FUELWOOD EFFICIENT STOVES AS STRATEGIES TO ADAPT THE EFFECTS OF CLIMATE CHANGE IN MUHEZA DISTRICT, TANZANIA

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ABSTRACT

The study was conducted in Muheza district, Tanzania to assess the fuelwood efficient stoves (FWES) as strategies to adapt to climate change effects. Specifically, the study assessed the extent of adoption of fuelwood efficient stoves, examined the direct and indirect benefits of the stoves in the context of climate change adaptation and determined the challenges of adoptions and up-scaling the FWES technology. Data were collected through household's questionnaire survey, checklists, and direct observations. Descriptive statistics and logistic regression model were used in the study. Findings showed that about 77% of households adopted the fuelwood efficient stoves. Five types of cooking stoves were observed in the area; improved stove with and without chimney, gas stoves, charcoal and three stones-traditional open stoves. Firewood consumption, low emission of smoke and restoration of landscapes were among the direct and indirect benefit of using the fuelwood efficient stoves in adapting to climate change effect in the area. Binary Logistic Regression Model Analysis (R^2 =0.73, F=9.57, $p<0.05$) revealed that age and fuelwood scarcity significantly showed a positive linear relationship with FWES adoption. T-sample test show that the average of the head load of fuelwood used per week by households after and before the introduction of stoves were statistically different. Results also revealed that adoption of stoves is the best strategy for communities in order to adapt to climate change effects in the area by reducing disturbances on the forest resources. Nevertheless, limited knowledge about the stoves and its usefulness in relation to climate change effects was among of the challenges for adoptions of the stoves in the area. Therefore, the adoption of fuelwood efficient stoves by the local communities in the area has assisted them to adapt on the effects of climate change while addressing the scarcity of fuelwood in the area and improving their livelihoods.

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DECLARATION

I, Lino, Gilya do hereby declare to the senate of the Sokoine university of Agriculture that this dissertation is my original work, done within the period of registration and that it has neither been submitted nor been concurrently submitted for a higher degree award in any other Institution.

____________________ ____________________

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(MSc Candidate)

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(1^{st} Supervisor)

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Dr. Alfred. Chitiki Date

(2^{nd} Supervisor)

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DEDICATION

To GOD the Creator, JESUS the Savior and HOLY GHOST the Leader.

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ABBREVIATIONS AND ACRONYMS

ESMAP	Energy Sector Management Assistance Programme
FAO	Food and Agriculture Organization of the United Nations
FWES	Fuelwood Efficient Stove
GHGs	Green House Gases
IAP	Indoor Air Pollution
LPGS	Liquefied Petroleum Gas Stoves
MDGs	Millennium Development Goals
MEM	Ministry of Energy and Minerals
MNRT	Ministry of Natural Resources and Tourism
NAFORMA	National Forest Monitoring and Assessment
NBS	National Bureau of Statistics
NGO	Non-governmental organization
NSGRP	National Strategies for Growth and Reduction of Poverty
NTFPs	Non-T Forest Products
ONGAWA	Organización No Gubernamental
SNAL	Sokoine National Agriculture Library
SPSS	Statistical Package for Social Science
TaTEDO	Tanzania Traditional Energy Development Organization
TFCG	Tanzania Forest Conservation Group
TTSOFS	Traditional three stone open fuelwood stove
UN	United Nations
UNDP	United Nations Development Programme
URT	United Republic of Tanzania
USAID	United State Agency for International Development

USD	United States Dollar
VNRC	Village Natural Resource Committee
WB	World Bank
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

In developing countries fuelwood is the most used fuel (Lusambo, 2016; Malimbwi *et al.*, 2001) for traditional methods of cooking; traditional three-stone open fire stove (TTSOFS). However, it has an impact on both environment and human health as it uses more fuel and releases more smoke to the environment. Fuelwood efficient stoves (FWES) as the technology for cooking and heating are thought to be more friendly to environment and human. FWES can be defined as stoves that need far less fuelwood to cook the same amount of food than a traditional one, produces less smoke hence reduces indoor air pollution (IAP) due to efficient combustion (WHO, 2006). Further, the FWES use small amount of fuelwood under high performance and it is cost-effective in term of time spent on both collecting the raw materials and cooking compared to TTSOFS (USAID, 2010). Currently there is a concern that many users of the fuelwood efficient stoves seem to be more aware of the negative environmental and social consequences of degrading the forests as associated with change in climate; however, this has not been translated into a major shift towards the adoption of sustainable practices Alonge and Martin (1995), cited by Green Heffernan (1998). Conversely, there are factors that influence the adoption of the fuelwood efficient stoves such as perceived relative benefits of the stoves, culture, and economic status, the effectiveness of stoves, diffusion approaches and compatibility of the measures to the existing values, experiences, and needs (Roger, 2003: USAID, 2007).

Climate change has been defined as a long-term change in the statistical distribution of weather patterns over periods ranging from decades to millions of years (Parmesan and Yohe, 2003; Robledo 2006). According to USAID (2007), climate variability is defined as the inherent characteristic of climate which manifests itself in changes of climate with time. Examples of climate variability include extended droughts and floods (Conway, 2008). Vulnerability to the impacts of climate change is a function of exposure to climate variables, sensitivity to those variables, and the adaptive capacity of the affected community (Fussel and Klein, 2006). Often, the poor are dependent on economic activities that are sensitive to the climate. For example, agricultural and forestry activities depend on local weather and climate conditions; and a change in those conditions could directly impact productivity levels and diminish livelihoods (USAID, 2007). Both climate change and variability may alter the productivity of forests and thereby shift resource management, economic processes of adaptation and forest harvests (Alig *et al*., 2002). It is widely recognized that climate change has caused substantial impacts on forested ecosystems (Kirilenko and Sedjo, 2007). The majority of the forest-dependent people have reduced the opportunity to cope effectively with the adversities of climate change due to low capabilities, poverty, weak institutional mechanisms (Shackleton and Shackleton, 2004) and lack of access to resources (Brooks 2003; Brooks *et al*., 2005). According to Regmi *et al.* (2016) climate change adaptation consists of initiatives and measures to reduce the vulnerability of natural and human systems to actual or expected climate change effects. Therefore, fuelwood efficient stoves are very crucial for rural communities' adaptation to climate change impacts.

The governments, local and international NGOs, and donor agencies have attempted to remedy the energy situation in the country. These initiatives towards developing and disseminating improved cooking stoves started in the late 1980's through developed programmes and projects (Omar, 2007). At the international level, the country was devoted to the implementation of Millennium Development Goals (MDGs) by reducing poverty, hunger, diseases, gender inequality and environmental degradation by 2015. At the national level, the country is striving to alleviate poverty through the National Strategy for Growth and Reduction of Poverty (NSGRP) 2005 framework. The NSGRP also have mentioned energy as an important factor for achieving social economic development of the country (URT, 2005). The 1992 National Energy Policy document which was reviewed in 2003 has recognized biomass as the main energy source for the majority of the country's population and added that inferior energy services among poor households in rural and semi-urban areas mainly affect women. Moreover, the policy associates time-consuming work in the wood collection, exposure to health hazards through smoke emission by application of traditional biomass technologies. The document sets nine overall goals among which was to arrest fuelwood depletion by evolving more appropriate land management practices and more efficient wood fuel technologies (URT, 2003). Nevertheless, thirteen years after the National Energy Policy document was published, neither the goals nor the strategies stipulated in the document were anywhere close to being reached (NSGRP, 2005). In 2005 the government in collaboration with the donor community launched the NSGRP; the strategies have identified the access to reliable energy as the engine of economic growth. It also goes more to instruct how unreliable and high-cost energy has undermined the country's efforts to reach the Millennium Development Goals (MDGs) by 2015. NSGRP, 2005 report show that, to achieve the MDGs access to reliable energy is a prerequisite. A highly ambitious target was to reduce the proportion of rural and urban population depending on biomass energy for cooking from 90 per cent in 2003 to 80 per cent in 2010.

Tanzania Forest Conservation Group (TFCG) is among of non-governmental organization established in 1985, with the mission of conserving natural forest, specifically in the Eastern Arc Mountains and Coastal forest of Tanzania. Currently the organization is working with the government, local and international NGOs and donors in up-scaling access to sustainable modern energy technologies. According to TaTEDO (2010), the problem associated with inefficient production and utilization of fuelwood in Tanzania includes increased women burden on firewood collection, indoor air pollution from greenhouse gas emissions (GHGs), the destruction of land through deforestation, desertification, loss of genetic resources, and soil erosion to mention some.

1.2 Problem Statement and Justification

According to the report by World Bank (2008), the majority of communities living adjacent to forest reserves (about 60 million) around the globe are estimated to be almost wholly dependent on forests. However, climate change is currently one of the greatest environmental challenges facing humankind (Totten *et al*., 2003). The changing climatic patterns in Tanzania, such as increased temperatures and changes in rainfall patterns, is predicted to have strong impacts on livelihood and biodiversity in the country (URT, 2003). In Tanzania, fuelwood is the major energy source and over 97% of the country's total energy for household cooking is derived from these resources (Lusambo, 2016). However, shortage of fuelwood is among the principal problems in Tanzania that pose pressure on the remaining forest resources as a result of inefficient cooking stove technology i.e traditional three stone open stoves (Mwampamba, 2007). But the introduction of fuelwood efficient stoves have been put into action in Tanzania since the 1980s.The UNDP report of 2009, revealed that only 1% of the local residents from both rural and urban were using fuelwood efficient stove in 2009. Currently, TFCG and ONGAWA in collaboration with Muheza District council have been working to promote the use of FWES by freely installing, as one of the strategies to rural households in the East Usambaras to adapt to the negative effect of climate change. Nevertheless, it is uncertain as to what extent this has been successful. Furthermore, there is inadequate information on benefits and limiting factors for adoption of fuelwood efficient stoves. This study is intended to close the gap by assessing the extent of fuelwood efficient stoves adoption to the local communities in Muheza and its associated benefits and limiting factors. Findings from this study will assist to address the challenges hindering the adoptions of stoves and to add knowledge on the existing database in Tanzania on the use and adoption of fuelwood efficient stoves as one of the strategies to adapt to the negative impacts of climate change. The findings also provide a basis for policy and decision makers to improve the status of biomass energy utilization in the country to serve the natural forests concurrently while adapting to climate change and variability.

1.3 Objectives

1.3.1 Overall objective

To assess the adoption of fuelwood efficient stoves as a strategy to adapt to climate change effects by rural communities in Muheza district, Tanzania.

1.3.2 Specific objectives

The specific objectives of the study are as follows:

i. To investigate the extent of adoption of fuelwood efficient stoves in the study area.
ii. To examine the direct and indirect benefits of fuelwood efficient stoves in the context of climate change adaptation in the study area, and
iii. To investigate the challenges of adoptions and up-scaling the fuelwood efficient stoves technology in the study area.

1.4 Research Questions

i. What types of energy are used by households in the study area?
ii. What quantities of fuelwood are used by households in the study area?
iii. What types of fuelwood stoves are available and used in the study villages?

iv. What is the status of fuelwood efficient stoves adoption in the study area?

v. What are the motivating factors for fuelwood efficient stoves adoption?

vi. What are the challenges associated with the adoption and up-scaling of fuelwood efficient stoves in the study area?

1.5 Theoretical and Conceptual Framework

1.5.1 Theoretical framework

A theory is defined as a reasoned statement supported by evidence and is meant to explain systematic relationship among certain phenomena (Kombo and Tromp, 2006); however, Mugenda (2008) defines a framework for explaining phenomena by starting construct and laws that interrelate these constructs. On other hand, a theoretical framework is defined as a collection of interrelated ideas based on theories derived and supported by evidence and it tries to explain and clarify the issue (Kombo and Tromp, 2006).

But household fuel and stove choice can be explained using various theories. One of the theories used is the Energy Ladder theory. In developing countries, this theory places more emphasis on income in both explaining and determine household fuel and stove (Masera *et al.,* 2000). It implies that a key driver to fuel and stove adoption is influenced by income raise which is likely to cause a shift of energy use from traditional to a more sophisticated or rather modern cleaner fuel at household level (Heltberg, 2004: 2005), however, there are more factors apart income that influence stove and fuel choice adoption. Several researches revealed that in developing countries households in both urban and rural areas do not switch to modern fuel and stove technologies rather than consume a combination of both technologies. This kind of combination then led to the formulation of fuel stack theory that implies use of multiple fuel and stoves by households. Heltberg (2005) observed that, this combination arises depending on one’s preference, budget and needs.

Multiple fuel use is not only driven by income but it cross-cuts other factors; family size, education, age and culture among others (Meckonnen and Kohlin, 2009). Price fluctuation of commercial fuels (Leach, 1992) and the frequenct shortage of modern fuels are also considered to positively contribute to fuel stacking concept. This therefore led to the development of more other theories that try to explain further.

Diffusion of innovation theory focuses on the conditions which positively or negatively affect adoption of new idea, product or practice within a certain society. Rogers (2003) advanced this model and it has been extensively used in assessing the impacts of technology diffusion and barriers or drivers to technology adoption. According to Rogers (2003) the theory observes that in a societal system, nature of communication, individuals and early adopters of a certain technology can act as drivers or barriers to new technology spread within an area. Therefore, diffusion is largely dependent on a range of factors such as social, cultural, economic and environmental and for it to achieve its goal, it must be with research and development which will lead to market development through promotions and finally market diffusion (Lunds, 2006).

The theory of subsidization has widely been used in standard economic theory as a way of improving market economies. In many cases, it has been associated with bridging the economic injustice of the poor and underprivileged and overseeing correctiveness of market inefficiency especially in the location of goods and services.This public subsidy provided have the potential of meeting both equities. In many rural areas, success stories of improved stoves projects are highly attributed to the use of subsidy in keeping the price affordable (Rai, 2009). He further says, direct subsidized (Price of the stove) offers little impact to stove adoption as compared to indirect subsidizes (training of constructors, covering the cost of research and development and marketing). However, Puzzolo *et al.*

(2013) observed the negative impacts of subsidy, especially to the end user. Rhefuess *et al*. (2014) observed that large subsidize results in poor stove usage and maintenance and also affects the user perceived value on the stove. Therefore, the economic approach of subsidization through proper program design and analysis is seen to help achieve the social goal and highlight correctiveness where they are regarded as wasteful.

1.5.2 Conceptual framework for factors that influence adoption of Fuelwood efficient stoves

Mugenda (2008) defines a conceptual framework as tools that help a reader understand the proposed relationship between the variables studied and show the same graphically or diagrammatically. The above theories and literature helped in the formulation of the conceptual framework for this study (Fig. 1) Socio-economic factors such as Household size, Age, community involvement and time spend on firewood collection play a key role in the adoption of Fuelwood efficient stoves. Another factor is environmental factors such as scarcity of fuelwood and climate change as a result of human population increase and associated anthropogenic activities.

Having knowledge on the use of fuelwood efficient stoves in relation to climate change and its benefits tend to increase its adoption through its demands by the users in the area, however, the subsidizing of the stoves by the government and other agencies can facilitate its adoption. Therefore, by integrating all these factors, demand for will increase fuelwood efficient stoves through reducing climate change effects and improving the livelihood and natural capital i.e forest, water and climate, also reducing the diseases by reduced Indoor Air pollution. The directions of the arrows show the interrelationships between the key variables for the adoption of the stove from the independent variable to an outcome of adoption (improved livelihood); however, the opposite directions of the arrows show the interrelationships from unimproved livelihoods as a dis-adoption outcome to key variables of the study (Fig. 1).

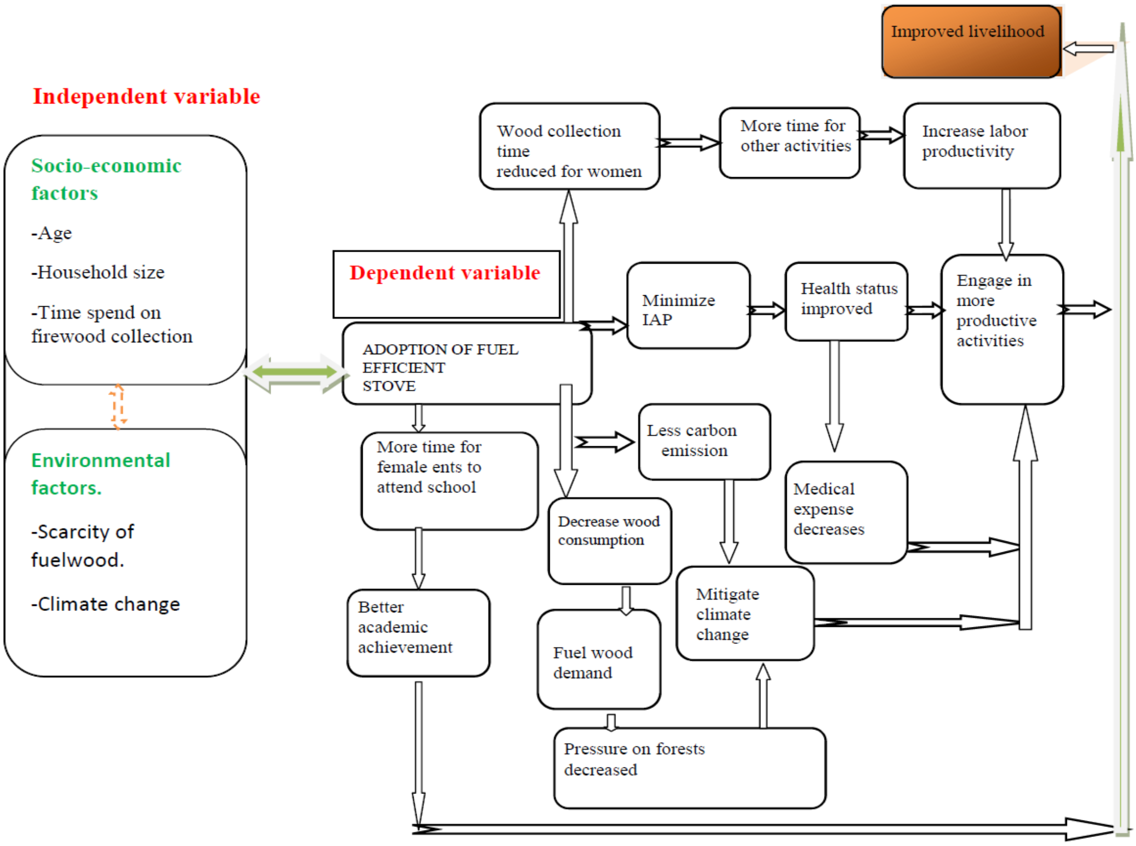

Figure 1: Conceptual Framework for the Stud;

SourcAdopted and modified from Rogers (1995) and Eshetu (2014)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1Climate Change Impacts

Climate change and variability are likely to cause disruptions in the earth systems, such as modifications to the precipitation regimes, frequency and intensity of extreme events (Bhutiyani *et al.,* 2010) which results into changes in the structure and function of ecosystems. Whether these changes lead to positive or negative consequences depends on the geographical, environmental, social and economic conditions of the affected area (Adger, 1999). For example, rainfall increase could be beneficial in some areas where water is scarce, but not in areas prone to floods. Easterling *et al*. (2007) point out that 'climate change will substantially impact other services, such as seeds, nuts, hunting, resins, plants used in pharmaceutical and botanical medicine, and in the cosmetics industry; these impacts will also be highly diverse and regionalized'.

In many regions, climate change is expected to result, into increased frequency and severity of extreme climate events such as heat stress, droughts, and flooding (Allen *et al.,* 2010). In particular, it will modify the risks of fires, pest and pathogen outbreaks, with negative consequences to food, fibre and forest production i.e. timber and non- timber forest products (NTFPS) (Easterling *et al.,* 2007). In regions with large forest-dependent populations, particularly in Africa, expected decreases in rainfall and increased in severity and frequency of drought, which can exacerbate current exploitation pressures on forest resources and expansion of agriculture into forest lands (Arnold and Perez, 2001). In these regions, this can be expected to impose additional stresses on people who depend on fuelwood for their domestic energy needs and their livelihoods (Arnold and Perez, 2001). Climate change may result into shift of forest boundaries. The change in weather may be higher compared to the adaptability capacity of plants and may result in the loss of some of the tree species (Scholes and Linder, 1998). Undoubtedly, human influences have implications for the present role of agricultural lands and forests in global carbon cycles and in future carbon sequestration. In order to mitigate climate change, more carbon should be sequestered in forest ecosystems and strategies for an adapted forest management are sought (Dixon *et al.,* 1994).

2.2 Energy Consumption and Environmental Degradation

In the Southern part of Africa, forest degradation is the outcome of agricultural activities, firewood extraction and charcoal production, mining, human settlement, infrastructural and industrial development, which are one of the biggest problems threatening the lives of many people (Boahene, 1998). Chamshama and Nduwayezu (2002) reported that in Sub-Saharan Africa, there is a continued environmental degradation caused by population growth with a high level of poverty. On the other hand, Blay *et al*. (2004) observed that, at least 90% of humid forests in Sub-Sahara Africa have been degraded, at the rate of 0.1-10%. However, Hartter and Boston (2007) claims those patterns of fuelwood production and intake in Sub-Sahara Africa and their consequent economic and environmental impacts are site specific. Due to that, deforestation, unemployment of youth and gender inequalities are selected obstacles for achieving the MDGs in SSA and Asia (UN, 2007). In the Southern Africa Development Community region, households depend on wood energy by 97%, for cooking and heating (Malimbwi *et al.*, 2001). Reddy (2004) observed that the use of fuelwood varies more in the urban compared to rural areas. Most of the African communities especially the rural and 73% of urban use fuelwood as their primary source of energy, where firewood and charcoal respectively used, due to availability and the income of the households (Ramachandra *et al.,* 2005; Lusambo, 2016).

2.3 Forests and Energy Consumption in Tanzania

Tanzania is endowed with forest resources, ranging from terrestrial to aquatic; forests, mangroves, and woodlands. According to Monela and Abdallah (2007), about 133.5 million hectares of the land area is occupied by forests and woodlands. Based on the 2012 census, the population of Tanzania mainland is 43.6 million, therefore; the per capita area of forest and woodland is 1.1 ha (Drigo, 2006; NAFORMA, 2015). According to NAFORMA (2015), the country deforestation rate stands at 372 816 ha/year implying to the wood deficit of 19.5 million m^3. It has been estimated that the rate of deforestation between 2008 and 2010 is about 2.4% (Morgan-Brown, 2012) which is within the Sub Saharan Africa estimated by Blay *et al.* (2004), in highly closed forests, closed and open miombo woodlands, and coastal mangroves.

In Tanzania, fuelwood is the most important source of energy, where the majority of households depend on it for home energy requirements particularly for cooking (Kigula, 1999). According to Mogaka *et al.* (2001), about 97% of energy consumed domestically is derived from natural forests. Due to that fact, Tanzanian energy balance is dominated by biomass-based fuels, particularly firewood and charcoal which is estimated at 1 m^3 of round wood capital per year.

2.4 Fuel Efficient Stoves and Human Well-being

Availability of clean and affordable energy plays a vital role in the fight against poverty (UN, 2007). Access to clean energy contributes to achieving the Sustainable Development Goals (SDGs) as it plays an important role in the ability of a household to overcome poverty and build resilience (Manyo-Plange, 2011). Burning of solid biomass fuels for cooking in indoor environments can lead to an increased disease burden. WHO has estimated that the impact of Indoor Air Pollution (IAP) on morbidity and premature deaths of women, older persons and children is among the critical public health issue in many developing countries, particularly for the poorest segments of the population (Modi *et al*., 2006). Exposure to IAP is linked to several adverse health effects including acute respiratory infection, chronic obstructive lung disease, pregnancy complications, daily discomfort in women from coughs, headaches, itching eyes and backaches. The supply of alternative energy services could positively benefit maternal health and reduce child mortality (USAID, 2010; Duflo and Greenstone, 2008; Barnes *et al.,* 2012; Rehfuess *et al*., 2014). In addition to the respiratory health burden posed by the use of traditional fuels, women also face health dangers such as vulnerability to cuts, animal bites, falls, sexual attack, and back injuries as they travel long distances to collect and carry traditional fuels for home use (Modi *et al.,* 2006: Barnes *et al*., 2012).

2.5 Factor Influencing Adoption of Fuelwood Efficient Stoves

People hardly ever adopt innovations without good reasons (Barnes *et al.,* 1994). The amount and quality of energy consumption have a correlation with poverty, deprivation, social seclusion, access to knowledge and achievements, health, livelihood, and security. This is because energy services are directly associated with the quality of life and level of development. Modi *et al.* (2006) stressed that progress towards providing greater access to modern energy services has been slow, due to a combination of interrelated circumstances. These include low-income levels among the unserved population; lack of financial resources for service providers to build the necessary infrastructure and reduce first-cost barriers to access; weak institutional, financial, and legal structures; and lack of long-term vision and political commitment to scale up services (Modi *et al*., 2006). The most important factor worth mentioning by different scholars is poverty and lack of access. Households at lower levels of income and development tend to be at the bottom of the energy ladder, using fuel that is cheap and locally available but not very clean nor efficient (Duflo and Greenstone, 2008). It has been shown that the economic status of the households is the main reason for the choice of fuelwood efficient stove (Manyo- Plange, 2011). This associated with household income, cost of stove and fuel, and non-economic costs such as time and access to fuels. Barnes *et al*. (1994) emphasized that the price of stoves can be a limiting factor for adoption because of its price. Ergeneman (2003) also showed that the incidence of rural poverty is an important factor in the adoption of improved stoves. However, it is hard to imagine a rural household which is scarcely meeting its subsistence needs being able to afford the whole cost of an improved stove. According to Bruce *et al*. (2000), improved stoves are more attractive to those households that experience a scarcity in fuelwood since they benefit in terms of time saved from collecting fuelwood or money from the purchase of fuelwood and the increased efficiency of the stoves.

Cultural factors play an important role in adopting the improved stoves. It has been shown that, the past practices and belief that food cooked on clay stoves tasted better than food cooked on other stoves, as main reasons for not switching from biomass to cleaner fuels (Manyo-Plange, 2011).

Educational status plays a significant role in determining stoves choice. Higher education leads to better knowledge regarding modern stoves which could result in a greater likelihood of improved stove switching (Manyo- Plange, 2011). High wood prices or scarce supplies of wood are also factors which increase the likelihood of stoves adoption (Barnes *et al*., 1994). Rehfuess *et al*. (2014) added that households that purchase rather than collect solid fuels are more likely to adopt, reflecting the greater perceived value of monetary savings compared to time savings. Diffusion of information has also its own impact on the adoption of fuel-efficient stoves. Information about the technology is more intensively diffused in villages which are likely to have strong levels of bonding social capital. This implies that bonding social capital played a crucial role in facilitating social learning during the adoption process of improved stoves. On the other side, Rehfuess *et al.* (2014) revealed that households' size is determinant of stove adoption, due to the low value assigned to time and labor used to collect firewood and/or the need to cook for more people. Similarly, lack of a permanent home or kitchen, as well as space limitations, can be obstacles to purchasing a built-in stove (Rehfuess *et al*., 2014).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the Study Area

3.1.1 Geographical location

The study was conducted in Muheza DistrictTanga Region of North-East Tanzania (5^0S, 39^0E) (Fig. 2). The district encompasses an area of approximately 4 922 km^2, ranging from a coastal plain at sea level to the Usambara mountains at 1500 m (Tungu *et al*., 2016).

Figure 2: Map of Tanga Region showing Muheza District.

Source: Emidi *et al*. (2017).

3.1.2 Climatic condition and soil

The climate of Muheza is typically tropical, experiencing high rain in winter, with relatively little rain in the summer. Also, the area receives an average annual temperature and rainfall of 25 °C and 1280 mm respectively. The soil is a typical sandy loam (Msanya *et al.,* 2002) and is covered with dense forest especially on the mountain regions.

3.1.3 Human population and economic activities

According to the 2012 Tanzania National Census, the population of Muheza District was 204 461. This included males 100 843 and 103 618 females with an average annual growth rate of 2.2 % and average household size of 4.3 (URT, 2012). The economy of Muheza like in many other parts of the country depends on subsistence agriculture, livestock keeping and fishing. Smallholders undertake food production to a large extent, while cash crop production is carried out by both smallholders and large scale farmers (public and private institutions). According to the Regional Development Report of 1961-1992, the leading and prominent food crops in terms of area coverage are maize, cassava, banana, pulses, mainly beans and rice. Important cash crops include sisal and cotton. Livestock reared are cattle, goats and sheep. Timber and non-timber forest products production are among of the economic activities in Muheza (URT, 1997).

3.2 Research Design and Sampling Procedures

3.2.1 Research design

The study adopted a descriptive and analytical cross-sectional research design, since because it sets out to describe the adoption of fuelwood efficient stoves as the means or strategies to adapt to climate change effects in the area. It is also an analytical study because it entailed regressions on the factors related to adoptions of the improved stoves.

Also, the study was dealing with the human being as its subjects and studied at one point in a time (Williams *et al.,* 2000).

3.2.2 Sampling procedures

3.2.2.1 Sampling frame and unit

A random sampling design was carried out; its main objective was to have a study sample which is sufficient and representative of the target population. The target populations for this study were households in Misalai and Zirai wards in Muheza district. The sampling frame was the villages in selected wards. Household was a sampling unit obtained from the updated list of households' registers was used to sample households for the study randomly. However, the study was conducted in two phases: the first phase being a preliminary survey prior to the main household's fuelwood survey for pilot testing questionnaires (Appendix 3) and checklist for key informants and FGDs (Appendix 1 and 2 respectively). This was crucial to enable the researcher to cross-check instruments for relevance and comprehensiveness of the data collection. The second phase was general survey where questionnaires were administered to the households and checklist to key informant interview and FGDs.

3.2.2.2 Sample size

The study area consisted of 33 wards and 137 villages. Among the 33 wards two wards, namely; Msilai and Zirai were selected. Five villages out of 137 were selected randomly. was10% of households was sampled from the total village household's population from all villages as recommended by Best and Khan (2003), to represent the entire population (Table 1). The study also purposively included the key informants mainly 2 respondents from TFCG and ONGAWA, 5 from VNRC for each village and 1 from the Ministry of Natural Resource and Tourism due to their understanding on the subject matter around the study area.

Table 1: Households survey sampling intensity

Village	Total number of households	10% of Households	Percent
Kwelumbizi	453	45	27
Kizerui	212	20	12
Misalai	352	35	21
Kazita	315	31	19
Mgambo	351	35	21
Total	**1683**	**167**	**100**

3.3 Data Collection Methods

Primary and secondary were collected in this study. Primary data at households' level were collected through households' questionnaire survey (Appendix 3), Key informant interview, Focus group discussion and field observations. The questionnaires were designed based on research questions. On the other hand, key informants and Focus Group Discussion were conducted through a checklist (Appendix 1 and 2).

Secondary data were collected from different sources which include; published research papers, journal, relevant reports from the projects, and books from both internet and Sokoine National Agriculture library as well as other relevant sources. This type of data was very crucial as it saved time and can reflect the past and the current situations of the adoption process of fuelwood efficient stove as among of the strategies for adapting to the effect of climate change were used to support the information to the collected data.

3.3.1 Household questionnaire Survey

During the survey, structured questionnaire with both closed and open-ended questions was employed. The questionnaire was administered to the respondents as an instrument that consists of a series of questions (Gault, 1907) (Appendix 3). It was designed to collect both quantitative and qualitative information based on key subjects on socio-economic, variables such as gender, household size, occupation, household income, age, and education level, type of fuelwood stove used, reasons for using fuelwood efficient stoves, access fuelwood and the benefits of using FWES in the perspective of climate change effects. Moreover, the challenges and up scaling of FWES adoption were assessed.

3.3.2 Focus group discussions

Focused Group Discussions were used since they give an understanding of the issue at a deeper level relative to a survey by adding meaning and understanding to existing knowledge of a topic (Freeman, 2006). During the discussion with the local communities, a checklist for FGDs was used (Appendix 2). A group of 10-15 peoples was used, which included both men and women from the communities and this was done once per village. FGD was used to collect the information on fuelwood efficient stoves and associated challenges of using FWES, the reasons for not adopting to the technology, and how the FWES have improved their livelihoods in relation to climate change impacts.

3.3.3 Key informant interview

The study involved four key informants (PM Officer, one field staff, and two village leaders) who were purposely selected. The key informants from TFCG and ONGAWA were selected to provide detailed information on the characteristics of the project. The criteria for selecting key informants based on the involvement of the informant in the project implementation. On the other hand, village leaders from the study village. were selected due to the fact that, the village leaders were involved from the project development phase to evaluation, and are the one how to know what is going on in the community. Consequently, they were also believed to have important experience on the project implementation. Key informant checklist (Appendix 1) was used to give the insight on the challenges and benefits of the fuel-efficient stove.

3.3.4 Direct observations

The direct field observations were done concurrently with the household survey. Observable features in the field such as smoke emission in the kitchen; stove design and firewood consumption were noted. Documentary search was done prior to and after fieldwork. Therefore, this mixture of methods was used in order to accomplish what is referred to as triangulation as it uses of multiple sources of evidence as well as seeking for convergence between the sources.

3.4 Data Analysis

3.4.1 Quantitative and qualitative data

Data collected through structured questionnaires were coded to facilitate data entry in the computer. Both quantitative and qualitative data analysis was done by using the Statistical Package for Social Science (SPSS) software tools from which tables, frequencies, and percentages were generated. However, the graphs were generated from the Excels. The Binary Logistic Model was used out to test the relationship between fuelwood efficient stove adoption and independent variables which included: Households' size, scarcity of fuelwood, time spent in fuelwood gathering and Age of respondents.

$Y_i = exp^u / 1 + exp^u$ …………………………………………………..……………..Equation 1

Where

$U = \beta_0 + \beta i x_i$

β_0 and β_i = Are regression coefficients

Yi = Dependent variable (the estimated probability of stove adoption)

x_i = Age of the respondent

x =Household size

x=Scarcity of firewood

x=Time spent in firewood collection.

The regression was tested at 5% level of probability. The model was preferred because it offers a full explanation to the dependent variable since very few phenomena are the product of a single cause and effect of a particular independent variable (Mendenhall, 1989). Other studies, for example, Pallant (2006) showed that the regression coefficients (independents variables as the function of dependent variables) are used to assess the goodness of fit of a linear relationship in the binary logistic regressions, where the higher coefficient of determination (R^2) measured in percentage is the better the precision.

In addition, independent t-test through Excel was applied to check whether the average of the head load of fuelwood used per week consumed in households after and before the introduction of stoves was statistically different.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.2 The Extent of Fuel Efficient Stoves Adoption

4.2.1 Adoption of fuelwood efficient stoves

About 77 per cent of the households adopted to use fuelwood efficient stoves while the rest of respondents claimed to adopt the inefficient fuelwood stoves i.e traditional three-stone open fire stove (Fig. 3). Five cooking stoves were being used for cooking in the area (Fig. 4) which were improved stove with and without a chimney, gas cooking stoves, charcoal cooking stoves and traditional three stone open firewood cooking stoves (Plate 1). The stoves were grouped into three groups namely fuelwood efficient; improved stove with and without a chimney and charcoal cooking stove, Liquefied Petroleum Gas stoves (LPGs) and inefficient fuelwood stoves (Traditional three stones open fire stove). However, the improved stoves included chimney (63%), traditional three stone stoves (23%), improved stoves without chimney (11%), 3% were charcoal stoves and only 1.0% gas cooking stoves (Fig. 4).

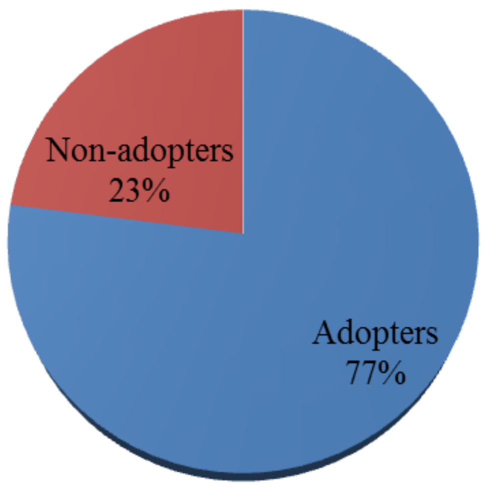

Figure 3: The proportion of adopters and non-adopters in Muheza

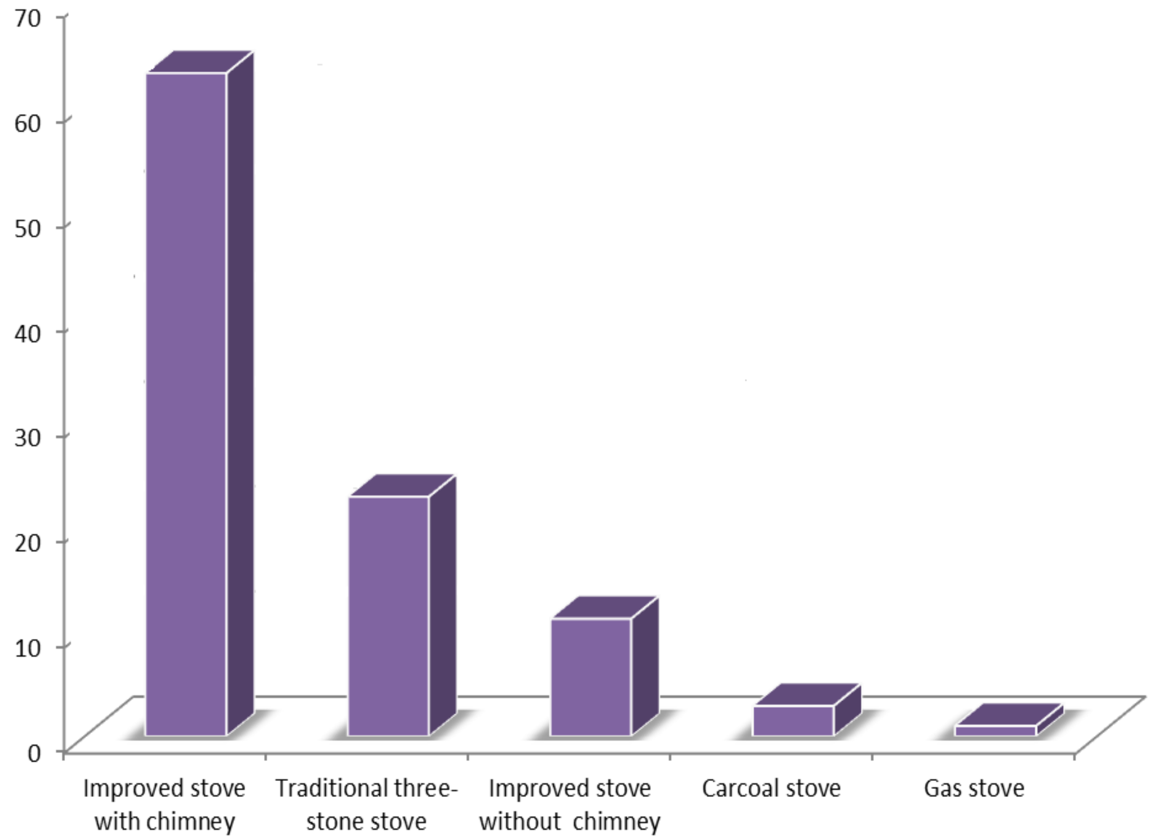

Figure 4: Types of cooking stoves adopted in Muheza

This implies that there was a good effort made by both Government and Non-governmental organization including the international agencies to promote the improved stoves technology through training given to only eight people per homestead/ kitongoji and freely installation at the household level. According to Puzzolo *et al.* (2013) community involvement, especially women, thought the process of design and distribution creates a sense of ownership thus positive relation to adoption.

Lim *et al*. (2013) found that community health workers play a critical role in creating demands, implementing, facilitation, delivering and monitoring of the stoves and related services thus making improved stoves available and sustainable option for the rural poor. Nevertheless, involvements of different stake holders including the Muheza district Council, ONGWA and the village government, this means the successful program involves proper planning and implementation at all stages from raw material to end users adoption with involvement and co-ordination among the various stakeholders (Rehfuess *et al.,* 2014) and adoption could substantially be improved if the government and non-governmental organizations play a greater role in overcoming the social, economic, cultural, political, and institutional barriers to adopting improved cooking technologies (Inayat, 2011).

However, household's survey noted that, education was also provided on issues of climate change and its impacts in natural resources and their livelihoods thus, encourage communities to adopt the technology which is friendly to environment. This was justified by Inayat (2011) in Pakistani, who found that education has influence on adoption of improved cooking stoves.

It was noted in the households which adopted the improved stoves that modifications were done for the improved stoves to have chimneys in order to discharge out the smoke from the kitchen room and reduce the indoor air pollution. Traditional three stone open firewood stoves were still used in the area, due to traditional beliefs that the smoke was very important in terms of drying crops such as maize, as well as a cooking tough foods like cassava locally known as *bada* thus, a challenge on improved stoves adoption.

Plate 1: Gas cooking stove (A) Improved stove with and without chimney (B).Charcoal cooking stove and (C) Traditional three stone stove (D)

4.2.2 Reasons for adoption of efficient fuelwood stoves by the communities

Results showed that different reasons have driven the communities to shift from the use of traditional three-stones open firewood stoves to efficient fuelwood stove including; its low fuel wood consumption and indoor air pollution from smoke, the time to cook food , its high cooking capacity and warming food and room.

Results imply that communities have shifted to the improved fuelwood stoves because of the direct benefits obtained. Ergeneman (2003) revealed that, both the internal and external benefits such as reduced concentrations of smoke and indoor air pollution, money and time saved in acquiring fuel and reduced biomass use have a greater influence on the decision to adopt the improved stoves. However, the internal benefits work to improve the condition of women, who are predominantly responsible for cooking and collecting fuelwood in the communities.

According to Person *et al.* (2012), the introduction of improved cooking stoves can do more than reducing kitchen air pollution, as they also, reduce the workload of women and children on fuel collection, hence more time in productive activities especially income generating activities. Furthermore, reduced time for firewood collection gives more time for education of rural children especially girls (Panwar *et al.,* 2009). The use of firewood and charcoal saving stoves in rural areas has been pointed out to reduce the additional daily workload of women for fetching firewood (Karekezi and Kithyoma, 2002). In Cameroon and Uganda, Tumwesige *et al*. (2017) observed that the reduction in smoke has motivated people to switch from firewood to biogas.

4.2.3 Factors influencing the adoption of fuelwood efficient stove in the area

Binary logistic regression analysis showed that age and scarcity of fuelwood influenced significantly at at $p< 0.05$ with the adjusted R^2 – value of 0.73adoption of fuelwood stove. This indicates that the model explained about correlation linearity (Appendix 4).

4.2.3.1 Age

Age had positive and significantrelationship to household adoptions of efficient fuelwood stoves ($p < 0.05$; $\beta = 1.164$) (Appendix 4). Generally, the study revealed that the improved stoves were more adopted by women above 50 years age group which was the dominant group in the area (Fig. 5).

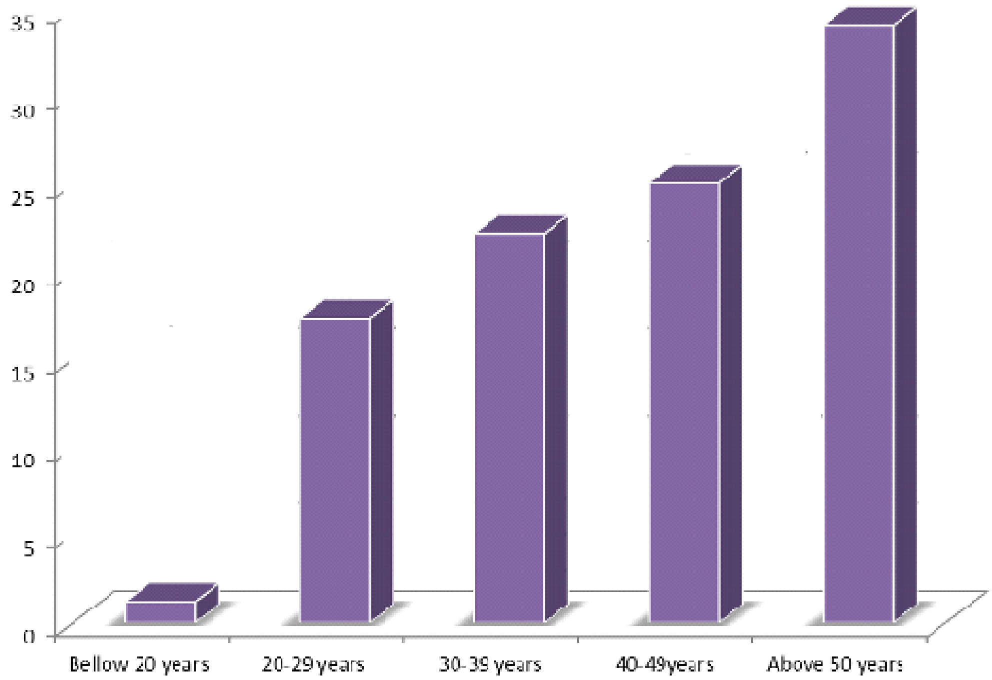

Figure 5: Age of respondents in surveyed villages

This was because of the burden they have in terms of firewood collection and other duties as the African women, also elders who could not even frequently go and collect the firewood compared to average women. Therefore, fuelwood efficient stoves seem to be of more advantage to them perhaps due to its efficiencies in term of firewood consumptions that have reduced the frequency for them to travel a distance on searching firewood.

Similar findings were revealed by Yannick (2010) in Kigoma. Gebreegziabher *et al.* (2017) basing their observations in Ethiopia concluded that the older a person the higher the chances of adopting cleaner cook fuels and stoves. On other hand by Baiyegunhi and Hassan (2014) in Nigeria observed that age of household head had no influence on fuel choice. Bwenge (2011) in Kibaha revealed that, 21 – 30 age group was considered to comprise of young and energetic people to handle family responsibilities and likely to adopt the improved stoves.

4.2.3.2 Scarcity of firewood

Scarcity of fuelwood had a positive and significant relationship to household adoptions of efficient fuelwood stoves ($p < 0.05$; $\beta=1.256$) (Appendix 4). Generally, most of the respondents were farmers who practiced in shifting cultivations farming often in the natural forests woodlands. It was observed that the cleared trees from their farmland and tea estate were collected and converted into fuelwood for cooking. This implies that the larger the land cleared by farmers the more scarce becomes the fuelwood to collect. Historically in the study area before and after independence the area was covered with plenty of vegetation whereby other areas were declared and gazette as Central and Local authority forest reserves aimed at production and environmental conservation (URT, 2003). This is a typical example showing that forests and its products including fuelwood were available and collections were taken for granted as a free access commodity. However, the establishment of the tea estate and other agricultural activities has cleared forest and left the land bare and lead to scarcity of fuelwood. Kalonga.

et al. (2017) reported that forests support the livelihoods of 87% of the rural poor in the country. Lipper (2000) reported that, the scarcity of fuelwood is often associated with other socio-economic and environmental problems which include land degradation, economic hardships, lowering of living standards and the decline of agricultural crop production. However, its solution is to enhance sustainable management of natural forest resources to ensure woodfuel supply to the communities (Levang *et al.*, 2005).

It has been established that the accessibility to modern commercial energy such as fossil fuels and grid electricity is not widely available to the majority of Sub Saharan countries (Karekezi and Kithyoma, 2002), and where there is electricity majority of the people still use biomass as their source of energy because of different reasons including high rainfall. In many areas, there is an increasing shortage of fuelwood supply, which adds more burdens to women who are responsible for household cooking energy management (Clancy *et al.*, 2003). Fuelwood as a traditional form of energy can only be termed as a renewable energy source if is protected and used in a sustainable manner (Mangi, 2011). It was found that firewood is the dominating energy consumed at the households in the study area (Fig. 6).

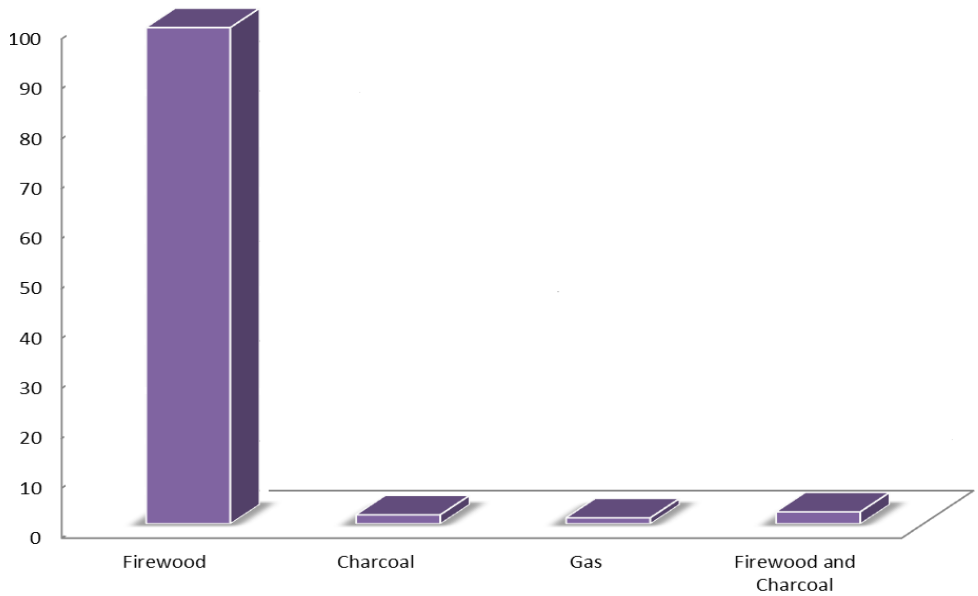

Figure 6: Energy used for cooking in Muheza

It was also observed that around homesteads respondents planted trees and most of them were cash crops like Cinnamon, Cloves and Jackfruit trees to enhance the continuity of getting forest goods including fuelwood as a renewable source of energy and to generate their income through it.

According to Bruce *et al*. (2000), improved stoves are more attractive to those households that experience a scarcity in fuelwood since they benefit in terms of time saved from collecting fuelwood or money saved from the purchase of fuelwood and from the increased efficiency of the stoves.

4.2.3.3 Time spent for firewood collection

Results indicated no significant relationship ($p < 0.05$, $\beta = - 0.237$) between fuelwood efficient stoves adoption and time spent on fuelwood collection (Appendix 4). Commonly, the adoption of efficient fuelwood stove at the households level depends on its availability. The more abundant the woodfuel the shorter the time spent in collection while the more scarce the fuelwood, the longer the time could be spent in collection., This was still not the incentives for communities to use the improved stoves because since the introduction of the stoves, people were spent an average of 4.5 hours per day which is the same as to day. It is indicated, that majority of the households in the study area 71% spent more than two hours in firewood collection (Table 2). The evidence from past research indicates women and children take more time, collecting woodfuel, which was formerly readily available close to homesteads (Malimbwi *et al.*, 2005).

Table 2: Percentage distribution of time spent on firewood collection in Muheza

Time spent (hrs.)	Frequency	Percent
<1	3	1.8
1	16	9.6
1.5	2	1.2
2	28	16.8
>2	118	70.7
Total	**167**	**100**

4.3 The Direct and Indirect Benefits of the Using Efficient Fuelwood Stoves

The use of fuelwood efficient stoves in the area has been a homeopath on mitigating the effect of climate change by improving the carbon pools in different ways as explained below:-

4.3.1 The Direct benefits of the Using Efficient Fuelwood Stoves

4.3.1.1 Firewood consumption

The average firewood consumed (low consumptions of fuelwood) by households were among of the direct benefits of the introduced stoves in the area. Where 4 head loads per week and 2 head load per week per household before and after the introduction of fuelwood efficient stove respectively was found. However, most of the households consume 2headload per week (Appendix 5). On the other hand 0.57 and 0.28 were consumption rate per week at the household level before and after the introduction of fuelwood efficient stoves respectively from the mean consumption rate (Appendix 5).

This implies that the firewood consumptions before and after the introduction of fuelwood efficient stoves in the area were significantly different $t=1.97$, $N=167$, $df=325$, $p<0.005$ (Appendix 6), perhaps due to households' size (Table 3) and efficient of the stove.

Table 3: Households size percentage distribution in Muheza

Household Size	Frequency	Percentage
2-6	125	74.9
7-11	36	21.6
Above 12	6	3.6
Total	**167**	**100**

Consumption of the fuelwood efficient stoves has significantly contributed to adapting to climate change effect as claimed by seventy-nine percent per cent of the respondents with reduction of firewood consumption by more than 50 per cent. Consequently, the low consumption rate of fuelwood efficient stoves has decreased pressure and disturbance in forest reserves which are among of five carbon pool. The installation of stoves in households has reduced the frequency of firewood collections for household cooking, which, in turn, should directly reduce the probability of forest disturbance, and accelerate the rate of afforestation and minimizing the effects of climate change.

According to URT (2003), change in forest and other woody biomass stock contributed 3 745 Gg of Carbon emissions in 1990. Sohel *et al.* (2010) shows that the introduction of improved cook stove in Bangladesh reduced the dependence of people on the forest, by reducing the quantity of fuel wood required to meet the household cooking energy needs. About 79% of improved stove users consume approximately 3 kg of firewood per day, in contrast to 74% of the traditional cooking stove users consuming about 10 kg per day.

4.3.1.2 Smoke emissions

Smoke emission was direct benefits mentioned by respondents (51.2%) to be one of the major downside of traditional firewood stoves and a driving force for its abandonment (Fig. 6). The smokes emitted from the stove were associated with air pollution; with, indoor air pollution was linked to respiratory infections, dizziness, and headache to women and young children who spent most of their time in the kitchen. About fifty percent of the respondents agreed on substantial reduction in smoke emission from the use of fuelwood efficient stoves as it produces and discharges less smoke, even though, field observations showed slight presence of smoke in the kitchen. It was observed that smoke is more emitted in poorly ventilated kitchens compared to well-ventilated ones which allow enough air to support the wood burning process (Plate 2).

Plate 2: Inventilated kitchen room (A) and adequately ventilated kitchen room (B)

The World Bank (2011) report denotes that, there is mounting evidence showing that inefficient burning of biomass fuels contributes to climate change effects at the national and global level. Replacement of traditional stoves to improved cooking stoves could be only affordable technology in the rural area. According to TaTEDO (2010), the problem associated with inefficient production and utilization of wood fuels in Tanzania includes increased frequency on firewood collection and air pollution from greenhouse gas emissions (GHGs). However, FAO (2010) argued that estimates of global emissions reduction from the improved efficiency of cooking stoves are uncertain since the underlying data are either unavailable or subject to considerable fluctuation. On the other hand, it is estimated that the new generation of advanced biomass cooking stoves would reduce CO_2 emissions by about 25–50 percent.

4.3.2 Indirect benefits of the using efficient fuelwood stoves

4.3.2.1 Restoration of landscapes

Fuelwood efficient cooking stoves might have contributed to reduction of the effects of climate change in the area through well-managed landscapes as the indirect benefits of using the stove. About 47 % of the respondents reported that, the stoves have restored their landscape since less firewood is used thus less disturbances on woodlots, farm plot, and forests (Plate 3).

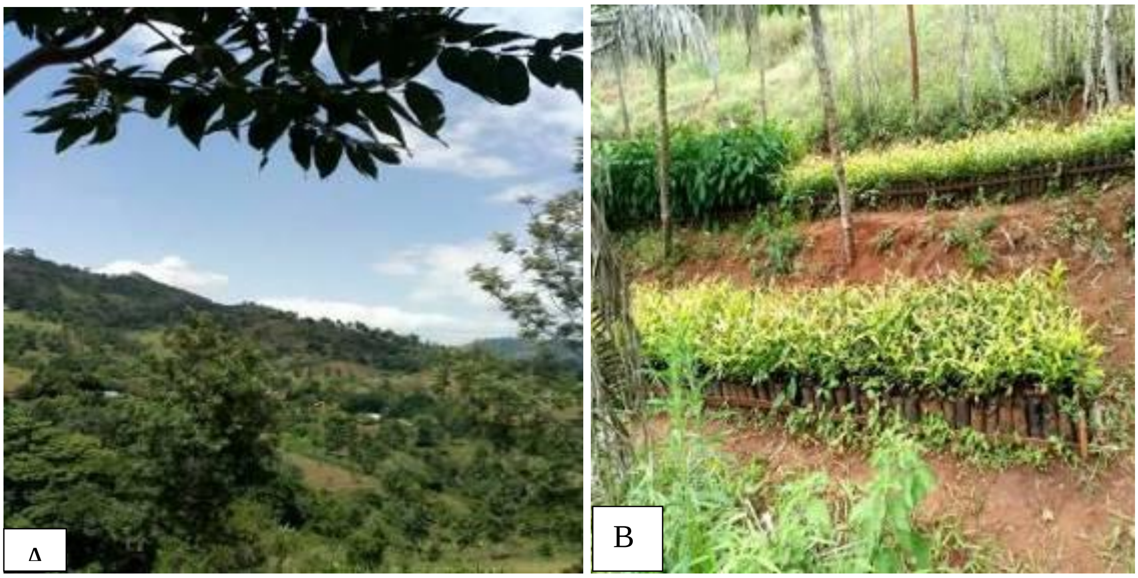

Plate 3: Restored landscape and (A) Tree nursery (B).

This has decelerated the climate change effect perhaps through increased carbon pools; biomass and soil organic matter. However, the restoration of the landscape in the area was both active and passive through agroforestry; Jack tree, Cinnamon, and Clove which were sometimes sources of fuelwood. Therefore, the stoves in the study area were likely to increase amount of carbon dioxide sequestered in the atmosphere through the restored landscapes by regrowth of vegetation. This is supported by Bailis *et al.*, (2003) who stated that the emitted CO_2 is sequestered into the biomass as it regrows. However, the amount of regrowth is likely to vary geographically.

4.3.2.2 Forest management

The management of the forest was mentioned to be indirect benefits of FWES in the area. Where firewood was found to be mostly consumed at households accounting for 95.5% and forests were the supplier in the area (Fig. 6). However, most households collected firewood from their farms; as they practiced agroforestry (Fig. 7). Households were also allowed to collect the firewood from the nearby forest like Nilo Forest Reserve twice per week; only the fallen and dead trees and branches were allowed cutting down without live trees.

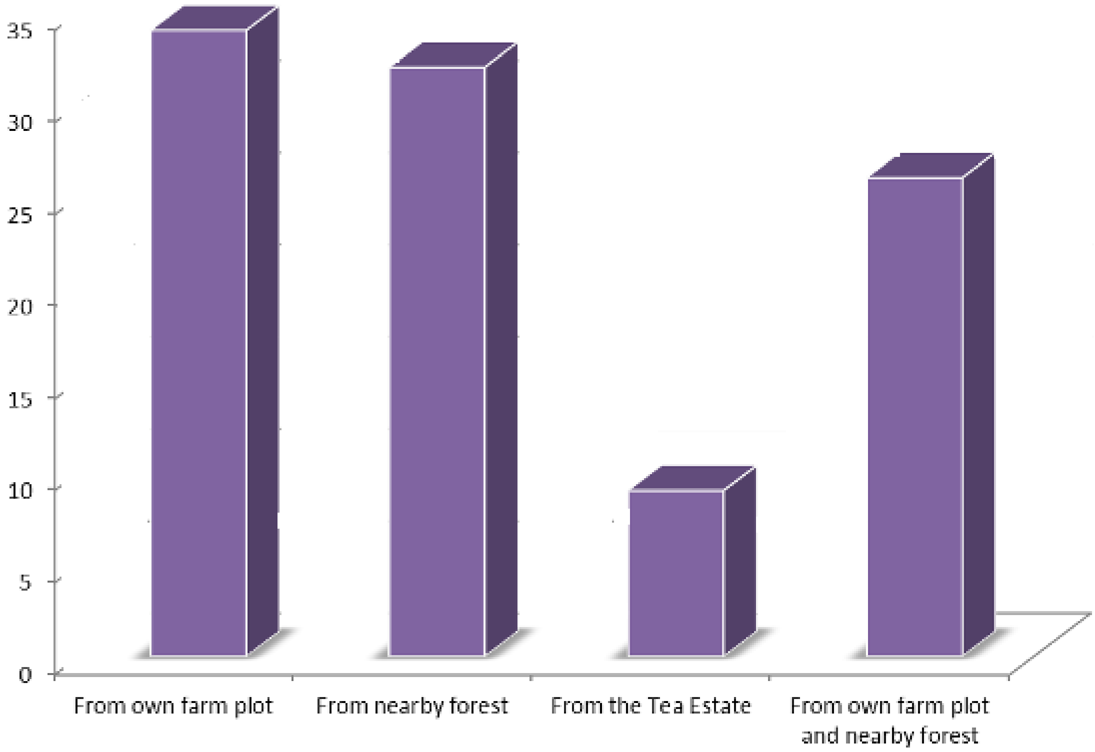

Figure 7: Firewood collection site in Muheza

According to Van Beukering *et al.* (2007), in developing countries for many decades fuelwood has been abundant and the collection was taken for granted almost around their homesteads. Recently woodfuel is no longer a free commodity but rather a commercial product in terms of its price which is gradually rising and increased distance walked in the collection. In most cases, natural forests, woodlands, plantations, woodlots or trees on farms are the main woodfuel energy supply sources in Tanzania (MNRT, 2001).

The introduction of fuelwood efficient stoves seemed to have addressed the effects of climate change in the area. As reported by 46.36% of the respondent who agreed that, the introduction of fuelwood efficient stove in the area has contributed much in adapting the effects of climate through management (Fig. 8).

Since people now can use only 5-8 piece of firewood per day to meet their daily needs and reduce disturbances on the forest. This is perhaps due to decreased fuelwood consumptions that have reduced the frequencies on firewood collections from the forest and reduced deforestation. Conveniently, forest management through the use of fuelwood efficient stoves has improved forest management and reducing deforestation.

According to FAO (2005) one of the major challenges facing Tanzania's forests is deforestation, estimated at 412 000 ha per annum between 1990 and 2005 which is equivalent to 1.1% of the country's total forest area. However, recent data show that deforestation rate between 130 000 -500 000 ha per year (FAO, 2010) since deforestation through burning accounts for at least 20% of global carbon emissions, measures to curb this complex phenomenon ought to be one of the principal strategies for reducing greenhouse gas emissions. Prevention of deforestation can maintain the amount of carbon held in forests. The Local government of the area has strengthened law enforcement and advocates participatory approaches to forest management as a means of reducing deforestation and degradations, where the local communities are being involved in patrol (Mr Hassan, 2018 personal communication).

According to Makame (2007) improved stoves are believed as the real option for reducing fuelwood consumption in both rural and urban areas, and thus reducing the rate of deforestation. However, this can be achieved only when the stoves are adopted and consistently used by the majority of both rural and urban population.

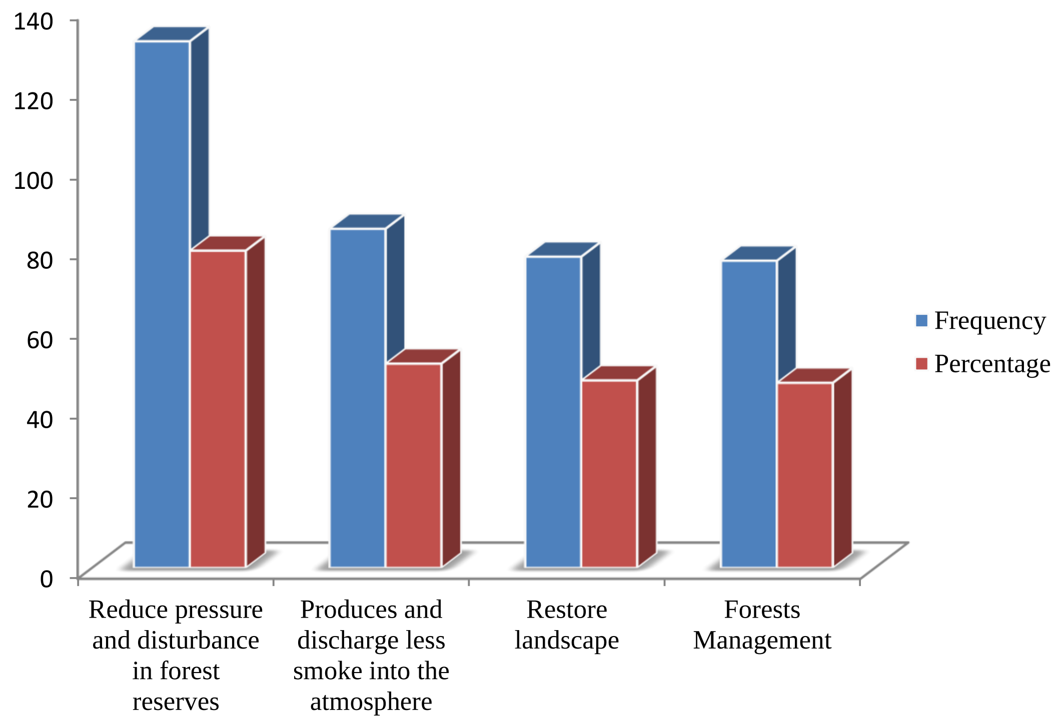

Figure 8: Benefits of Fuelwood efficient stove in relation to climate change effects in Muheza.

4.4 Challenges of Adoptions and Up -Scaling of Fuel Efficient Stove Technology in the Area

Results indicated that the adoption of efficient fuelwood stoves as the strategies for climate change adaptation by households in the study area have been successful by 77%of the respondent. However, the adoption of the stoves is faced with many challenges. 47% of the respondent claimed that, limited knowledge about the fuelwood efficient stoves and its usefulness in relation to climate change effects (Table 4). Where 24% of the respondents reported technical challenges. Nevertheless, financial reasons, shortage of the service providers, availability of fuelwood, cultural reasons and inadequate of bylaws were also among the challenges Table 4.

Table 4: The challenges affecting the adoption of Fuelwood efficient stoves

Valiable	**Male**	**Female**	**Total**
Limited knowledge on stoves and climate change	9(5.48)	69(42.02)	78(47.5)
Technical challenges	5(3.08)	35(21.54)	40(24.62)
Poverty	2(1.27)	14(8.89)	16(10.16)
Shortage of service provider	1(0.64)	13(8.31)	14(8.95)
Availability of fuelwood	0(0)	4(2.93)	4(2.93)
Cultural reasons	0(0)	5(3.52)	5(3.52)
Lack of bylaws	0(0)	3(2.32)	3(2.32)
Total	**17(10.47)**	**143(89.53)**	**160(100)**

Note: Numbers in the parentheses are percentages

Limited knowledge on the stoves and its usefulness in relation to climate change effect was the main challenges for communities to adopt. This perhaps could be a result of not involving communities in the whole process of installing the stoves, despite, only a few being trained by TFCG and ONGAWA. A poverty constraint was encountered as one of the drawbacks of fuelwood efficient stove adoption in the study area. Field observations noted most of the households were lacking a permanent and well-constructed kitchen room, and some of them reallocated their kitchen and settlements. Nevertheless, some households were unable to prepare the construction materials especially the iron sheets, because most of them lived in the house roofed with grasses.

Technical challenges such as daily repair of the stoves, compatibility with the cooking chair (Kigoda) were among the reasons hindering the diffusion of stoves. Results of this study are similar to Manyo-Plange (2011) who pointed out that the design of equipment, its size, perceived safety and even the type of existing cooking utensils are technical aspects which have impact on efficient stoves adoption. A stove design plays a key role in its adoption and sustained use. Rehfuess *et al.* (20140) found that majority of the initial improved cooking stoves program had specific design problems that led to the use of traditional stove. Incidences of stove cracks and improper stove installation has led to negative impact on stove functionality and sustained use (Chowdhury *et al.*, 2011).

Culture was among the challenges for the households to switch from the traditional three-stone to efficient cooking stoves (Table 5). Cultural factors have significance to adoption may and form the basis through which individual decisions are made. Some households failed to adopt the efficient fuelwood stoves because the food cooked on them does not have better taste compared to the ones cooked from the traditional stoves. According to Manyo-Plangen (2011) in Ghana women's choices of fuel-efficient stoves depend upon existing environmental factors and culture. The author further revealed that the open firewood was preferred to smoke fish. Furthermore, a study conducted in Sri Lanka by Wijayatunga and Attalage (2003), to determine barriers to fuel switching, revealed that cultural factors play an important role in the cooking fuel decision-making and a need to re-look this during promotion was emphasized.

Puzzolo *et al.* (2013) found that households prefer preparing their meals using traditional stoves so as to achieve a preferred smoky taste of the food. In India IEA (2006) found that baking bread using wood stoves is highly preferred by households. Similarity, Lohani (2010) found that traditional laws prohibit from cooking animal meat in an enclosed house especially where people sleep, thus they prefer cooking meat from outside. A similar finding in Burkina Faso where by Ouedraogo (2006) found that preparation of staple traditional meals increases the likelihood of using fuelwood. This shows the significant influence of traditional stove to rural households despite introduction of the improved cooking stoves.

4.5 Community Opinions on up-scaling Fuelwood Efficient Stove in the Area

About 46.1% of the 167 respondents suggested environmental education to communities on stoves and its implications on adapting to the effect of climate change should be mainly. Also the installations of stoves to the households' for those who were either not around during constructions for some reasons or because of poor condition of the kitchen room and reallocations of settlements and kitchen room should be done.

Table 5: Distribution of views on up-scaling Fuelwood Efficient stove adoption

Variable	Frequency	Percent
Environmental education	77	46.1
Installation of Fuelwood efficient stoves	58	34.7
Improvement of technology	25	15.0
No any opinion	7	4.2
Total	**167**	**100**

Environmental education on the use of stoves in relation to climate change to the community seems to be a significant step towards adoption of fuelwood efficient stove in the short and long-term planning. Similar finding by Mangi (2011) indicated that education has significant influence on the use of efficient stove by the communities adjacent to natural resources or to those who suffer from scarcity of energy.

Success of stoves adoption in the study area could rely on the provision of education on the importance of fuelwood efficient stoves in terms of its direct and indirect benefits for community livelihood i.e. health and income generation and conservation. Both the Government and NGOs sensitization efforts through its policies, National sustainable energy campaign for the future generation in the study area and the country as a whole should continue.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion the study has found that:

The majority of households surveyed have adopted the use of fuelwood efficient stoves, only two types of fuelwood efficient stove: Improved stove with chimney and improved stove without chimney were commonly used. The adoption was influenced by age of the respondents and scarcity of firewood. Firewood consumption, emission of smoke, restoration of landscapes and forest management were the direct and indirect benefit of using fuelwood efficient stoves in adapting to climate change effect.

The adoptions and up-scaling of fuelwood efficient stoves face different challenges mainly limited knowledge on fuelwood efficient stoves and its usefulness in relation to climate change effect, technical challenges i.e repairing and difficulties of cooking some traditional foodstuff (e.g *Bada*). Poverty and cultural were also among the challenges in the area that influenced adoption and up-scaling of fuelwood efficient stoves.

5.2 Recommendations

From the study results, the followings are recommended:

There is a need to sensitize local communities on fuelwood efficient stoves and its use in relation to climate change for natural capital protection and utilization to be effective and sustainable in the area , both the Government and development agencies should view 78 percent of households which adopted the efficient stoves as a target while monitoring the dissemination efforts closely to make sure that the adoption of stoves results on improving the livelihoods of the communities by addressing the effects of climate change on the natural resources where more than 95% depends on for their day-to-day life. Agroforestry system practices should be emphasized to communities to meet their wood products demand around home locale and reduces a burden to women and children who spend long walking distance and time for fuelwood collection. This will in turn restore landscapes; deliver fuelwood, fodder and food. Planting of cash crops such as Cinnamon, cloves and Jackfruit trees should also be promoted to improve the livelihood of communities for earning economic benefits while conserving and addressing the effect of climate change in the area. On up-scaling the dissemination of fuelwood efficient stove, the Government, NGOs and other development partners should continue to promote its uses in relation to climate change effects and wellbeing of societies and seek for feedback from the users for improvement of the stoves, nevertheless, it should install the stoves which can last for a long time with less repairing, and training on installations should be given to the communities to assist them to install when they allocate their kitchen rooms or settlements rather than training a few peoples who can install with less involvements of the households. This will assist them when they migrate to other places for the new settlement.

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APPENDECES

Appendix 1: Key Informant Checklist

What is the source of fuel wood in the village?

What type of stove available and used in the village?

What types of fuel wood efficient stove are available in the village?

What are the benefits of using the mentioned stove?

Why people should adopt it in relation to climate change?

What are the limiting factors for adopting fuel wood efficient stove in the village?

What should be done for the local communities to adopt to the fuel wood efficient stove?

Appendix 2: Focused Group Discussion Checklist

What are the main sources of energy in the village?

What are the sources of fuel wood in the village?

What type of stove available and used in the village?

What types of fuel wood efficient stove are available in the village?

What are the benefits of using the mentioned stove?

What are the challenges of using the Fuelwood efficient stove?

What are the limiting factors for adopting the stove?

What should be done for the local communities to adopt to the Fuelwood efficient stove?

Appendix 3: Household's Questionnaire on Adoption of Fuelwood efficient cook stove technology in Muheza

S/No.	**A. General Information**	
01	Ward	
02	Village	
03	Household No.	
04	Number of Respondent	
05	Date	
06	Time	
	B. SOCIO DEMOGRAPHIC INFORMATION	
	QUESTION	CODING CATEGORY
1	Are you head of this household?	Yes …………..1 No …………...2
2	If **Not,** what is your relationship with the head of the household?	Wife ……………….1 Son ………………....2 Daughter ………..…..3 Others specify ………4
3	How old are you?	………….
4	Have you been born in Muheza?	Yes …………1 No ………….2
5	For how long have you been living in Muheza?	Less than 10 years 11 – 15 years ………...1 16 – 20 years…………2 21 – 25 years…………3 26 – 30 years…………4 31 – 35 yers…………..5 36 – 40 years………….6 More than 40 years……7
6	What is your marital status?	Married…..………1 Single……..…..…2 Divorced ………...3 Widow……………4
7	If married, how many children do you have?	…………….
8	What is your household size?	………………..
9	In your opinion, how many children would you like to have?	1 – 2 children ………1 3 – 4 children ….……2 5 – 6 children ……….3 7 –10 children ………4 10 children ………….5
10	Have you attended the formal school education?	Yes……………..1 No………………2

11	If yes, what is the highest level of education you have attained?	Primary school …………………… ...1 Vocational education ……………….…2 Secondary education (o-level) ………3 High school education (A-level) …….4 Certificate holder ……………………5 Diploma holder ……………………...6 University Degree ………………..…7
12	Do you have a paid job?	Yes ………..1 No ………...2
13	If Yes, what kind of job do you do?	…………………
14	If Not, what do you do for your living?	A farmer ……………………..1 A businessman ………………2 Others (specify) ………………3

C. Types of fuelwood cook stoves in use and sources of energy in the study area

S/No	QUESTION	CODING CATEGORY
1	What type of energy do you use for cooking at home?	Firewood ………………………..1 Charcoal ………………………….2 Kerosene …………………………3 Gas ………………………………4
2	Where do you get/ collect firewood?	From own farm plot ……….….…..1 From nearby forest …………………..2 From the Tea Estate …………………..3
3	How long does it take to collect firewood?	< 1 hour ………………………..1 1 hour ………………………….2 1.5 hours ……………………….3 2 hours ………………………….4 > 2 hours ………………………..5
4	Who is responsible for firewood collection in your household?	Wife …………………………1 Daughters..…………………..…2 Sons. …………………………3 Head of the house ……….…..4 All members in the family ……5
5	What type of cook stoves do you use at home?	Traditional 3 – stone stove …………….1 Improved stove without chimney ......…2 Improved stove with chimney…………..3 Electricity cook stove ………………….4 Gas cook stove …………………………5

6	What is the current consumption rate of you cook stove?	< 1 head load per week 1 head load per week 2 head load per week 3 head load per week 4 head load per week > 4 head load per week
7	What is the previously consumption rate of your cook stove?	< 1 head load per week 1 head load per week 2 head load per week 3 head load per week 4 head load per week > 4 head load per week

D. Direct and indirect benefits of the use of efficient fuelwood stoves in relation to adaptation to the climate change effects

S/No	QUESTION	CODING CATEGORY
1	Do you have information on efficient fuelwood cook stoves?	No, no information……………………..1 Yes, but insufficient information……....2 Yes, sufficient information ……………..3 Yes, extensive information ……………..4
2	If YES; Who gave you this information? (*more than one answer is possible)*	TFCG staff ………………………….... 1 CBT member(s) ……………………….2 Governmental campaigns …………….3 Friends ……………………………...…4 Others ………………………….(specify)
3	What type of cook stove were you using before introduction of EFW cook stove technology?	Traditional 3 – stones cook stove (1) Improved stove without chimney (2) Kerosene cook stove ……………(3) Gas cook stove ………………….(4) Electricity cook stove …………...(5)
4	What are the benefits of using this EFW cook stoves? (*Tick all he/she knows*)	It uses less firewood (1) It cooks faster (2) Can cook 2 food at one go (3) Removes smoke from the kitchen room (4) Keep food warm for longer time after cooking without adding firewood (5) Keeps the room warm for long time (6) Others ……….

5	Have you participated in any training on construction and maintenance of the EFW cook stoves?	Yes …………1 No …………..2
6	If Yes, how important was that training to you?	Totally unimportant …………1 Important …………….………2 Very important ………………3
	Answer the following questions if you have any lessons with your experience in the use of traditional 3 stone cook stove: Which of the following disadvantages did you or your family experienced? More answers are possible. (Tick for the response)	
7	Traditional 3-stone stove:	Consumes more fuelwood than the improved ones ……………………1 Takes longer time to cook compared to the improved ones …………2 Cannot cook 2 food at one go …………3 Produces a lot of smoke thus exposes us to eye and lungs related diseases ………………4 More time spent on firewood collection …..5 Frequencies of firewood collection is high thus increases the risk of forest disturbance and deforestation rate……….......……………6 Exposes the family into risk of being burnt by the open fire………………………………7
8	How important is the EFW cook stove in relation to climate change adaptation? More answers are possible. (Tick for the response)	It uses less amount of firewood thus reduces pressure and disturbance in our forest reserves. So our forests will be well managed ……………..……….……………………(1) It produces and discharge less smoke into the atmosphere (because it uses less amount of firewood then less smoke is produces) ………………….(2). Less amount of firewood means less disturbance in our woodlots and farm plots thus our landscape is well restored and maintained….(3). EFW cook stoves provide for well-managed forests as well as water sources. So the community can get water all year around …….(4).

E. Challenges associated with the adoption and up-scaling of EFWs in the study area

S/No	QUESTION	CODING CATEGORY
1	What are the challenges affecting adoption of the EFW cook stoves in this area? (*More answers are possible. Tick for the appropriate response*)	Limited information/ knowledge about the EFW cook stoves…………………………….….. (1) Economic / financial reasons ……….……..(2) Availability of fuelwood have never been a problem. So no need to change into the improved one ……………….…………….…..(3) Fear or misconception that the chimney will cause fire especially for the houses using thatches as roofing and poles as construction materials…………………….…..(4). Lack of knowledge about usefulness of the EFW cook stoves in adapting to the negative effects of the climate changes……………………(5) Non-availability / Shortage of the service providers (Community Based Trainers (CBTs)) ……………………………….… (6) Traditional / Cultural reasons ……………… (7) Notion/ perception that EFW cook stoves not as good as the traditional one when it comes to warming and heating ……………………….(8) Lack of the support from the Village leaders / VGC / district authority …………………….(9). Lack of bylaws governing implementation of the EFW cook stoves ………………………..….(10) Others (specify) ………………………………………… ………………………………………… …………………………………………
2	In your opinion, what do you think should be done to improve adoption of the EFW cook stoves in this area? *(Explain)*	………………………………………… ………………………………………… …………………………………………

Appendix 4: Binary Logistic Regression model analysis

Factors	Standardized Coefficients		
	Beta(β)	T	Sign
Constant	-3.135	0.43	0.000
Age	**1.245**	**1.819**	**0.023**
Household size	19.55	3.944	0.131
Scarcity of firewood	**1.366**	**3.887**	**0.001**
Time spend on Fw collection	-0.312	3.782	0.016

Fw -firewood, R^2= 0.73 F=9.57 P < 0.05

Appendix 5: Consumption rate of Firewood after and before the introduction of FWE stove

	Before EFWS introduction		After EFWS introduction	
Head load	**Frequency**	**Percent**	**Frequency**	**Percent**
<1 head load per week	**8**	**4.8**	**8**	**4.8**
1 head load per week	16	9.9	50	29.9
2 head load per week	58	34.1	53	31.7
3 head load per week	27	16.2	33	19.8
4 head load per week	34	20.4	8	4.8
>4 head load per week	24	7.2	15	9
Total	**167**	**100**	**167**	**100**

Appendix 6: t-Test: Two-Sample Assuming Equal Variances to show the head load per week

	Before the introduction of FWES	***After the introduction of FWES***
Mean	4.059006211	2.024096386
Variance	3.419934006	1.247900694
Observations	167	167
Pooled Variance	2.317209401	
Hypothesized Mean Difference	0	
Df	325	
t Stat	12.08524985	
P(T<=t) one-tail	2.53032E-28	
t Critical one-tail	1.649555622	
P(T<=t) two-tail	5.06063E-28	
t Critical two-tail	1.967290077	