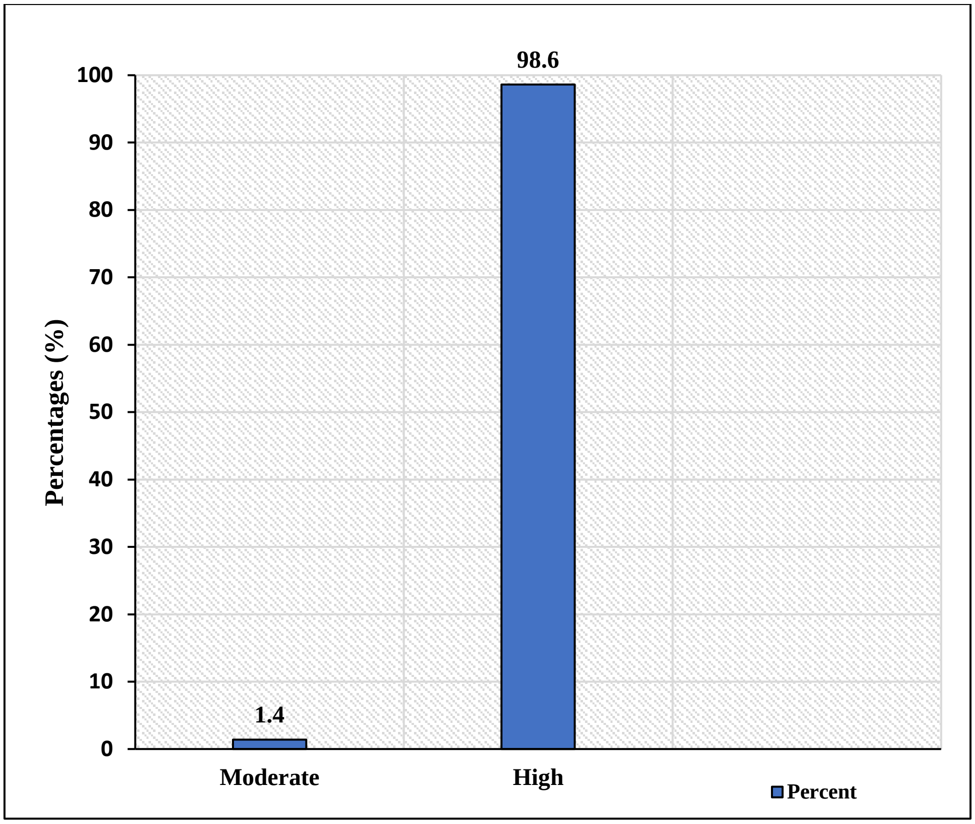
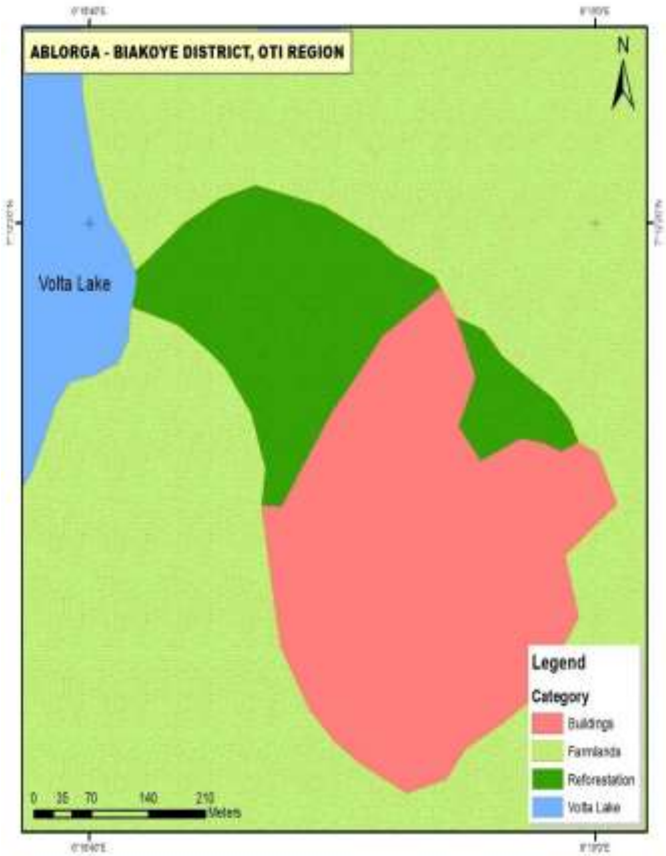


Figure 4. 9: General performance of ICS

4.10 Remote sensing / GIS base maps of reforested areas

Base maps of four (4) of reforested areas were analyzed using Remote Sensing imagery to provide classifications of the areas (Ablonga, Aveme, Odormitor and Kpeve-Tornu) as shown in Plates 4.6 to 4.9. The imagery of the other four (4) communities were too small to be captured in the 10 by 10 pixel. The reforested areas showed low vegetation growth with patches of farmlands very close to the Volta Lake. The study further realized fewer undergrowth's and absence of tree canopy as well as scattered trees (Plate 4.5).



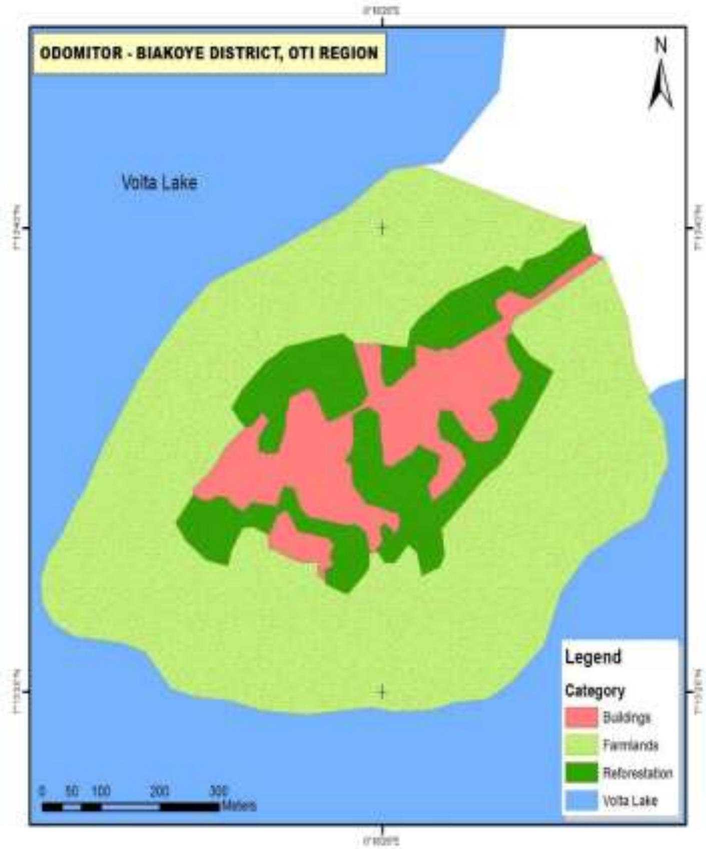


Plate 4.6: Map of reforested area in Ablonga

Plate 4. 7: Map of reforestation area in Odormitor

Ablorgah	Area in sqkm (2018)	Odormitor	Area in sqkm (2018)
Reforestation	0.060	Reforestation	0.086
Farmlands	0.642	Farmlands	0.373
Buildings	0.112	Buildings	0.070

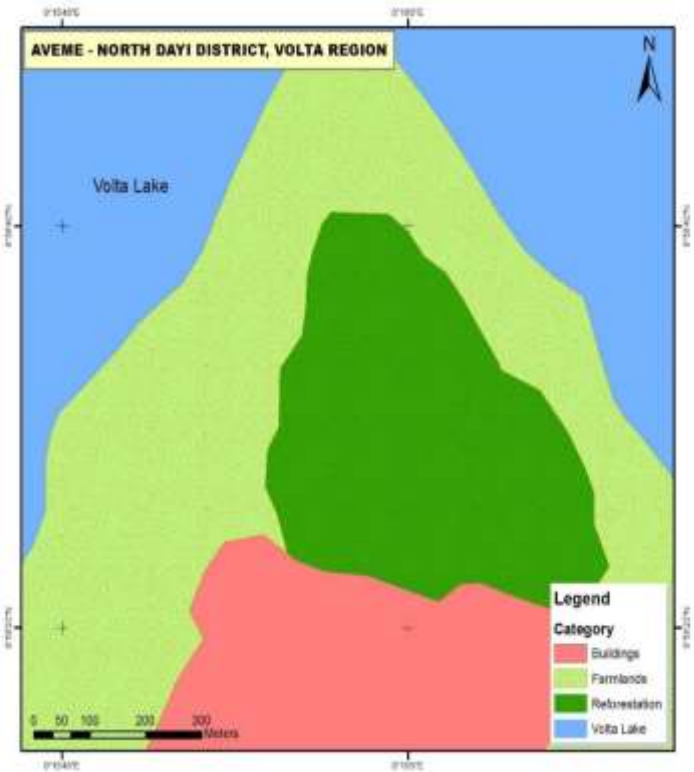


Plate 4.8: Map of reforested area in Aveme

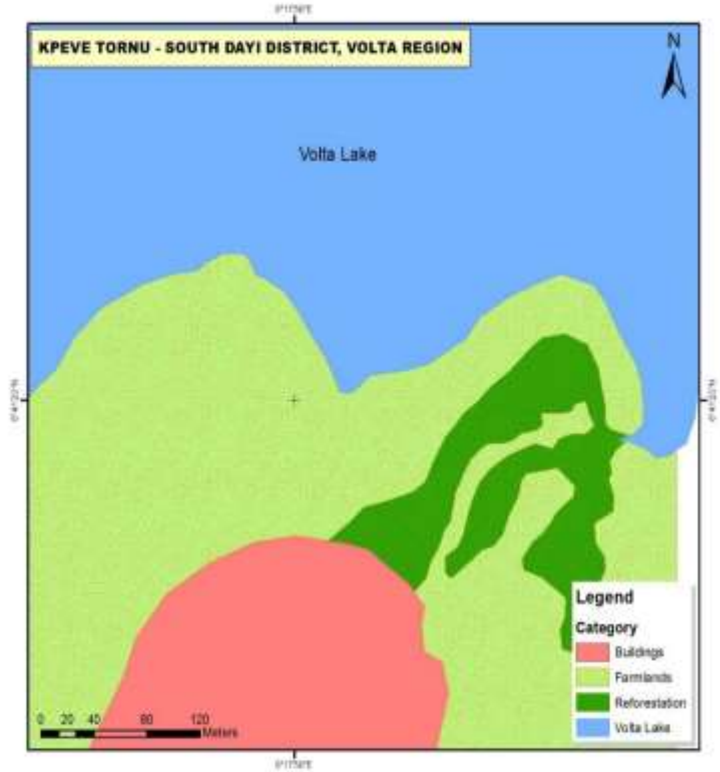


Plate 4.9: Map of reforested area in Kpeve-Tornu

Aveme	Area in sqkm (2018)	Kpeve-Tornu	Area in sqkm (2018)
Reforestation	0.242	Reforestation	0.017
Farmlands	1.019	Farmlands	0.097
Buildings	0.205	Buildings	0.031

4.11. Additional stove use (stove stacking) in the study areas.

The study revealed that those who were using the ICS did not use it alone; rather, they complement it with either 'T3SS', coal pot or metal tripod. The reasons for additional stove use was mainly attributed to bulk cooking. Some of the respondents constituting 43.2% were engaged in smoking or frying fish, others processed gari or oil, and cooking large meals for sale. Another reason given was the difficulty in preparing "Banku" on the ICS; hence, their children mostly preferred to use 'T3SS' because it was more comfortable for them. The ICS have two openings but some of the respondents normally used 'T3SS' or coal pot to warm food or prepare a single meal. Table 4.6, shows the types of stoves used in addition to ICS.

Table 4. 6: Other stoves used in addition to the ICS

Cooking with ICS only	Stove added to ICS				Total
	Metal firewood	Coal pot	'T3SS'	Coalpot &'T3SS'	
Yes	0	0	0	0	0
No	1	19	14	9	43
Total	1	19	14	9	43

Also, 11% respondents among the 'T3SS' users had used ICS before but stopped using them. Their reasons were that, ICS was not convenient for cooking, it had slow cooking rate, it burnt their kitchen or a neighbors', it cracked or the chimney were spoilt (Figure, 4.10).

An FGD revealed that most people were not familiar with the use of ICS, though they were trained on how to use the ICS. Because, it had two openings and the beneficiaries find it difficult to use the ICS when preparing a single meal.

Majority of the respondents' constituting 79.8% believed that the 'T3SS' is very comfortable for cooking. Others also believed it does not cost anything to get the 'T3SS' and it can prepare all their dishes with any saucepan (Figure 4.10 and 4.11).

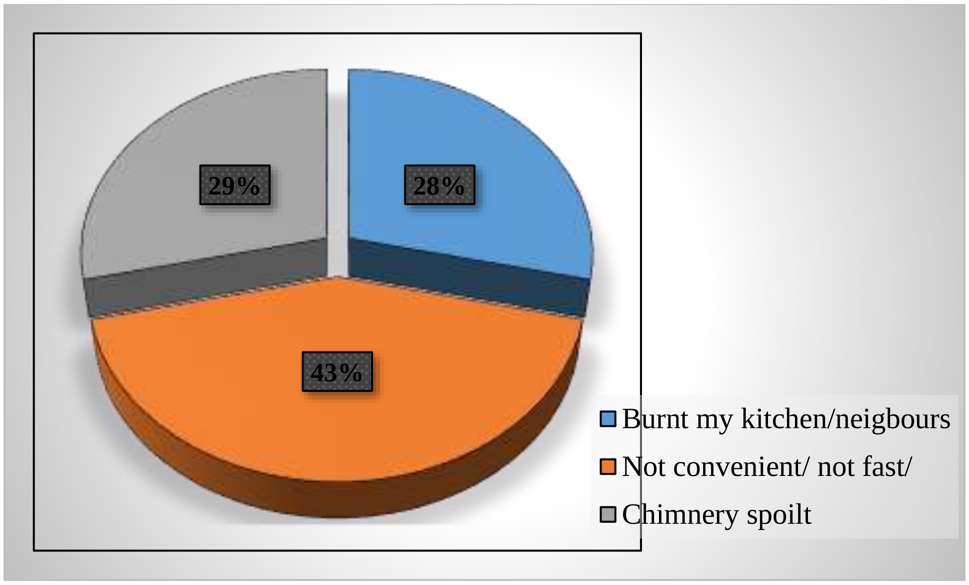


Figure 4. 10: Reasons for abandoning ICS

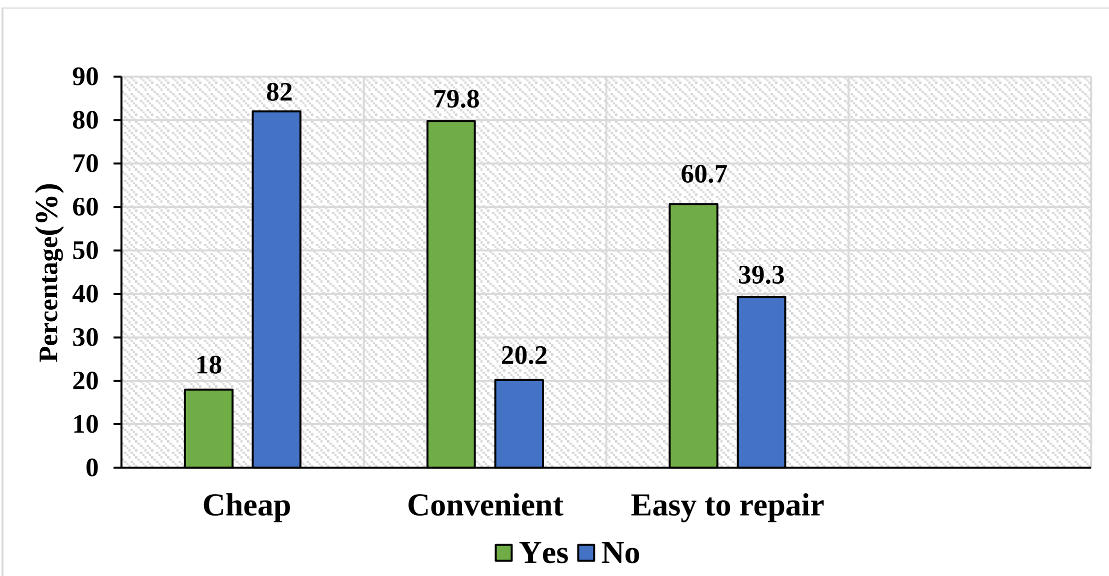


Figure 4. 11: Reasons why respondents preferred 'T3SS'

4.12 Hypothesis Testing Using Binary Logistic Regression (BLR)

The hypothesis tested were

H_0 socio-economic variables do not have significant influence on adoption of ICS

H_1 socio-economic variables have significant influence on adoption of ICS

The socio-economic variables tested were age, education, occupation, income, knowledge about ICS and cultural practices. The regression tested the dependent variable (type of stove) against independent variable (socio-economic factors) to know which of the independent variables were statistically significant. The first stage of the Hypothesis testing referred to as "step 0" tested the dependent variable to know the statically significant variables (Table 4.9). From step 0, only the significant variables were entered into the next step. Table 4.7 shows the number of households that were included in the binary logistic regression.

Table 4. 7: Summary of households in the BLR

Selected cases	N	Percent
Included in analysis	162	100.0
Missing cases	0	.0
Total	162	100.0

Table 4. 8: Value of dependent variable

Dependent variable encoding	
Original value	Internal value
Yes	0
No	1

The Table 4.8 showed the values of dependent variable encoded 0 representing Yes or No representing 1, dependent variable representing ownership of ICS.

Table 4. 9: Classification Table

			Predicted		
			type of stove		
Step 0	Observed		ICS	T3SS	Percentage Correct
	type of stove	ICS	0	73	.0
		T3SS	0	89	100.0
	Overall Percentage				54.9

Table 4. 10: Equation variables

Variables in the Equation							
		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 0	Constant	.198	.158	1.575	1	.209	1.219

The equation for the model is

Ln (P/1-P) = $B_O + \beta_1 X_1$

Ln (P/1-P) = $(0.198) + \beta_1 X_1$ Where;

Ln = Log

P = Probability

Ln (P/1-P) = the dependent variable thus the Probability of adopting ICS

$\mathbf{B_0}$ = intercept or constant of the dependent variable (0.198)

$\mathbf{B_{1}}$= intercept or constant of the independent variable (socio economic factor)

X_1 = independent variable socio economic factor

Looking at Table 4.11, the logistic model explains 42% probability of adopting ICS.

Table 4. 11: Summary of Model

Model Summary			
Step 1	**-2 Log likelihood**	**Cox & Snell R Square**	**Nagelkerke R Square**
	133.673[a]	.424	.567

Table 4. 12: Dependent variable for Socio-economic hypothesis

Variables in the Equation							
		B	**S.E.**	**Wald**	**Df**	**Sig.**	**Exp(B)**
Step 0	**Constant**	.198	.158	1.575	1	.209	1.219

The first step analysis of the BLR showed age, cultural practices and knowledge about the ICS as the only statically significant socio economic factors as shown in Table 4.13.

Table 4. 13: Socio economic variables not in the equation

Socio economic variable snot in the equation				
Variables		Score	df	Sig.
Step 0	Age	38.525	1	.000
	Cultural practices	5.111	1	.024
	Knowledge about ICS	36.619	1	.000
	Education	1.471	1	.225
	Occupation	.226	1	.635
	Income	3.062	1	.080

Table 4. 14: Socio economic variables in the equation

Socio-economic Variables in the equation							
		B	S.E	Wald	df	Sig.	Exp (B)
Step 1[a]	Age	-1.297	-267	23.60	1	.000	.273
	Cultural practices	20.081	14452.118	.000	1	.999	526099817.5740
	Knowledge about ICS	-21.705	6166.787	.000	1	.997	.000
	Constant	**26.896**	**18999.494**	**.000**	**1**	**.999**	**479356238667.439**
a . Variable(s) entered on step 1: only statistically significant Socio-economic factors from Step 0							

These variables entered into step 1 were age, knowledge about ICS and cultural practices as presented in Table 4.14. The BLR showed age to be statically significant variable in affecting adoption of the ICS with a p-value of 0.000 i.e. $p<0.05$.

The BLR equation model for socio-economic factor is

Ln (P/1-P) = $(26.896+ (\beta_{1i}+X_{1i})$

Where $\mathbf{B_{1i}}$ = intercept/ constant for socio-economic variables

$\mathbf{X_{1}i}$ = the respective socio-economic variables

The classification shows that 73 (45%) households own an ICS while 89 (55%) households own 'T3SS'. From the Table 4.9, if everyone own an ICS, the model will be 55% accurate. The Beta Weight "B" is the Intercept is 0.198 and Exp (B) is 1.219. This shows responses of "no" ('T3SS') divided by responses of "yes" i.e. (89/73) as presented in Table 4.10. At a standard error of 0.158, the significance of adopting an ICS is 0.209. This means there is 21% difference in factors influencing adoption ICS when studied in a larger population.

As shown in Table 4.14, the socio-economic variable that is statistically significant is age. Based on the rule of the Hypothesis, at least one of the socio-economic variable must be significant hence H_1 (alternative hypothesis) which states socio-economic factors have significant influence on ICS adoption was accepted the null hypothesis (H_O) is rejected.

4.13 Hypothesis Testing Using Chi-square to establish association between type of stove and self-reported health issues

The hypothesis tested were:

H_O there is no significant relationship between types of stove and self-reported health cases

H_1 there is a significant relationship between type of stove and self-reported health issues.

The Tables 4.15, 4.16 and 4.17 below represent outcome of the statistical analysis.

Table 4. 15: cross tabulation of self-reported health issues and type of stove

			Type of stove		
			ICS	**T3SS**	**Total**
health issues	**yes**	Count	0	78	78
		% within type of stove	0.0%	87.6%	48.1%
		% of Total	0.0%	48.1%	48.1%
	no	Count	73	11	84
		% within type of stove	100.0%	12.4%	51.9%
		% of Total	45.1%	6.8%	51.9%
Total		Count	73	89	162
		% within type of stove	100.0%	100.0%	100.0%
		% of Total	45.1%	54.9%	100.0%

Table 4. 16: Chi-Square Test for strength of association between self-reported health cases and type of stove

	Value	Df	Asymptotic Significance (2 – sided	Exact Sig. (1-sided)
Pearson Chi-Square	123.385a	1	.000	
Continuity Correction	119.900	1	.000	
Likelihood Ratio	157.780	1		
Fisher's Exact Test		1	.000	.000
Linear-by-Linear Association	122.624	1	.000	
N of Valid Cases	162	1	.000	

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 35.15.

b. Computed only for a 2x2 table.

Table 4. 17: Symmetric Measures for Chi-square result between self-reported health cases and type of stove

Nominal by Nominal	Phi	-.873	.000
Nominal by Nominal	Cramer's V	.873	.000
N of Valid Cases		162	

Not assuming the null hypothesis.

Results from Chi-square test indicates a significant relationship between type of stove and self-reported health issues. Thus, 0% likelihood of developing health issues when using ICS while 87% likelihood of developing health issues when using 'T3SS'. Phi's effect also indicated a large effect size (Table 4.17). A rise in self-reported health cases is linked with the use of 'T3SS' whereas the use of ICS is associated with lower self-reported health cases.

The alternative (H_1) which states there is a significant relationship between type of stove and health issues was accepted because p >0.05 and the null (H_o) hypothesis states there no significant relationship between type of stove and health issues was rejected.

4.14 Hypothesis testing using t-test (comparing Means of firewood consumption)

The hypothesis tested were:

H_O there is no significant statistical difference in fuel consumption between ICS and 'T3SS'.

H_1 there is significant statistical difference in fuel consumption between ICS and 'T3SS'.

Based on the procedures (Bailis *et al.*, 2007), each test, for the CCT constituted cooking the same meal three times with different sets of ingredients, firewood and water. With a total of 20 stoves (10 ICS and 10 T3SS), each stove was tested three (3) times thus, 60 tests in all. The average length, diameter and weight of firewood used was 86 cm, 17cm and 53136g (53.14kg) respectively, with a constant moisture level of 16%. The average weight of corn and cassava dough used was 1363g (13.63kg) and 1120g (11.20kg) respectively and thoroughly mixed with 1750g (17.50kg) average volume of water in the size two pot, which weighed 600g (0.60kg). Table 4.18 shows the general outcome of fuel consumption and duration of cooking on ICS and T3SS.

Table 4. 18: t- test of significance on fuel consumption and duration of cooking

Group Statistics

	Stove	N	Mean	Std. Deviation	Std. Error Mean
Specific fuel wood consumption	1.00	30	245.8667	179.84068	32.83427
	2.00	30	295.6667	349.92199	63.88672
Duration	1.00	30	20.4000	7.54115	1.37682
	2.00	30	14.3333	4.22091	.77063

An independent sample t- test was performed to compare fuel consumption between ICS and 'T3SS'. The outcome variable shows, Levene's test for equality of variance was violated p = 0.003 hence the bottom row of results for "t" was interpreted as presented in Table 4.19. Results indicated 'T3SS' (M=295.67, SD=349.93) consumed more firewood than ICS (M = 245.87, SD = 179.84) in the CCT, t (43) = -0.69, as shown in Table 4.18 but not statistically significant ($p > 0.05$).

The null hypothesis (H_O) which states, there is no significant statistical difference in fuel consumption between ICS and 'T3SS' was accepted because $p > 0.05$ and the alternative (H_1) which states there is significant statistical difference in fuel consumption between ICS and 'T3SS' was rejected.

Table 4. 19: Independent Samples t- test on firewood consumption, duration of cooking and type of stove

		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Specific fire wood consumed	Equal variances assumed	9.889	.003	-.693	58	.491	-49.80000	71.83037
	Equal variances not assumed			-.693	43.321	.492	-49.80000	71.83037
Duration	Equal variances assumed	2.214	.142	3.845	58	.000	6.06667	1.57782
	Equal variances not assumed			3.845	45.546	.000	6.06667	1.57782

4.15 Hypothesis testing using t-test comparing emission of CO and PM $_{2.5}$ from stoves.

The hypothesis tested were:

H_O there is no significant statistical difference in CO and PM $_{2.5}$ emission;

H_1 there is significant statistical difference in CO and PM $_{2.5}$ emission.

The outcome variable from independent sample t-test performed shows; Levene's test for equality of variance was violated $p < 0.05$. Hence, the bottom row of results for "t" was interpreted (Table 4.21). Results indicates 'T3SS' (M=1.79, SD=1.55) emitted more CO than ICS (M = 0.75, SD = 1.14) in the CCT, t (1021) = 14.09, and statistically significant ($p < 0.05$). 'T3SS' (M=1.13, SD=1.89) emitted more PM $_{2.5}$ than ICS (M = 0.57, SD = 1.68) in the CCT, t (862) = 5.39, and statistically significant ($p > 0.05$) in preparing 2604g (26.04kg) of "Banku" (Tables 4.20 and 4.21) with standard error margin showing level of variance (Figure 4.5).

The alternative hypothesis (H_1) which states there is a significant difference in emissions of CO and $PM_{2.5}$ from 'T3SS' and ICS was accepted and the null hypothesis (H_O), which states there is no significant difference in emissions of CO and $PM_{2.5}$, from 'T3SS' and ICS was rejected.

Table 4.20: T-test on means of emissions (CO and $PM_{2.5}$) from ICS and T3SS

Group statistics

	type of stove	N	Mean	Std. Deviation	Std. Error Mean
PM	ICS	866	.57062	1.680833	.057117
	T3SS	467	1.13416	1.893995	.087644
CO	ICS	866	.7471	1.13960	.03873
	T3SS	595	1.7943	1.54752	.06344

Table 4.21: Results of independents samples t-test on $PM_{2.5}$ and CO

Independent Samples Test

		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
PM	Equal variances assumed	32.165	.000	-5.582	1331	.000	-.563541	.100952
	Equal variances not assumed			-5.387	862.109	.000	-.563541	.104612
CO	Equal variances assumed	63.019	.000	-14.888	1459	.000	-1.04722	.07034
	Equal variances not assumed			-14.089	1021.699	.000	-1.04722	.07433

4.16 Chapter summary

This chapter presented the results of the study. It was indicated that firewood and charcoal were the major sources of heat energy for cooking, processing of gari and oil at the study communities. As such, fuel wood harvesting as well as bush burning, and farming were the major cause of deforestation along the Volta Lake. Also, age, was the major demographic factor that influenced ICS adoption. Although many acknowledged the health and environmental benefits of ICS, its rigid functionality, repair difficulties and risk of their kitchen catching fire have made them less interested in using the ICS. They prefer the T3SS to the ICS.

CHAPTER 5

DISCUSSION

This chapter presents further insight into the results obtained from this study and a linkage to other studies conducted on the benefits of ICS and the barriers to ICS adoption and its benefits.

5.1 Socio economic factors affecting adoption of Improved Cook Stoves (ICS)

The study observed a general abandonment and low adoption of Improved Cook Stoves (ICS) because the 100 ICS provided by VRA reduced to 73 ICS in use in the study areas. However, in Ablonga in the Biakoye District, the adoption rates increases as they have built new stoves in addition to what VRA provided. This is attributed to the fact that most of the people understood the value of the stove. The trained stove makers in that community took it upon themselves to convince others and built the ICS for them. Further, they have adjusted the stove design to suit their use thus an improvement in what was constructed earlier in terms of size, height and pot area opening. Studies noted that several ICS projects have suffered lower adoption rates because people 'did not value the benefits of it' compared to using 'T3SS' which is more familiar (Lewis & Pattanayak, 2012; Fitzgerald *et al.*, 2012; Pattanayak & Pfaff, 2009; Owusu *et al.*, 2015).

The Binary Logistic Regression (BLR) model revealed age was the only socio-economic factor that contributed statistically to the adoption of ICS and this compared favorably with the findings of Odongo (2017), in his study in Kenya where older people adopted ICS. This meant, as one grew older, the probability of adopting ICS increased. This can have a negative effect on the ICS project because age distribution in the study areas are quite young and if these age groups do not embrace the ICS, the project might not be successful in the future.

Although, education, income, knowledge about ICS, occupation and cultural practices may play significant roles in studies of this nature, the Binary logistic model revealed that they did not contribute significantly to the adoption of ICS in the study areas. This results deviates from findings of Odongo (2017), Owusu *et al*. (2015), Jan (2012) & Omar (2007) who found out age, education, income, occupation, knowledge about ICS significantly affected the adoption of ICSs in their studies conducted in northern region of Ghana, Kenya, Pakistan and Zanzibar.

The study realized the beneficiaries of ICS did not make any conscious decision to purchase ICS based on educational level, occupation, income or knowledge about it. The ICS was molded for individuals who attended the educational seminar and picked "Yes" in a balloting at no cost. There was no criterion for getting the ICS other than applying a balloting system. Once an individual did not receive the ICS, using 'T3SS' irrespective of their income levels or education or knowledge about ICS, became the only option. This meant people with higher incomes could have benefited as well as those with lower incomes, though the former group has the power to purchase. The same applies to education and occupation where anyone with any education level or occupation could have benefited. This is the reason why slightly more than half of the respondents though had knowledge about ICS continued to use the 'T3SS'. This further explained why the socio-economic factors like education, occupation, income, knowledge about ICS and cultural practices did not contribute to the Binary Logistic Regression Model. It was further noted that based on the extended family practice that, the older members represented most families while the young went to attend to their business. This could also be the reason why the respondents with higher age seems to have ICS more than the young ones and age contributed significantly to Binary Logistic Regression.

The qualitative data collected from FGD, key informant-interviews indicated cost of ICS, other uses of 'T3SS' and the limitations associated with ICS use as the barriers affecting adoption of ICS by others and sustained use by beneficiaries.

The study revealed that the cost of getting materials like chimney & iron rods to mold an ICS ranged from 50 to 450 Cedis and this made some respondents reluctant because they felt cheated, as some community members had received it free. Majority of 'T3SS' users indicated they also want the ICS made at no cost for them; those who were willing to pay to get the ICS done for them showed some reluctance to pay anything more than 30 Cedis for the ICS.

The cost of ICS is a determinant factor for its adoption (Fullerton *et al*., (2008). This finding was similar to Grant's study in 2012, which also indicated the cook stove's price was an important factor that affected the adoption decision of respondents. A study by Levine *et al.* (2013) also supported the fact that cost of ICS was an important adoption barrier. Due to the cost of getting ICS, the respondents felt comfortable using 'T3SS' since it cost nothing to get it. In addition, the study noted that the price for getting the materials for ICS varied in all communities. Different price levels did not promote adoption of the ICS but rather limited the interest of adopters. Prices for ICS must be same in all communities for the people to be able to adopt it.

Culturally, 71% of respondents using 'T3SS' revealed that smoke from 'T3SS' served as a post – harvest tool used to preserve harvested maize, while 63% indicated that was used for warming at night. This supports the findings of Keese *et al.* (2017), who noted that some respondents relied on heat from 'T3SS' to warm themselves in Cuzco (Peru). Furthermore, a biomass stove (traditional or improved) heats the room and stays warm for hours. However, because 'T3SS' is relatively cheaper than ICS respondents in the cold mountain environments of Peru preferred to use 'T3SS'. A fewer number of respondents alluded to using 'T3SS' to light their houses at night, which was predominant in Odormitor where there was no electricity as at the time of the study. From the study, the opportunity cost for abandoning the use of 'T3SS' for ICS was huge, hence, adopting ICS was limited, a situation that confirmed Gill (1987) and Rogers (2003), which indicated that diffusion of a new technology will be difficult if the adopters do not perceive it to be better at performing their traditional activities than its counterparts. This also highlighted Barnes (1994), who stated no matter how efficient a new stove is, adopters will be reluctant to adopt ICS if it is not favorable towards their cooking practices. A study by Bielecki & Wingenbach (2014) in rural Guatemala found that adopters of ICS must be willing to sacrifice some cultural attachments to 'T3SS' as seen in this study. Consequently, adopters looked out for stoves that they can use to perform their traditional cooking practices without compromise.

Another feature limiting adoption of ICS was its physical features. Half of the 'T3SS' users who used it for commercial purposes pointed out the pot area of ICS was too small to accommodate their huge frying/smoking trays or huge pots for "Banku" for sale. They also indicated frequent cracks of ICS, suggesting it is not very strong. Others also raised issues about heating of the chimney and transferring smoke to the ceiling that is predominantly made of thatch, as well as general maintenance or repairs of damaged ICS or chimney, which was time consuming. A marginal number of respondents' (7%) noted the physical properties of the clay in the Adzamasu community was not good for ICS making. Rahman *et al*. (2006) in an assessment of existing ICS in Bangladesh revealed that lack of good clay and other components like brush, technology led the users reluctant to reconstruct the damaged ICS in most cases; these were revealed in this present study.

The study noted that chimneys were perforated because the material was thin, the seams of chimneys were not tight enough and this retained the smoke to stay in the cooking area instead of going out. Another interesting finding was in Ablonga where most of the respondents had built new cook areas with cement and roofed with aluminum but the chimneys were not tall (above the roof) enough hence the smoke from the fire was returning into the cooking area. The top of the chimneys was not broad enough hence rainfall usually dripped off the chimneys into the kitchen and melted the ICS since most cook areas were predominantly made with mud. This was also a physical flaw of the ICS, which limited its adoption.

Generally, the study revealed that ICS was not convenient for users as compared to 'T3SS', as some of them could not prepare "Banku" on the ICS and this made adoption of ICS limited. This is because of factors like cultural issues, size, strength and maintenance which affect adoption of ICS as revealed by this study is consistent with several studies (see, Barnes *et al.*, 1994; Chaigneau, 2013, Rehfuess *et al.*, 2014; Odongo, 2017). This revealed cultural practice such as using 'T3SS' for warming, preparing medicine or repelling insects from harvested maize was affecting adoption of ICS. Some of the users indicated that ICS needed extra care to keep it suitable for cooking as it cracked frequently and getting wet after rainfall because of the rain running on the 'Chimney' to the stove. In some cases, users mentioned that it was not possible to cook for large number of family members at a time using ICS, as the design did not allow using large cooking pots, a finding which was consistent with Rahman *et al.* (2006). The study also realized that respondents were just not interested in acquiring the ICS, which was similar to Hanna *et al.* (2016), in a randomized study where the zeal to repair ICS was lacking, leading to abandonment.

The respondents using stove for commercial activities like smoking /frying fish, processing oil/gari could not rely on ICS because it was too small, hence, preferred using 'T3SS' or metal 'T3SS'. Other respondents stacked stoves because they could not conveniently prepare "Banku'' (a traditional meal) on the ICS. Another finding similar to that of Bensch & Peters (2012), observed that the ICS could not be used for all dishes. The study realized children were more comfortable using 'T3SS' because they are not conversant with ICS, an observation which should be severely addressed for sustainable management of the forest. A major advantage of the 'T3SS' stove is its flexibility regarding different pot sizes noted by Gill (1987) and confirmed by Hafner *et al.*, (2018). The dimensions of the holes for pots were predefined for ICSs (Masera *et al.* 2007) and other pot sizes based on Ruiz-Mercado *et al.* (2011) do not fit inside the defined holes of ICSs. Keese *et al*. (2017) also identified issues with pot area sizes. This indicates that the ICS is not as flexible as the 'T3SS' hence also limited adoption of ICS.

Significantly, most people were not used to cooking two food types simultaneously, but using ICS meant this could be done with some difficulty. Ruiz-Mercado *et al.* (2011) and Zamora (2010) found that several households did not use the ICS for all types of cooking activities. Nonetheless, field observations by Hafner *et al.* (2018), DeWan *et al*. (2013) and Burwen & Levine (2012), revealed 'stacking' of stove as a common practice. This is due to cultural cooking practices that the ICS lacks. This goes a long way to indicate that, people will not completely discard their "T3SS if these physical flaws were not addressed.

The study also noted that it was not possible to shift ICS from open place especially during rainy season and from closed/dark environment to an open place during the winter season as revealed by Rahman *et al*. (2006) because the ICS are fixed. The study also found out that people of Ablonga adjusted their buildings to suit the ICS because they appreciated its value, no doubt, most members of that community have built new cook areas that is enclosed and roofed with aluminum. The study also found that out averagely 'T3SS' was often used than ICS, which confirmed similar reports by Burwen & Levine (2012), indicating extensive use of traditional stoves than ICS.

It was observed that, respondents using 'T3SS' at the time of the study had used ICS before and stopped using them because it was not convenient and slow for cooking, while some indicated that the ICS caused fire in their cook area and those who witnessed the incidence stopped using their ICS and others lost interest in adopting it. Other users stopped using ICS because chimney was spoilt and frequent cracking of stoves. A study by Rahman *et al.* (2006) noted similar case where ICS users stopped using

ICS because of damages, inability to get other tools and time consuming to reconstruct ICS. This conforms to Barnes (1994) theory on innovation; that durability and complexity of innovation (ICS) affects its adoption and sustained use. The ICS is an innovation that is quite complex to the members of the study area and this also contributed to cultural factors limiting their interest in adopting the ICS.

5.2 Perception about ICS as an innovation that improves health and environmental status

All the users of ICS perceived it to be an innovation that protected their health and the environment. About 74% of 'T3SS' users saw nothing special about ICS because they indicated ICS has limited use because users of ICS were still using 'T3SS'. The rest 26% saw ICS to be an innovation and special because it took out smoke from the kitchen and left the users' utensils clean, neat kitchen and smell of smoke was out of kitchen. Based on Tebugulwa's research (2015) in central Uganda, the apparent benefits of improved cook stoves over the 'T3SS' influenced their adoption and subsequently continuous use, which supports Barnes *et al*.'s assertion in 1994 that diffusion of an innovation is influenced by apparent attributes of the innovation. Community members of the study areas perceived ICS as a foreign innovation that is not able to fully address their cooking practices. The study realized ICS is very good when compared to TS3S when rated on a Likert scale by its users. Further, this study observed that many prospective users did not prioritize the procurement of ICS despite its benefits, relating similarly to Keese *et al*. (2017) in a follow up study of ICS adoption in Cuzco (Peru), Tebugulwa's (2015) in adoption of ICS in Bunga, Central Uganda. When adopters perceived the ICS to be innovation that they have to compromise some of their traditional cooking practices, then their interest in adoption is limited.

5.3 Impact of ICS

The study observed significant impacts of the use of ICS on the lives of people in the study area. The benefits derived from ICS ranged from socio-economic, health to environmental reforestation. The use of ICS reduced respiratory diseases from less smoke, less usage and purchase of firewood but cooking was slower compared to T3SS.

5.3.1. Health (Self-reported health status)

The study also noted ICS was beneficial due to absence of smoke in the kitchen, which was ascribed to "chimney" attached to the ICS that took smoke out of the kitchen efficiently. The study further revealed that users of ICS no longer felt pain in their eyes, no coughing and no headaches. Respiratory diseases like Asthma attacks reduced as well, which meant that the use of ICS has reduced self-reported health cases.

Health issues emanating from cookstoves is linked to the emission of smoke from combustion of wood releasing toxic gases. Pearson's correlation between health and adoption of ICS showed that the coefficient of correlation (r) was -.873 at p-value 0.000 thus $p < 0.05$ (Table 4.16), which interprets into self-reported issues increasing with the use of 'T3SS' and reducing with the use of ICS. The discussion above indicates that, the adoption of ICS and its usage have a great impact in reducing self-reported health issues of community members, which is part of the reason for the introduction of ICS in the study areas.

The t-test of significance conducted on Controlled Cooking Test (CCT) results revealed ICS reduced CO emission by 58% and $PM_{2.5}$ by 50% when compared to 'T3SS'. This is similar to studies by Suresh *et al. (*2016) and Singh *et al.* (2014) who found out those ICSs reduced the emission of harmful gases and aerosols during CCT in northern India. In addition, $PM_{2.5}$ and CO reduced by 74% and 78% respectively in Mexico using ICS (Bielecki & Wingerbach, 2014). However, a study by Council for the Scientific and Industrial Research, Ghana (2017), realized a 38% reduction in $PM_{2.5}$ emission from the same ICS used in this study, but there was no significant difference in emission of CO from ICS and 'T3SS'.

This similarity indicates that exposure to carbon monoxide and $PM_{2.5}$ is directly related to self-reported health issues. Notably, Guatemalan women reported fewer bouts of recurring headache and less eye discomfort after installation of ICS for cooking (Diaz *et al.*, 2007). Critchley *et al.* (2015) also noted improvements in self-reported respiratory health of women and children due to adoption of ICS. ICS reduces emission of hazardous health pollutants within a small pace of time and reduces greenhouse gas emission in the end (Odongo, 2017; Puzollo *et al.*, 2013; Burwen and Levine, 2012). The reduction of Green House Gas is a vital component for the introduction of ICS in the study areas in order for the Volta River Authority to earn carbon credit.

Although ICS emission of CO and $PM_{2.5}$ were low at 0.75mg/m^3 and 0.57 mg/m^3 respectively, in comparison to 'T3SS' (1.79 mg/m^3 and 1.134 mg/m^3); it was realized that respondents' exposure to indoor air Pollutants like CO and $PM_{2.5}$ (Figure 4.6) exceeded the World Health Organization air quality guidelines of 30mg/m^3 as the average limit for 1-hour exposure (WHO, 2006). The Controlled Cooking Test (CCT) averagely took place within an hour. This meant that respondents were exposed to factors likely to cause respiratory diseases with serious effect on children and unborn babies, since they are likely to spend more than an hour cooking. This could subsequently contribute to smog formation (ground-level ozone) which could cause respiratory problems (Singh *et al.*, 2014). Burwen & Levine (2012) recorded similar findings. These concentrations were high and could result in adverse health effects through reduction in oxygen transfer to the body's organs and tissues.

During the CCT, ICSs emitted some amount of smoke due to failures of the 'chimneys', for example chimney outlet being too low to create strong vacuum effect, seams not well-closed, perforated chimneys, smoking of fish around, cooking and burning in the area. Other observations were improper use of ICS like overloading and pushing firewood too far into the stove, unexpected cooking behavior like removing a pot from the fire for some time or use of a small pot that leaves a space between the pot side and the wall where smoke escaped. These activities were the reasons for difference in recordings of emission of ICS and 'T3SS' as inferred from the ANOVA results presented in (Tables 4.22 and 4.23). These observations confirmed those of Mishra *et al.* (2014) who indicated that habits during cooking practices might influence and could affect duration of cooking and the quantity of fuel consumed.

5.4. Deforestation

Deforestation of the reforestation project embarked on by the Volta River Authority along the Volta Lake to protect water volumes in the Akosombo Reseviour was affecting water volumes and power generation.

The study revealed the major cause of deforestation as firewood harvesting and charcoal burning in the study areas. However, most of the trees for these activities were taken from farms. It was however, unclear, if the primary motive for vegetation removal was for firewood making, charcoal burning or to make new farms. Studies quantifying cause of deforestation are very complex because of multiple use of trees. A study by Omar in (2007), however, noted firewood wood demand as the primary cause for deforestation in poor areas around the globe. Discussions with communities in the study area revealed that charcoal burners usually purchased the wood from lumbers who often got the trees along the Lake or farms. However, because charcoal burning requires large tress, the trimmed portions of rose wood logs were used. Firewood is relatively smaller hence; those ones are easily harvested from the farm.

The study found out that population growth and deforestation played a role in scarcity of firewood. Scarcity was explained in three dimensions, economic scarcity, where there was wood but people could not afford to purchase, seasonal scarcity where rainfall caused wood to be wet and cannot be used, or physical scarcity where wood though available cannot be used because it was not mature enough or small in sizes. Keese *et al.* (2017) also reported on these dimensions of scarcity in their study in Cuzco

(Peru). Deforestation has not reduced in the study areas because of felling of trees for purposes like charcoal burning and farming as shown in Plate 4.5. This action has implications for water conservation in the Lake and hydropower generation. The inability of the tress to grow into forests and form canopy increased the rate of evaporation of water in the Lake as current farming activities also caused siltation from exposed soils hence, reducing water volumes.

Likert scale indicates that ICS promotes fast cooking because it has two openings and is able to save fuel. This translates into money saving because one purchased less firewood. This finding relates favorably to the results of Otieno *et al.* (2014), who found out that users of ICS spent less money on firewood in Kenya.

Users noted frequency of buying fuel had reduced because ICS consumed less fuel and time spent in search for firewood has reduced. According to ICS users, combusting of fuel took place in a closed chamber hence; the user was not exposed to any heat from the stove. Studies by Horrell *et al.* (2008) and Chowdhury *et al.* (2011), in Zimbabwe, Ethiopia and India respectively, found out that the motivation for adoption of ICS by women is the belief that it would reduce fuel wood use and cooking time. Other studies conducted in different parts of the world highlighted fuel and money savings, speed of cooking and comfortability for ICS users as benefits of using ICS by (Grieshop *et al.*, 2011; Ruiz-Mercado *et al.*, 2011; Dresen *et al.*, 2014; Odongo, 2017). These findings were consistent with the results of this research, indicating an improvement in the socio economic wellbeing of most people and their livelihoods in the study areas.

The Controlled Cooking Test (CCT) showed that ICS saved 50g (0.05kg) of firewood constituting 17% used to prepare 2604g (2.604kg) of “Banku” but this was not statistically significant at 95% confident interval in a t-test of significance (Tables 4. 18 and 4.19). These results contrast with the findings of Brooks (2014), who observed a significant reduction in firewood consumption by ICS users in a CCT.

However, results of Council for the Scientific and Industrial Research, Ghana (2017) indicated a 51% savings in firewood by ICS, which was statistically significant in a water-boiling test conducted on ICSs in the study area.

The study realized the first cook on all ICSs during the CCT averagely lasted longer than subsequent ones thus consuming more firewood. Because the stove, which is made of clay, takes time to heat up before heating the pot. Once the ICS is heated, it cooks fast. This observation was made in the second and third cooking times where firewood used was low. In addition, this could be the reason why ICS mean level of fuel consumption was a little lower than fuel consumption in 'T3SS'.

Even though fuel consumption was not statistically significant, cooking two meals could have consumed same amount of fuel because ICS cooks two meals simultaneously. Grimsby *et al*. (2016) noted that fuel consumption varies depending on the stove design and the meal cooked exemplified by the fact that when CCT was conducted on six different stove models, it showed low or no firewood savings using ICS compared to 'T3SS' stoves. Hafner *et al*. (2018) also observed similarly with lower and higher firewood savings of 16% when ICSs were compared to 'T3SS' in preparation of different meals on both stoves. The large number of observations in this study recorded fuel consumption variances with an average reduction of 17%. Though this percentage was not significant, ICS did show that reduction in fuel consumption, translating in lower fuel purchase and lesser time in search of firewood. This meant a higher adoption and usage of ICS will actually help reduce deforestation on the reforested areas and help in water conservation on the Reseviour to ensure hydro – power generation.

5. 5 Socio economic

The Controlled Cooking Test (CCT) revealed 'T3SS' cooked "Banku" faster than Improved Cook Stoves (ICS); the observed time difference was statistically significant (Table 4.19). Duration of cooking with ICS was longer than 'T3SS'. 'T3SS' saved 30% of cooking time in preparing "Banku", indicating a large size effect. This meant cooking on 'T3SS' was shorter than cooking on ICS, which deviated from the findings of Bentson & Li. (2015) where 'T3SS' use led to high fuel consumption and prolong cooking.

This study also observed that, because ICS had two openings, cooking on it was faster since two meals could be prepared using same time. However, CCT prepared only one meal "Banku", making the 'T3SS' produced a faster cooking time. Users of ICS during the CCT placed a pot of water on the second opening throughout the test for the cook not to suffer from heat and smoke from that chamber. In addition, the study realized that ICSs that were not being used before the CCT took longer time to cook (45 minutes). This could have affected the results as proven by Mishra (2014), who said that using ICS that has being abandoned for some time takes longer to cook than those frequently used. Information on length of time for cooking on ICSs and 'T3SS' stoves is inadequate in the literature due to varying stove testing procedures and stove designs (Hanna *et al*., 2016). Therefore, a valid comparison to other studies investigating the timesaving of ICSs compared to "T3SSs" is difficult.

An additional benefit from the ICS is the empowerment of women and girls, which is consistent with Sustainable Development Goal 5. The use of ICS requires few amounts fuelwood; women and girls gain time and reduced drudgery as they walked shorter distances to collect firewood in shorter time (Lewis & Pattanayak, 2012). Finally, the use of efficient cookstoves is a great step in the transition to modern sources of energy, which is in accordance with Sustainable Development Goal 7 to ensure access to affordable, reliable, sustainable, and modern cook stove and fuel for all by 2030. This project will enable Ghana to attain these goals if the stoves are adopted and used sustainably.

5.6 Guidelines put in place by VRA to ensure sustainable use of the ICS in the study areas

The study confirmed that education and awareness creation activities were the guides put in place to ensure sustainable use of resources. Even though most respondents have some form of education on benefits of ICS, the education was limited to older women and men with children not actively involved thus influencing negatively on the sustainability of adoption of ICS in this study. The frequency of education was also low.

A systematic review of the enablers and barriers to the adoption of cook stoves by households suggested seven domains as influential in large-scale uptake of stoves (Rehfuess *et al*., 2014). These domains include household and setting features, knowledge and perception of subsidies, market development, regulations and legislation, programmes and policy mechanism, equality in adoption and sustained use (Rehfuess *et al.*, 2014). Another enabler is the perceived attributes of the stove where the ICS must be compatible to traditional cooking methods and perceived to be better than 'T3SS' in cooking practices. This was supported by Rehfuess *et al.* (2014) indicating that guidelines must ensure that the ICS satisfied cultural practices in addition to its perceived attributes including fuel and money saving.

Rehfuess *et al* (2014) noted that ICS programmes were likely to be more successful with the seven domains. One of those domains is equality in adoption and compatibility. The study realized that adoption of ICS was not equal. Limitations associated with ICS use was also not compatible with local practices, which is another reason for low adoption. The study also realized respondents were just not interested in acquiring the ICS, which was similar to Hanna *et al* (2016), in a randomized study where the zeal to repair ICS was lacking leading to abandonment. The study also found out there was no concrete policy on making parts of materials for ICS accessible to adopters. This was reflected in general abandonment of spoilt ICS in favour of 'T3SS'.

5.7 Base maps of reforested areas

The loss of trees in the reforested areas increased rate of evaporation around the catchment areas. Remote Sensing and GIS imagery of some of the reforested areas in the study showed that vegetation was sparse with few scattered trees (Plates 4.6 to 4.9). The base map imagery shows outlines of reforestation, farmlands, built-up areas and the Volta Lake. The land size of reforested area of Awatey, Dzigbe-Avertikope, Abui and Dafor Tornu were not captured by the GPS, as these were not big enough to be captured in 10 by 10 pixel on the satellite image. The biggest reforested area was Aveme with a land size of 0.24 km^2. The reforested areas has not grown into a forest yet due to wood harvesting. The study realized cutting of young tress from the reforested areas to make way for farming activities and firewood as shown in Figure 4.5. This was because of ineffective monitoring and protection of reforested area.

The study found out most people tasked to monitor the reforested area were unable to monitor they were busy attending to their main occupations, which took their time. Because the reforested area is not well monitored, people were able to go and cut trees. These activities have serious effect on the protection of water levels in the reservoir. If the reforested area was not well managed, the goal of protecting the reservoir to ensure sustainable hydropower generation was at stake. The siltation of the reservoir from farming activities will kill fishes in the Lake hence, affecting the people's economic livelihood since most of them were engaged in fishing and fish smoking or frying. The remote sensing imageries served as a reference map for further studies to identify the extent of change in reforested areas.

Replacing Traditional Three Stone Stoves (T3SS) with Improved Cook Stoves (ICS) may seem straightforward because it saves fuel (reduces deforestation) and improves health issues, but it not readily accepted by households.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study sought to assess the socioeconomic factors influencing ICS adoption in the study areas. The most important socio-cultural factor that influence the adoption of ICS was age. Older respondents were willing to adopt the ICS than the younger ones. Other socio economic factors that influence adoption were costs of ICS, cultural practices and limitations associated with the use of ICS. Most people were not willing to adopt the ICS because it was not as convenient and versatile as the 'T3SS'. As such, some ICS users still relied on 'T3SS' to provide some services like using smoke to repel insects, providing light at night, preparing traditional medicine, cooking certain meals ("Banku") and commercial activities such as frying or smoking of fish and gari processing. These findings indicated that adoption was difficult when the ICS was not adaptable to local cooking practices.

In addition, the molding of the stoves was done in a rush; they got cracked earlier than expected because the clay was not kneaded ahead of time to increase its malleability. The users could not reconstruct the ICSs after damage because it was time consuming to reconstruct the ICS. Hence, they resorted to 'T3SS', which was easy to construct, with accessible materials and compatible with all cooking activities. About 70% of respondents in the study areas were willing to adopt ICS but not willing to discard their 'T3SS' because of cultural attachments' to 'T3SS'. Adoption was higher in Ablonga than other communities were because the people have valued the stoves and were willing to sacrifice some cultural benefits from using ICS. Even though their initial set of stoves did not meet their cooking settings, they reconstructed them to suit their use. The social system there has given power to women leaders and trained individuals to educate others to adopt the ICS. The study also, revealed that in the other communities, some respondents who received the ICSs earlier abandoned them after they cracked, or chimneys were spoilt. It is important, however, to state that, with a close analysis of cooking activities, the study deduced that the problem of adoption was more of a socio-cultural issue than a technical one.

Secondly, the study sought to know how people perceived the ICS as an innovation and benefits to health and the environment. The study realized that the respondents perceived the ICS to be an innovation that improved their lives by spending less money on fuel, keeping their kitchens and saucepans clean. They also perceived the ICS improved good health and was environmentally friendly because it consumed less firewood. The ICS saved 50g (0.05 kg) of firewood per cook during the Controlled Cooking Test. Though this is not statistically significant; the use of ICS to cook three times per day, for a year (365 days) will save 54750g (54.75kg) of firewood per household. This will reduce the pressure of firewood harvesting from the reforested areas, allowing the trees to grow and reduce the evapotranspiration effect on the Akosombo Reservoir. This will also ensure sustainable power generation and help VRA reduce green House Gas emission as well as ensuring sustainable hydropower generation. Generally, the ICS was perceived to be foreign to their cultural practices. Comparing the ICS to T3SS, the study revealed the overall performance of the ICS was better than 'T3SS'.

In addition, the study sought to determine emission of CO and $PM_{2.5}$ from ICS and "T3SS as a proxy to cause of health status in the study areas. The study realized that users of the ICS have lower exposure to self-reported health issues like coughing, headaches, pain in the eyes, asthma attacks and watery nose. This is because of ICS emitted lower rates of smoke constituting CO and $PM_{2.5}$ during the Controlled Cooking Test, which was statistically significant.

Further, the study sought to examine the major factors (firewood use, farming, charcoal burning, bush fire & fishing) contributing to deforestation in the study areas. The study revealed firewood gathering and charcoal burning as the main causes of deforestation in the study. The firewood was harvested along the Lake, from farms and the reforested areas. The reforestation project is still under threat because over 80% of members of the communities in the study areas still harvest wood from the reforested area. Lumbering of rosewood and charcoal burning along the Volta Lake for economic purposes persisted.

In addition, the study sought to assess the policies put in place by VRA to ensure adoption and sustainable use of the ICS in the study areas. The policies revealed by the study was education and monitoring. However, education and monitoring was not frequent. This affected the operability of ICS such that some users eventually abandoned them. The language used in the education, English, was not locally friendly. Local knowledge on design was over looked during the education and awareness creation about the ICS. The protection of the reforested areas was not effective because those in charge have other economic activities that took their time and attention off the monitoring of the reforested areas.

Finally, the objective to create base maps to show density of forest growth in reforested areas using a GIS and Remote Sensing images were done. GIS and Remote Sensing images were used to create a base map for further studies to assess change in growth of the reforested areas in the future.

Even though some alternative livelihoods such as beekeeping and mango farming was implemented to reduce farming activities in the reforested areas, most members in the study areas still preferred to farm because farming provided them with variety of food products than bee keeping and mango farming.

Ultimately, ICS projects were assessed by how much ‘T3SS’ was displaced. In this study, the ‘T3SSs’were not been displaced.

6.2 Recommendations

Socio economic factors influencing adoption of ICS and its impact on deforestation and health issues in the study areas shows the ICS project is moderately successful. To ride on this to ensure a total success, the Volta River Authority need full commitment with time, money and personnel to ensure success and possibly expand to other rural communities in the country. Recommendations made from the study are as follows.

- The VRA should revise its guidelines on stove adoption to include accessibility of materials needed to mold the ICS to ensure sustainable use.
- Efforts of the VRA field officials in exploring traditional leadership such as Chiefs and political leaders in the study communities must be fortified. This will make them feel engaged and contribute to the reforestation project by ensuring adoption, maintenance and release of lands from farming for reforestation in the study areas.
- Education by the VRA field officials should be frequent and done in the local language (Ewe) as well as headed by women. In addition, The VRA field officials must include reasons behind the introduction of ICS, its impact on the hydropower generation, their health and their economic activities especially fishing. In addition, peer education should be done for other communities by the users of ICS in Ablonga to help the diffusion process
- Different days must be designated for education and ICS molding. Specific days and time of visitation must be agreed upon between community leaders, members and the VRA field officials. This will help the members prepare the clay ahead of time to construct the ICS or make time for discussions.
- The cost for an ICS for domestic or commercial use must be the same in all communities. How to operate the ICS and its maintenance must be emphasized.

- The community (Abui) which witnessed the burning of a cook area from initial use of ICS should be assisted with counseling to help them realize the benefits of ICS and adopt them. In addition, Adzamasu, a community that have problems with the malleability of its clay must be assisted to get clay from other communities for the ICS.
- The management of the VRA should give permanent employment to people from the study areas as guards to effectively monitor the reforested areas.
- The length of "Chimneys" must be increased by adding two (2) meters to the existing length to accommodate new cook areas. The cover of the chimneys must be made broader than the existing ones to enable rainwater to directly hit the ground rather than dripping over the stems of the chimney to prevent melting the ICS especially for those whose cook areas are made with clay. The materials used in making the "chimneys' must be thicker to ensure the durability of the "chimneys".
- Considering the fact that most people use 'T3SS' for their economic activities, the commercial ICS should be promoted in order to help reduce firewood consumption.
- A technology should be developed with the people to harvest smoke from the chimney to repel insects. In addition, respondents who have developed skills in molding the ICS must be consulted to build the stoves for others to suit the local cooking practices in terms of size, pot area wideness and height.
- The VRA should mould the ICS for those willing to use it than randomly selecting beneficiaries who may abandon them.
- Further studies should look at diseases that the people in the study areas are exposed to through their exposure to excessive smoke.

- Further research is required to explore ways of breaking economic barriers and other alternative livelihoods for the people to help lower their dependence on the forest resources. In addition, a scientific analysis to understand why the clay in Adzamasu is not malleable is recommended since it will have future implication for adoption of the ICS and sustainable use.
- For ICS to be adopted and use sustainably, it must be affordable, accessible, compactible and durable. Even though these goals may be difficult to achieve simultaneously, a conscious effort backed by political will can cause a great change.

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APPENDIX

APPENDIX 1

SAMPLE OF QUESTIONAIRE- ICS USERS

My name Is Pearl Awudor, I am conducting a study on the use of Improved cook stoves (ICS) in reducing Deforestation and Health problems as well as the problems affecting its adoption. The data collected for this survey is for academic purposes only and shall be kept strictly confidential. Your identity shall be required for the purposes of crosschecking information provided and for any future developments.

Enter appropriate code(s) in space(s) provided.

Background Information

N0	**Variable**	**Response**	**Code**
1	District	1= Biakoye 2= South Dayi, 3= Kpando municipality	
2	Community		
3	Respondent name		
4	Sex of respondent	1= Male 2= Female	(…………)
5	Age of respondent	1=19 and below 2=20-29 3=30-39 4= 40-49 5= 50 -59 6= 60 -69 7= above 70	(………..)
6	Marital Status of Stove user	1= Single 2= Married 3= Divorced 4= Widowed	(………)
7	Gender of Stove user	1= Male 2= Female	
8	How many persons are in your household?	1= below 3 2= 3-5 3= 6-8	(………)

		4= above 8	
9	Formal educational level attained by household head	1= No formal schooling 2= Primary school 3= Junior secondary school 4= Senior secondary school 5= Tech/Vocational 6= Tertiary	(………..)
10	Formal educational level attained by stove user	1= No formal schooling 2= Primary school 3= Junior secondary school 4= Senior secondary school 5= Tech/Vocational 6= Tertiary	(…………..)
11	Occupation of respondent/stove user	1= Farming 2= Fishing 3= Self employed 4= public/civil servant 5= Crafting 6= trader 7= other	(………..)
12	Estimated MONTHLY income of household.		(………..)

Fuel use

13	Which of the following fuels do you use? (Several answers possible)	1= Firewood 2= Charcoal 3= Both 4=Other	(………)
14	**If firewood is used:** Do you buy it, collect it or both?	1= Collect 2= Buy 3= Buy and Collect 4= other	(…………..)
15	***If firewood is collected:*** Where do you get your firewood? (Several answers possible)	1= From farm 2= Bare ground 3= Wood lot 4= Other	(………)
16	How long does it take to fetch firewood?	1= below 20 minutes 2= 20- 30 minutes 3= 31 – 40 minutes 4= 41- 50 minutes 5= 51- 60 minutes 6= above 1 hour	(……….)
17	Who normally gets the firewood?	***Low*** ***moderate*** ***high*** 1= Girls 1 3 5 2= Boys 1 3 5	

		3= Husband 1 3 5 4= yourself 1 3 5 5= other 1 3 5	
19	***If firewood is bought:*** How much money do you spend per week/meal on firewood.	1= 5gh and below 2= 6 -10gh 3= 11-15ghc 4= 16 - 20ghc 5= 21 -25ghc 6= other	(………)
20	Do you make charcoal / firewood in this community?	1= Yes 2= No	
21	If yes, Where do you get the wood?		
22	What do you use the trees for?	***Low*** ***moderate*** ***High*** 1= to farm 1 3 5 2= to sell to others 1 3 5 2= to get fire wood 1 3 5 3= to make charcoal 1 3 5 4= bush fire 1 3 5	
23	Does the use of ICS prevent you from cutting down trees?		

Stove information and perception

24	Do you know about ICS?	1= Yes 2= No	
25	How did you know about the improved stoves for the first time? (*Several answers possible*)	1= Neighbours, family, friends 2 = Public meeting 3= Media (radio) 3= Installers 4 = Others (specify	(………)
26	When did you acquire your improved cook stoves?	1= 2016 2= 2017 3= 2018 4= 2019	(………..)
	How much did you pay for the ICS?		
27	How often do you use the stove?	1= 1 - 2 days per weeks 2= 3 - 5 days per week 3= everyday 4= depend on type of food	(…………)

		5= other	
28	How many times do you cook with the stove in a day?	1= once 2= Twice 3= three times 4= above 3 5= other	(………)
29	Do you prepare all meals using ICS?	1= Yes 2= No	(……….)
30	If **No,** why?	1= can't cook some meals 2= pot chamber small to cook a large meal 3= not used to ICS 4= Other	(……….)
31	Why did you decide to acquire an improved cook stove?	***Low*** ***Moderate*** ***High*** 1=appearance 1 3 5 2= fast cooking 1 3 5 3= low fuel use 1 3 5 4=Less smoke 1 3 5 5=others getting it 1 3 5	
32	Which type of stove were you using before you got an ICS?	1= Metal firewood stove 2= Coal pot 3= three stone stove 4= Other	(………..)
33	Do you cook with ICS alone?	1= Yes 2=No	(……….)
34	**If No,** which other type of stove do you use in addition to ICS?	1= Metal firewood stove 2= Coal pot 3= three stone stove 4= other	(………..)
35	Why do you use another stove in addition to ICS?	***Low*** ***moderate*** ***High*** 1= cook single meal 1 3 5 2= warm water /food 1 3 5 3= taste of food 1 3 5 4= uncomfortable 1 3 5	
36	What are the good things about using the new stove?	***low*** ***Moderate*** ***High*** 1= Fuel saving 1 3 5 2 = cooks fast 1 3 5 3=Reduced smoke 1 3 5 4=Clean kitchen 1 3 5 5=less burns, accidents 1 3 5 6=less watery eyes 1 3 5 7=more comfort 1 3 5 8=better taste of food 1 3 5 9=Saves money 1 3 5 10= less respiratory issues 1 3 5 11= others 1 3 5	

37	Do you have any problem with the new stove?	1=Yes 2=No	(………..)
38	If **yes,** What are the problems of using the new stove?	***Low*** ***moderate*** ***high*** 1=longer cooking time 1 3 5 2=can't be moved around 1 3 5 3=can't cook certain meals 1 3 5 4=can't hold big saucepans 1 3 5 5=needs maintenance 1 3 5 6= Lifespan 1 3 5 7= uses too much fuel 1 3 5 8= others (specify)	
39	Have you ever replaced or repaired your ICS	1= yes 2= No	(…………)
40	What type of repair	1= chimney 2= Cracks 3= Pot area 4= Everything 5= other	(………..)
41	Did you receive training on the use of ICS?	1= yes 2= No	(…………..)
42	If yes, in which area?	1= put few fuel wood in stove chamber 2= remove surplus wood once food starts to boil 3= Split fuel wood before putting into stove chamber 4= other	(………..)
43	How do you perceive someone using ICS	***Low*** ***moderate*** ***High*** 1= cares about his health 1 3 5 2= cares about environment 1 3 5 3= Rich 1 3 5 4= Show off 1 3 5 5= other 1 3 5	
44	How would you rate the general performance of the stove compared with T3SS?	***Low*** ***Moderate*** ***High*** 1= worse 1 3 5 2= no difference 1 3 5 3= better 1 3 5	
45	What should your preferred ideal stove be like?		

Health

46	Does the use of ICS affect your health?	1=yes 2=No	(…………)
47	**If Yes,** how are you affected?		(…………)
48	Have you used a traditional stove before?	1= Yes 2= No	(………..)
49	If Yes, What were some of the health problems you faced while using the traditional stove?	1= pain in eyes 2= coughing 3= headache 4= watery nose 5= others	
50	If **No,** why do you think ICS does not affect your health?	***Low moderate High*** 1= no open fire to burn 1 3 5 2= chimney collects smoke 1 3 5 3= no headache from smoke 1 3 5 4= no eyes pain from smoke 1 3 5 5= less coughing 1 3 5 6= others 1 3 5	
51	Has your health problems reduced/ gone while using ICS as compared to T3SS?		
52	Would you encourage anyone using T3SS to change to use ICS?	1= Yes 2= No	
53	If Yes, why?		
54	If No why?		

SAMPLE OF QUESTIONNAIRE -T3SS USERS ONLY

Background Information

N0	Variable	Response	
1	District	1= Bia 2= South Dayi 3= Kpando municipality	
2	Community		
3	Name of Respondent		
4	Sex of respondent	1= male 2= female	
5	Age of respondent	1=15-19 2=20-39 3=40-59 4= 60-70 5= above 70 6= other	(………..)
6	Marital Status of Stove user	1= single 2= married 3= Divorced 4= Widowed	(………)
7	How many persons are in your household?	1= below 3 2= 3-5 3= 6-8 4= above 8	(……….)
8	Formal educational level attained by household head.	1= No formal schooling 2= Primary school 3= Junior secondary school 4= Senior secondary school 5= Tech/Vocational 6= Tertiary	(……….)
9	Formal educational level attained by stove user	1= No formal schooling 2= Primary school 3= Junior secondary school 4= Senior secondary school 5= Tech/Vocational 6= Tertiary	(……….)
10	Occupation of respondent/stove user	1= Farming 2= fishing 3= Self employed 4= public/civil servant 5= trader 6= other	(………)
11	Estimated monthly income of household.	1= below 100 Ghc 2= 101-200 Ghc 3= 201-301 Ghc	(……….)

		4= 401-500 Ghc 5= above 500 Ghc 6= other	
12	Why are you using the traditional cook stove?	1= food tastes good 2= cheap 3= convenient for most meals (culture) 4= easy to repair 5= other	(………..)
13	Apart from cooking, warming, boiling, what else do you use the traditional stove for?	1= lightening at night 2= warming while telling stories 3= repel insects 4= other	(…………)
14	What type of fuel do you use?	1= fuel wood 2= charcoal 3= Both 4= Other	(………….)
15	**If firewood is used:** Do you buy it, collect it or both?	1= Collect 2= Buy 3= Buy and Collect 4= other	(…………..)
16	***If firewood is collected:*** Where do you get your firewood? (Several answers possible)	1= From farm 2= Bare ground 3= Wood lot 4= Other	(………..)
17	How long does it take to fetch firewood?	1= below 20 minutes 2= 20- 30 minutes 3= 31 – 40 minutes 4= 41- 50 minutes 5= 51- 60 minutes 6= above 1 hour	
18	Who normally gets the firewood?	***Low moderate high*** 1= Girls 1 3 5 2= Boys 1 3 5 3= Husband 1 3 5 4= yourself 1 3 5 5= other 1 3 5	(…………)
19	***If firewood is bought:*** How much money do you spend per week/meal on firewood.	1= 5gh and below 2= 6 -10gh 3= 11-15ghc 4= 16 - 20ghc 5= 21 -25ghc 6= other	(…..……)
20	How often do you get the firewood?	1= everyday 2= twice per week 3= 3-5 times per week 4= above 5 times per week	

21	Do you make charcoal / firewood in this community?	1= Yes 2= No	
22	If yes, Where do you get the wood from?		
23	What do you use the trees for?	***Low moderate High*** 1= to farm 1 3 5 2= sell 1 3 5 2= fire wood 1 3 5 3= charcoal 1 3 5 4= bush fire 1 3 5 5= other (specify)	
24	Have you heard/seen of ICS before?	1= yes 2=no	
25	Have you used it before?	1= yes 2= No	
26	**If yes,** why did you stop using it?	1= expensive to get 2= slow cooking 3= high cost of maintenance 4= not convenient for most meals (culture) 5= cook two meals at the same time 6= other	
27	**If No**, why are you not using it?		
28	How much does it cost to get an ICS?		
29	Do you think the use of ICS is status symbol?	1= yes 2= No	(………..)
30	If Yes, why yes?		(………..)
31	If ICS was given to you for free, would you use it?	1= Yes 2= No 3 = Maybe	
32	If yes, Would You use it alone?	1= Yes 2= No	(………)
33	If No why?	1= expensive to Maintain 2= space 3= heat in room	(………..)

Health

34	Does the use of T3SS have any effect on your health?	1=yes 2=No	(……..)
35	If yes how?	1= pain in eyes 2= headache 3= coughing 4= watery nose 5= respiratory diseases	(……….)
36	Do you report to any Health facility about your health?	1= yes 2=No	(……..)
37	If yes, which health Facility?		
38	If No, why?		

APPENDIX 2

USERS OF ICS—SAMPLE OF FOCUS GROUP GUIDE

Introduction

My name Is Pearl Awudor, I am conducting a study on the use of Improved cook stoves (ICS) in reducing Deforestation and Health problems as well as the problems affecting its adoption. The data collected for this survey is for academic purposes only and shall be kept strictly confidential. Your identity shall be required for the purposes of crosschecking information provided and for any future developments.

Please can I have your permission to record our discussion?

1. Do you know about improved cook stoves?
2. How did you know about improved cook stoves?
3. Are you using your ICS?
4. Are you using it alone or with others?
5. Which type of stove were you using to cook before you obtained an improved cook stove?
6. What are the advantages of using this stove over the one you had?
7. What are the disadvantages of using this stove compared to the old one?
8. Was it difficult to use the new stove?

9. Do you use your cook stove for all dishes you make?
10. Do you use your cook stove every day?
11. Do you think improved cook stoves are a status symbol?
12. Do you use lower amount of fuel for ICS?
13. What will make you stop using ICS?
14. Do you know why you asked to use the ICS?
15. What do you think authorities should do to make sure everyone is using the ICS forever?
16. How would you rate the general performance of the stove?

NON-USERS (T3SS) SAMPLE OF FOCUS GROUP GUIDE

1. Do you know about improved cook stoves?
2. Where did you obtain the information about improved cook stoves?
3. Do you have it?
4. Why are you not using an improved cook stove?
5. If you decide to get one, what factors would you consider when getting one?
6. What do you know are the disadvantages of using an improved cook stove?
7. Do you think improved cook stoves are a status symbol?
8. Are some people using the ICS and the Traditional Stove together?
9. What else do you use the traditional stove for apart from cooking?
10. How much volume of Firewood do you use daily?
11. What else do use trees /wood for?
12. What should the authorities do, to make sure everyone is using the ICS alone?

APPENDIX 3

SAMPLE OF INTERVIEW GUIDE FOR KEY INFORMANT

Introduction

My name Is Pearl Awudor, I am conducting a study on the use of Improved cook stoves (ICS) in reducing Deforestation and Health problems as well as the problems affecting its adoption. The data collected for this survey is for academic purposes only and shall be kept strictly confidential. Your identity shall be required for the purposes of crosschecking information provided and for any future developments.

Please can I have your permission to record our discussion?

1. Have many people adopted the ICS in this area?
2. Do you know why VRA wants you to use the ICS?
3. Are they using it every day?
4. Do they use it with other Stoves?
5. Have you heard anything about why they use it with other stoves?
6. What are some of the challenges faced by households in adopting ICS?
7. In what ways can these challenges be overcome to ensure more adoption of the ICS?
8. Have you heard anyone suggesting how they wish the ICS was?
9. Do you think using ICS is a status symbol?
10. Do you think the use ICS is reducing deforestation?
11. What else are trees/wood used for in this area?

SAMPLE OF E&SDD (VRA) - INTERVIEW GUIDE

Introduction

My name Is Pearl Awudor, I am conducting a study on the use of Improved cook stoves (ICS) in reducing Deforestation and Health problems as well as the problems affecting its adoption. The data collected for this survey is for academic purposes only and shall be kept strictly confidential. Your identity shall be required for the purposes of crosschecking information provided and for any future developments.

Please can I have your permission to record our discussion?

1. What was the motivation for VRA to encourage people in riparian communities to use ICS?
2. Are the people aware of reasons why you want them to use ICS?
3. How do you intend to make sure everyone adopt the stove and use it sustainably?
4. Do you think you are achieving your goal of reducing deforestation?
5. What would you do if adoption rates reduces and people stop using ICS even though they have it?
6. What happens when every household adopts the ICS?
7. What were some of the Health issues recorded in relation to the use of T3SS

APPENDIX 4

ANOVA (Post Hoc Tests) illustrating variations in firewood consumption in study communities.

Multiple Comparisons

Dependent Variable: Specific fire wood consumption

Tukey HSD

(I) Community	(J) Community	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Aveme	Awatey	-63.00000	114.76633	.982	-386.6786	260.6786
	Ablonga	-144.91667	114.76633	.715	-468.5953	178.7620
	Odormitor	-7.08333	114.76633	1.000	-330.7620	316.5953
	Dafor Tornu	-10.50000	114.76633	1.000	-334.1786	313.1786
Awatey	Aveme	63.00000	114.76633	.982	-260.6786	386.6786
	Ablonga	-81.91667	114.76633	.952	-405.5953	241.7620
	Odormitor	55.91667	114.76633	.988	-267.7620	379.5953
	Dafor Tornu	52.50000	114.76633	.991	-271.1786	376.1786
Ablonga	Aveme	144.91667	114.76633	.715	-178.7620	468.5953
	Awatey	81.91667	114.76633	.952	-241.7620	405.5953
	Odormitor	137.83333	114.76633	.751	-185.8453	461.5120
	Dafor Tornu	134.41667	114.76633	.768	-189.2620	458.0953
Odormitor	Aveme	7.08333	114.76633	1.000	-316.5953	330.7620
	Awatey	-55.91667	114.76633	.988	-379.5953	267.7620
	Ablonga	-137.83333	114.76633	.751	-461.5120	185.8453
	Dafor Tornu	-3.41667	114.76633	1.000	-327.0953	320.2620
Dafor Tornu	Aveme	10.50000	114.76633	1.000	-313.1786	334.1786
	Awatey	-52.50000	114.76633	.991	-376.1786	271.1786
	Ablonga	-134.41667	114.76633	.768	-458.0953	189.2620
	Odormitor	3.41667	114.76633	1.000	-320.2620	327.0953

APPENDIX 5

ANOVA

Statistical analysis of $PM_{2.5}$ and CO from ICS in various communities

		Sum of Squares	Df	Mean Square	F	Sig.
PM	Between Groups	219.647	4	54.912	21.257	.000
	Within Groups	2224.151	861	2.583		
	Total	2443.798	865			
CO	Between Groups	236.651	4	59.163	57.447	.000
	Within Groups	886.721	861	1.030		
	Total	1123.372	865			

ANOVA

Statistical analysis of $PM_{2.5}$ and CO from T3SS in various communities

		Sum of Squares	Df	Mean Square	F	Sig.
PM	Between Groups	25.530	4	6.383	1.791	.129
	Within Groups	1646.114	462	3.563		
	Total	1671.644	466			
CO	Between Groups	254.895	4	63.724	32.199	.000
	Within Groups	1167.636	590	1.979		
	Total	1422.531	594			

ANOVA, Post Hoc Tests of variations in emission of PM 2.5 from the ICS in study communities.

Multiple Comparisons

Dependent Variable: $PM_{2.5}$

Tukey HSD

(I) Community	(J) Community	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Aveme	Awatey	-.00579	.31529	1.000	-.8677	.8561
	Ablonga	-.07177	.12827	.981	-.4224	.2789
	Odormitor	-2.09111*	.26803	.000	-2.8238	-1.3584
	Dafor Tornu	-.86551*	.17702	.000	-1.3494	-.3816
Awatey	Aveme	.00579	.31529	1.000	-.8561	.8677
	Ablonga	-.06598	.30854	1.000	-.9094	.7774
	Odormitor	-2.08532*	.38805	.000	-3.1461	-1.0246
	Dafor Tornu	-.85972	.33178	.073	-1.7667	.0472
Ablonga	Aveme	.07177	.12827	.981	-.2789	.4224
	Awatey	.06598	.30854	1.000	-.7774	.9094
	Odormitor	-2.01934*	.26005	.000	-2.7302	-1.3085
	Dafor Tornu	-.79374*	.16469	.000	-1.2439	-.3435
Odormitor	Aveme	2.09111*	.26803	.000	1.3584	2.8238
	Awatey	2.08532*	.38805	.000	1.0246	3.1461
	Ablonga	2.01934*	.26005	.000	1.3085	2.7302
	Dafor Tornu	1.22560*	.28724	.000	.4404	2.0108
Dafor Tornu	Aveme	.86551*	.17702	.000	.3816	1.3494
	Awatey	.85972	.33178	.073	-.0472	1.7667
	Ablonga	.79374*	.16469	.000	.3435	1.2439
	Odormitor	-1.22560*	.28724	.000	-2.0108	-.4404

*. The mean difference is significant at the 0.05 level.

ANOVA, Post Hoc Tests of variations in emission of CO from the ICS in study communities.

Multiple Comparisons

Dependent Variable: CO

Tukey HSD

(I) Community	(J) Community	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Aveme	Awatey	-.23281	.19908	.769	-.7770	.3114
	Ablonga	.15377	.08099	.319	-.0676	.3752
	Odormitor	-2.32483*	.16923	.000	-2.7874	-1.8622
	Dafor Tornu	-.09649	.11177	.910	-.4020	.2090
Awatey	Aveme	.23281	.19908	.769	-.3114	.7770
	Ablonga	.38658	.19482	.274	-.1460	.9191
	Odormitor	-2.09202*	.24502	.000	-2.7618	-1.4222
	Dafor Tornu	.13632	.20949	.967	-.4363	.7090
Ablonga	Aveme	-.15377	.08099	.319	-.3752	.0676
	Awatey	-.38658	.19482	.274	-.9191	.1460
	Odormitor	-2.47860*	.16420	.000	-2.9275	-2.0298
	Dafor Tornu	-.25026	.10399	.114	-.5345	.0340
Odormitor	Aveme	2.32483*	.16923	.000	1.8622	2.7874
	Awatey	2.09202*	.24502	.000	1.4222	2.7618
	Ablonga	2.47860*	.16420	.000	2.0298	2.9275
	Dafor Tornu	2.22834*	.18137	.000	1.7326	2.7241
Dafor Tornu	Aveme	.09649	.11177	.910	-.2090	.4020
	Awatey	-.13632	.20949	.967	-.7090	.4363
	Ablonga	.25026	.10399	.114	-.0340	.5345
	Odormitor	-2.22834*	.18137	.000	-2.7241	-1.7326

*. The mean difference is significant at the 0.05 level.

APPENDIX 6

ANOVA, Post Hoc Tests of variations in emission of $PM_{2.5}$ from the T3SS in study communities.

Multiple Comparisons

Dependent Variable: $PM_{2.5}$

Tukey HSD

(I) Community	(J) Community	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Aveme	Awatey	.26756	.29196	.891	-.5320	1.0671
	Ablonga	.07118	.29196	.999	-.7284	.8707
	Odormitor	-.37788	.23322	.485	-1.0166	.2608
	Dafor Tornu	-.26127	.29058	.897	-1.0570	.5345
Awatey	Aveme	-.26756	.29196	.891	-1.0671	.5320
	Ablonga	-.19638	.32859	.975	-1.0962	.7035
	Odormitor	-.64544	.27771	.139	-1.4060	.1151
	Dafor Tornu	-.52883	.32736	.488	-1.4253	.3677
Ablonga	Aveme	-.07118	.29196	.999	-.8707	.7284
	Awatey	.19638	.32859	.975	-.7035	1.0962
	Odormitor	-.44906	.27771	.487	-1.2096	.3115
	Dafor Tornu	-.33245	.32736	.848	-1.2290	.5641
Odormitor	Aveme	.37788	.23322	.485	-.2608	1.0166
	Awatey	.64544	.27771	.139	-.1151	1.4060
	Ablonga	.44906	.27771	.487	-.3115	1.2096
	Dafor Tornu	.11661	.27625	.993	-.6399	.8732
Dafor Tornu	Aveme	.26127	.29058	.897	-.5345	1.0570
	Awatey	.52883	.32736	.488	-.3677	1.4253
	Ablonga	.33245	.32736	.848	-.5641	1.2290
	Odormitor	-.11661	.27625	.993	-.8732	.6399

ANOVA, Post Hoc Tests of variations in emission of CO from the T3SS in study communities.

Multiple Comparisons

Dependent Variable: CO

Tukey HSD

(I) Community	(J) Community	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Aveme	Awatey	-1.28982*	.21405	.000	-1.8755	-.7041
	Ablonga	-1.28982*	.21405	.000	-1.8755	-.7041
	Odormitor	-1.23144*	.16936	.000	-1.6949	-.7680
	Dafor Tornu	-1.83475*	.16306	.000	-2.2809	-1.3886
Awatey	Aveme	1.28982*	.21405	.000	.7041	1.8755
	Ablonga	.00000	.24489	1.000	-.6701	.6701
	Odormitor	.05838	.20697	.999	-.5079	.6247
	Dafor Tornu	-.54493	.20184	.055	-1.0972	.0074
Ablonga	Aveme	1.28982*	.21405	.000	.7041	1.8755
	Awatey	.00000	.24489	1.000	-.6701	.6701
	Odormitor	.05838	.20697	.999	-.5079	.6247
	Dafor Tornu	-.54493	.20184	.055	-1.0972	.0074
Odormitor	Aveme	1.23144*	.16936	.000	.7680	1.6949
	Awatey	-.05838	.20697	.999	-.6247	.5079
	Ablonga	-.05838	.20697	.999	-.6247	.5079
	Dafor Tornu	-.60331*	.15364	.001	-1.0237	-.1829
Dafor Tornu	Aveme	1.83475*	.16306	.000	1.3886	2.2809
	Awatey	.54493	.20184	.055	-.0074	1.0972
	Ablonga	.54493	.20184	.055	-.0074	1.0972
	Odormitor	.60331*	.15364	.001	.1829	1.0237

*. The mean difference is significant at the 0.05 level.

APPENDIX 7

CCT Data Sheet

Name of Community:

Type of Stove: ICS

	Test I	Test II	Test III
Environmental Variables			
Ambient Temperature (^oC)			
Humidity			
Physical Test Parameters			
Wood Moisture Content (%)			
Weight of Char Container (g)			
Weight of Pot Before Cooking (g)			
Initial Cooking Time (T_1) (Mins)			
Final Cooking Time (T_2) (Mins)			
Weight of Pot + Food After Cooking (g)			
Weight of Char Container + Charcoal (g)			
Weight of water			
Weight of firewood			
Weight of corn and cassava dough			
Length of firewood			
Diameter of firewood			
Observations during the Cooking test			

CCT Data Sheet

Name of Community:

Type of Stove: T3SS

	Test I	Test II	Test III
Environmental Variables			
Ambient Temperature (^{o}C)			
Humidity			
Physical Test Parameters			
Wood Moisture Content (%)			
Weight of Char Container (g)			
Weight of Pot Before Cooking (g)			
Initial Cooking Time (T_1) (Mins)			
Final Cooking Time (T_2) (Mins)			
Weight of Pot + Food After Cooking (g)			
Weight of Char Container + Charcoal (g)			
Weight of water			
Weight of firewood			
Weight of corn and cassava dough			
Length of firewood			
Diameter of firewood			
Observations during the Cooking test			