IMPACT OF TOBACCO CURING ON THE ENVIRONMENT AND SOCIO-ECONOMIC ASPECTS IN THE URAMBO DISTRICT

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ABSTRACT

Despite the efforts that have been employed to reduce tobacco curing related deforestation in many countries including Tanzania. The economic importance of tobacco production on employment creation and foreign exchange makes production continue to increase which increases the demand for wood fuel that results in deforestation. This study assessed the impact of the tobacco curing process on the environment and socio-economic aspects. This was achieved through a structured questionnaire and Specific Fuel Consumption (SFC) assessments. A cross-sectional study design was adopted whereby structured questionnaires were administered to 892 respondents who are tobacco farmers from nine Primary Tobacco Farmer Cooperatives in the Urambo district. Structured questionnaires' data were analyzed using Microsoft Excel to determine the Cost-Benefit Analysis then subjected to SPSS for descriptive statistics. In addition, SFC data were employed to estimate annual woodland area cleared, carbon emission, and carbon dioxide hindered from sequestration. The results show that 95% of all tobacco farmers have been harvesting wood fuel from forest woodland. This caused tobacco related-deforestation of 6355.47 ha in 2018/19 that hindered 6 3554.73 tons of atmospheric carbon dioxide from sequestration. Also, the emission of 3 3366.24 tons of carbon dioxide was recorded during the curing process. Rocket barn version 2 (RB2) and traditional barn (TB) were observed to have higher net revenue compared to rocket barn version 3 (RB3) and standard barn (SB). For this reason, rocket barn and traditional barn are more preferred than rocket barn and standard barn. The findings also revealed the social aspects associated with tobacco curing including labor intensity and food insecurity. Based on these findings, it is recommended that to improve the sustainability of tobacco farming, alternative and affordable tobacco curing technologies should be instantly developed to replace wood fuel that poses problems of environmental degradation.

DECLARATION

I, Domitius Katatwile do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

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CERTIFICATION

The undersigned certify that they have read the dissertation title "*In vitro antiproliferative effects of Crude Extracts of Carica papaya black seeds against prostate cancer cell lines*" and it is recommended for examination in the fulfillment of the requirements for the degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology (NM-AIST).

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DEDICATION

I would like to dedicate this work to my family for endless love, encouragement, support and prayers with love and respect.

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LIST OF ABBREVIATIONS AND SYMBOLS

AOTTL	Alliance One Tobacco Tanzania Ltd
ATTT	Association of Tanzania Tobacco Traders
BAT	British American Tobacco
BOT	Bank of Tanzania
CAGR	Compound Annual Growth Rate
CBA	Cost Benefit Analysis
DAC	Dark Air-Cured
DFCT	Dark Fire Cured Tobacco
FAOSTAT	Food and Agriculture Organization Statistical Database
FCV	Flue Cured Virginia
GDP	Growth Domestic Product
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
JTI	Japan Tobacco International
LAC	Light Air-Cured
NM-AIST	Nelson Mandela African Institution of Science and Technology
RB2	Rocket barn version two
RB3	Rocket barn version three
SB	Standard Barn
SFC	Specific Fuel Consumption
TB	Traditional Barn
tCO2e	Tons of Carbon DioxideEquivalent
TFS	Tanzania Forest Service
TORITA	Tobacco Research Institute of Tanzania
TTB	Tanzania Tobacco Board
UCCP	Ugalla Community Conservation Project
VFC	Virginia Flue Cured
WETCU	Western Zone Tobacco Growers Cooperative Union
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Tobacco (*Nicotiana tabacum*. L.) is grown in 120 countries around the world, with about 80% of global tobacco being grown in 10 countries which are China, Brazil, India, United States of America, Malawi, Indonesia, Argentina, Pakistan, Zimbabwe and Tanzania (Sacchetto, 2012).

In Africa continent, the top three tobacco growing countries are Malawi, Zimbabwe, and Tanzania (Food and Agriculture Organization Statistical Database [FAOSTAT], 2017). In Tanzania, tobacco is highly grown in Tabora, Iringa, Mbeya, Shinyanga and Rukwa regions Tobacco Research Institute of Tanzania [TORITA], 2020). According to Tanzania Tobacco Board (TTB, 2019), the Tabora region contributed about 39%, while the Urambo district contributed about 11% of tobacco production within the country in 2018/19. Thus, Tabora region contributes about 50% of the tobacco produced in Tanzania. There are two major types of tobacco crop grown in Tanzania, which are Flue-Cured and Dark-Flue Variety. Because of its higher market demand Clark *et al.* (2020), Flue-Cured tobacco accounts for about 80% of all tobacco grown in the country (TTB, 2019). Also, strong tobacco companies such as Japan Tobacco International (JTI) and Alliance One Tobacco Tanzania Ltd (AOTTL), which guarantee the purchase of produced tobacco than other cash crops influence its growth in Tanzania (TTB, 2019).

Economically, tobacco production contributes to tax revenue, employment and cash income that reducing household poverty and contributes to foreign exchanges (Chacha, 1996; Hu & Lee, 2015). Even in countries where it is not significantly produced, tobacco production contributes to farmers' incomes (Mergos, 2001). This can be well explained in Brazil, where approximately 135 000 farmers produce tobacco as their main economic activity that contributed to US$ 5000 of individual income in 2000/01 (De-Leite & Da-Conceição 2020). Globally, tobacco production value was approximately USD 849.09 billion in 2019 and was expected to grow at a compound annual growth rate (CAGR) of 3.1% from 2020 to 2027 (Dhungana, 2020). In most tobacco-producing countries, tobacco contributes more to their national economies than other cash crops (Ngarava, 2020). Additionally, tobacco production contributes significantly to creating permanent jobs for many people at different levels Rubhara *et al.* (2020) and those involved in various activities such as preparation, cultivation, curing, transport and manufacturing (Masvongo *et al.*, 2013). For instance, in Brazil, tobacco production employed about 2.2 million people, whereas 700 000 people are involved in tobacco cultivation, and 1.5 million people are engaged in tobacco manufacturing (Mergos, 2001).

In Tanzania, 98% of produced tobacco is exported and generates over US$ 364 million per annum of foreign exchange (Bank of Tanzania [BOT], 2020). Furthermore, tobacco production contributes to 17% of agricultural Growth Domestic Product (GDP) (Yuan & Peng, 2017). International Labour Organization (ILO, 2013) indicated that paid employment in tobacco manufacturing contributed to 4.3% of the Tanzania's total labour force. The higher percent of employment is from tobacco cultivation and curing while few people are engaged in the manufacturing process (Bank, 2017; TTB, 2019).

Despite the economic benefits of tobacco, the environmental degradation issue remains an overlooked problem concerning to the production and curing process. Since the 1970s nearly 1.5 billion hectares of forests have been cleared for tobacco curing in the world leading to 20% of carbon dioxide accumulation annually (World Health Organization [WHO], 2017). It is estimated that tobacco production contributes to about 84 megatons of carbon dioxide globally, causing global warming (Hopkinson *et al.*, 2019). In Tanzania, studies have consistently shown that tobacco production results in severe deforestation (Mangora, 2005; Sauer & Abdallah, 2007; Mangora, 2012b). Approximately 16 500 ha of forest woodland are cleared annually in Tanzania for the tobacco curing process alone, which contributes about 4% of total deforestation (Kagaruki, 2010). Regions highly affected by tobacco deforestation include Tabora, Ruvuma, Mbeya and Shinyanga (Misana, 1999; Ndomba, 2018).

Table 1: Tobacco production trend in Tanzania from 1961-2017

Range of Years	Tobacco production trend (Tons)	Change in percentage of Tobacco production	Increase in Area for harvesting Tobacco (ha)	Types of barn used
1961-1970	2701-11971	77.44	12239	
1971-1980	14154-16771	15.60	10700	Traditional
1981-1990	17200-16459	-4.50	-6053	barns
1991-2000	23322-26384	11.61	12525	
2001-2010	24522-60000	59.13	44430	Improved barn
2011-2017	13000-104471	98.76	-49725	and traditional barn

(FAOSTAT, 2017)

From 1961 to 2017, tobacco production in Tanzania increased from 2701 tons to 104 471 tons (Table 1). The rapid increase of tobacco production directly correlated to more wood fuel required for the tobacco curing process resulting in increased deforestation, leading to an increase in atmospheric carbon dioxide accumulation (Chaves *et al.*, 2020). Furthermore, tobacco product usage leads to human respiratory diseases and vulnerability to tuberculosis (WHO, 2020).

Various practices, such as afforestation and reforestation, have been done to avert deforestation and carbon dioxide accumulation due to the tobacco curing process (TORITA, 2020). For example, the Association of Tanzania Tobacco Traders (ATTT) supported a project in the Urambo district that initiated and implemented a "Tree Planting Policy" in 2001 to provide enough firewood for tobacco curing. Also, Ugalla Community Conservation Project funded by Africare was introduced in Tabora to reduce the clearance of miombo woodlands. Despite the good implementation of tree planting promotion programs, the tobacco farmers' response was very low since it requires a commitment and tree's maturity takes time and a quest for forest sustainability (Mangasini, 2007).

Similarly, different statutory organizations such as Tanzania Forest Reserve (TFS), Tobacco Research Institute of Tanzania (TORITA) and Tanzania Tobacco Board (TTB) have implemented tree planting policies in protecting the forest woodland from tobacco related-deforestation but with little success (Blomley & Iddi, 2009).

Furthermore, tobacco companies started to use green supply chains to increase tobacco production sustainability by reducing tobacco-related deforestation (TORITA, 2020). However, Mitchell and Baregu (2012) revealed that deforestation continues since the Tobacco Companies used nominal self-evaluation (not truly independent evaluators) and public relations to create the impression of social responsibility.

Currently, improved barns have been developed to reduce deforestation and carbon emission (Sauer & Abdallah, 2007; Musoni *et al.*, 2013). Despite this huge improvement, there is very little information about the effect of using the existing barns model on environmental degradation. Different studies have estimated tobacco curing related to deforestation in Tanzania (Kagaruki, 2010; Mangora, 2012b). However, they did not include improved barns and atmospheric carbon dioxide accumulation.

This study assessed the tobacco curing process's effect on the environment and the social-economic aspects of each tobacco barn model, looking for alternative tobacco curing technologies. The information may be useful to agriculturalists, government officials, experts and policymakers interested in designing alternative tobacco barn technologies as Tanzania considers options for the future.

1.2 Statement of the problem

There is continuous tobacco-related deforestation which increases the challenges of tobacco sustainability and forest conservation (Mangora, 2012b). Apart from the massive clearance of forests, the tobacco curing process emits carbon dioxide gas leading to global warming. To protect the environment in rural tobacco areas and provide green energy for rural areas, the traditional tobacco curing barn model eventually improved to use lower wood and hence reduce deforestation and carbon emission (TORITA, 2020). Despite the huge improvement, they are still powered by wood fuel, whereas the increase of tobacco production trend increases wood fuel consumption; hence it poses a threat to the destruction of forest woodland and carbon dioxide emission (Lencucha *et al.*, 2020). Therefore, this study estimated the actual area of forest woodland cleared and carbon emitted in the 2018/19 season. Furthermore, the study evaluated social aspects for alternative curing technologies in the Urambo district.

1.3 Rationale of the study

Increased tobacco production in the Urambo district increases the demand for wood fuel for curing, which causes massive clearance of forest woodland. There was a need to conduct research to estimate the current tobacco-related environmental degradation and social-economic aspects of the existing technologies that will help in the development of alternative tobacco curing technologies to replace wood fuel. For tobacco production sustainability, alternative curing technologies should consider the environmental, economic and social aspects.

1.4 Research objectives

1.4.1 General objective

The general objective of this study was to assess the impact of tobacco curing process on the environment and social-economic aspects of sustaining tobacco production and environmental conservation.

1.4.2 Specific objectives

(i) To assess the impact of the tobacco curing process on the environment in Urambo district.

(ii) To evaluate social-economic aspects/challenges related to tobacco curing in Urambo district.

1.5 Research questions

(i) To what extent does tobacco curing contribute to environmental degradation in Urambo district?

(ii) What are the socio-economic aspects/challenges related to tobacco curing technologies in Urambo district?

1.6 Significance of the research

This study will provide useful information that tobacco researchers and barn installation experts can use to design and size alternative and affordable curing technology based on the financial capacity of tobacco farmers in the Urambo district. This study also provides knowledge to environmentalists to find an effective solution to remediate the degraded forest woodland due to the tobacco curing process. A clear understanding of tobacco curing impacts in the Urambo district will attract many tobacco farmers to adopt cleaner tobacco curing technologies. These will conserve the forest woodland from tobacco curing related degradation while increasing the household income to tobacco farmers.

1.7 Delineation of the study

Tobacco production is the major source of household income in the Urambo district. However, it contributes to deforestation and atmospheric carbon dioxide accumulation (Siddiqui & Rajabu, 1996; Mangora, 2012b). Currently, different improved barn models have been developed to reduce environmental degradation. However, they are powered by wood fuel, whereas the increase in tobacco production results in an adverse effect on the environment. The present study focused on assessing the impact of tobacco curing on the environment, which gives room for scientists to design the appropriate tobacco curing technologies that are environmentally friendly and cost-effective to replace wood fuel usage. The data obtained from this research provide valuable scientific information to tobacco curing related deforestation and atmospheric carbon dioxide accumulation. Also, this study shows the need for the development of environmentally friendly tobacco curing technologies for tobacco production sustainability. Furthermore, the study provides the necessary costs and profits of the existing tobacco curing barn model to help in the formation of affordable tobacco curing technologies.

CHAPTER TWO

LITERATURE REVIEW

2.1 Tobacco production in Tanzania

British colonial government introduced tobacco cultivation after the failure of the groundnuts scheme in the Tabora region (Waluye, 1994). Tobacco cultivation continued to increase after independence in 1961 due to the supply of tobacco inputs by World Bank finance in 1970 (Alibhai, 1968; Waluye, 1994). According to FAOSTAT (2017), tobacco production increased from 2701 tons in 1961 to 14 157 tons in 1970 which is almost 77.4% of tobacco production.

Later, tobacco primary cooperatives under the West zone Tobacco Growers Cooperative Union (WETCU) were formed for easier supply of tobacco inputs and selling (TTB, 2019). Thus, it increased the number of tobacco farmers, which accelerated the deforestation of virgin land. According to TTB (2019), the number of families in Urambo district increased from 6070 in 1970 to 25 880 in 1978. While the area of woodland deforested increased from 5540 ha in 1970 to 12 000 ha in 1978 (Waluye, 1994). Another factor that led to increase in tobacco production was the increase in selling price per kilogram from 900 TZS/kg in 1987 to 1500 TZS/kg in 1990. This attracted more farmers from neighboring regions like Kigoma, Mpanda and Shinyanga to start growing tobacco which exerted more pressure on the woodlands (Temu, 1980). The increase in the tobacco price caused a lot of immigration for tobacco production in Tanzania (Jew *et al.*, 2016). Tobacco farmers decided to cultivate tobacco crop due to the increase in tobacco selling price and abandon tobacco production when the tobacco price is low (Jew *et al.*, 2017). For example, tobacco farmers in the Chunya district initiated tobacco production during the rise of tobacco price, and they quit artisanal gold mining in Lupa Godfield when the price drop (Jew *et al.*, 2017).

2.2 Tobacco related deforestation

Tobacco is among cash crops in Tanzania that cause massive deforestation in growing regions. According to Geist (1999), tobacco and tea contribute to the massive woodland clearance due to additional wood for curing. The global assessment of tobacco related deforestation estimated 200 000 ha of natural forests woodlands are cleared by tobacco farming each year (Giannetti *et al.*, 2020). Different researches have reported higher deforestation rate in Africa, due to tobacco curing process (Chacha, 1996; Mandima, 2017). For example, tobacco production accounts for 15% of deforestation in Zimbabwe and 26% in Malawi (Jimu *et al.*, 2017). A study done in Tabora region by Kagaruki (2010) reported that Tanzania loses an average of 16500 hectares of forest woodland annually from tobacco curing alone. This is almost 4% of total deforestation in Tanzania since the net loss of forest woodland in Tanzania was 403 000 hectares per annum. However, in Zimbabwe tobacco related deforestation is higher than in Tanzania since it contributed to 15.9% of the total annual deforestation in 2003 (Jimu *et al.*, 2017; Munanga *et al.*, 2017).

In Urambo district, a traditional barn requires one hectare of forest woodland to cure one hectare of planted tobacco (Mangora, 2005). This led to high deforestation in most growing areas. For example, in Tanzania about 8 470 350 ha of forests woodland were cleared between 1990 and 2010 due to tobacco curing alone (Mganilwa *et al.*, 2009). Nationwide, this woodland area may seem to be low but high in the specific tobacco growing regions. Besides from tobacco curing, tobacco production also contributes to deforestation through various purposes such as poles for barn construction, sticks and tiers for hanging tobacco leaves (Geist, 1999; WHO, 2013).

2.3 Public health due to tobacco

Tobacco use has significant human health effects contributing to different human diseases. For example, smoking causes respiratory diseases such as cancer, chronic obstructive pulmonary disease, diabetes, chronic bronchitis and emphysema. Layden *et al.* (2020) reported that tobacco smoking leads a person to be vulnerable of different diseases including tuberculosis, immune diseases, hearing loss and glaucoma.

This is because people using tobacco products become dependent due to addiction of tobacco nicotine. World Health Organisation (WHO, 2020) revealed that people from local area especially in middle and low income countries are at risk of tobacco related human disease. Although some people use tobacco products from their will but structural force play a vital role in tobacco product uptake in give society. For example, men especially adults, are more exposed to tobacco use as compared to women. Brake *et al.* (2020) reported that 91% of men are more exposed to a high risk of tobacco use. In South Africa males are about four times prevalence to tobacco as compared to females. Tobacco products use also contributes indirect and direct cost including health expenditure (Lecours *et al.*, 2012). In India, the results show that illness caused by tobacco products use that amount US $27.5 billion, of which 22% is direct and 78% is indirect cost (John *et al.*, 2009; John *et al.*, 2021). Munthali and Xuelian (2020) and WHO (2020) reported that tobacco kills almost 50% of all users, whereas 85% are results of direct use while 15% are due to indirect use (second-hand smoke). Tobacco products consumption continues to be used despite the tobacco control policy. Mohan *et al.* (2018) reported that tobacco use and its determinants have to be monitored in order to reduce health and diseases.

2.4 Initiatives employed to reduce deforestation and atmospheric carbon accumulation

Many initiatives have been employed to reduce tobacco related deforestation without much success (TORITA, 2020). These initiatives include afforestation, reforestation and agricultural remains as the source of energy and improving existing tobacco barn models to more energy efficiency, as explained in the preceding paragraph.

2.4.1 Afforestation and reforestation

Tree planting activities have been employed to reduce the impact of tobacco curing on the environment. The TORITA (2020) reported that planting of trees is the effective effort that has been done in tobacco growing regions to reduce tobacco related deforestation. According to Campbell (1995), reducing of tobacco related deforestation and to ensure tobacco production availability, especially in the local setting, tree planting is the major approach that tobacco farmers in tobacco growing areas should be implemented. In 1983, British American Tobacco (BAT) established an afforestation programme for tobacco farmers to reduce deforestation. Approximately, 40 million survived trees were planted during the BAT programme, which would reduce the depletion of natural forests such as Imiyuuyi of Kurutiange forest reserves. Planting the tree also increases income to tobacco farmers and conserves the environment (Ramadhani *et al.*, 2002). This is through the UN-REDDS programme that emphasizes planting trees and conserving forest woodland to reduce and mitigate greenhouse gas emission (Burgess *et al.*, 2010). In Tabora region, farmers have now started rotational woodlot system, whereas farmers intercrop food crops with leguminous trees such as *Acacia crassicarpa* and *Acacia jurifera* (Ramadhani *et al.*, 2002). Various tree planting programmes in Urambo district include the Association of Tanzania Tobacco Traders (ATTT) supported projects in Urambo district which initiated and implemented a “Tree Planting Policy” in 2001 in order to provide firewood that would be sufficient for tobacco curing (Katundu & Mwaseba, 2009). Also, Ugalla

Community Conservation Project (UCCP) (funded by Africare) was introduced in Tabora to reduce the clearance of miombo woodlands (Danny de Vries, 2000). Despite the implementation of tree planting promotion programs, the response is very low since it requires the tree planting, which takes time for forest sustainability (Mangasini, 2007).

Similarly, different statutory organizations such as Tanzania Forest Reserve (TFS), Tobacco Research Institute (TORITA) and Tanzania Tobacco Board (TTB) have implemented tree planting policies in protecting the forest woodland from tobacco related deforestation but with little success (Blomley & Iddi, 2009).

Also, Tanzania Tobacco Board tried to push for the by-law's enactments, each each village was required to set aside 10% of land to plant trees for tobacco curing; however, the idea was not implemented by the local government (TTB, 2019). Another reason for the tree planting programme failure was that most of tobacco farmers are small scale holders; hence it was impossible to devote both lands for tobacco cultivation and tree plantation. Hu and Lee (2015) concluded that; "reforestation efforts by the tobacco industry have been done for a decade, but deforestation remains a common phenomenon in developing countries".

2.4.2 Biomass energy

The tobacco curing process is an energy-intensive process that contributes to the massive clearance of forest woodland. Globally, there are ongoing efforts to increase tobacco sustainability and forest woodland conservation using alternative biomass energy (Bortolini *et al.*, 2019). This type of energy is produced from agricultural remains such as tobacco stems, pellets, sawdust, crops residues of sugarcane and corn (Zhai, 2011). Worldwide, agricultural activities are the leading anthropogenic activity; hence a large amount of waste biomass is produced. This makes agriculture remains a promising renewable energy source to replace wood fuel usage (Gwenzi *et al.*, 2020). However, there are no effective ways for the tobacco sector to utilize biomass energy. Hu *et al.* (2020) and Xiao *et al.* (2015) revealed that biomass energy usage reduces exhausts gases such as CO_2, CO, and SO_2 from biomass briquettes by 57.28%, 95.45%, and 98.06%, respectively, compared with coal. Also, it was reported that biomass usage during tobacco curing is incomplete, producing less than 1.7% carbon monoxide (Wang *et al.*, 2019). That means using agricultural remains during the tobacco curing process reduces greenhouse gases in the atmosphere (He *et al.*, 2021). Furthermore, the study conducted in Italia reported that tobacco curing's biomass usage contributes to 13% as annual cost saving and up to 95% of carbon dioxide reduction (Bortolini *et al.*, 2019).

Moreover, in Southern Brazil, tobacco farmers are now using sawdust and pellets instead of wood fuel since they were identified as high energy efficient and more profitable (Welter *et al.*, 2019). Also, tobacco farmers in China have started using stem briquetting and honeycomb briquette to replace wood fuel energy as an alternative. Xinfeng *et al.* (2015) revealed that tobacco stem briquetting is the alternative and affordable energy source for tobacco curing due to high energy efficiency and high return as compared to honeycomb briquette. Tobacco curing trials carried out by Dasgupta *et al.* (1991) reported that rice husk usage during tobacco curing has lower cost as compared to wood fuel usage.

Apart from agricultural remains, there other sources of biomass energy as the industrial wastes from the sawmill industry, sugarcane plantations, sugar industry by-products, cashew nut industry, coffee industry and sisal industry (Sheya & Mushi, 2000). Wang *et al.* (2019) concluded that biomass energy is higher energy efficiency than wood fuel; hence can be good alternative energy. These results indicated that the biomass briquette is an excellent renewable industrially useful fuel with potential for future application and is an environmentally-friendly fuel, which can be widely used for tobacco curing. However, all types of biomass energy requires modification of fire furnace (Welter *et al.*, 2019). Sheya and Mushi (2000) concluded that there is a need for alternative energy; however, the limiting problem is the inadequate data on the potential energy and lack of experts to design and manufacture energy related equipment and their spare parts.

2.4.3 Improved tobacco barn models

Currently, improved tobacco barns from traditional tobacco barns have been developed and adopted to sustain tobacco farming (Musoni *et al.*, 2013; Chirindo *et al.*, 2017). According to TORITA (2009), improved tobacco barns reduce wood consumption and carbon emission up to 50%. Tanzania Tobacco Board report shows that almost 65% of improved barns are now adopted, and up to 2020, all local barns will not be allowed. However, tobacco production increases these efforts challenges since it increases the demand for wood fuel consumption for tobacco curing. This study estimated the amount of woods currently used by existing tobacco barns and the forest woodland that is converted into beared land.

2.5 Tobacco curing processes

Tobacco curing is the drying process by which the harvested tobacco leaf is made ready for the market (Siddiqui, 2001; Condorí *et al.*, 2020). It is the essential process during tobacco production processing as it is the one that determines the quality of the leaf (Chirindo *et al.*, 2017). Tobacco curing involves chemical and physical changes that are essential for high-quality cured leaf (Sumner & Moore, 2009). It is a well standardized process, especially in FCV tobacco, to achieve the desirable qualities in the cured leaf along with the removal of moisture. The process of curing has an intimate bearing on the quality of cured leaf. A good quality leaf from the field can be made poor by improper curing (Siddiqui, 2001). The quality of the cured tobacco is determined by three factors: agro-economic practices (input supply during farming), appropriate harvesting and following standard curing methods. Thus, farming practices have a significant impact on the quality of cured tobacco. The proper supply of inputs produces high quantity and quality cured (Nicotine production and accumulation) tobacco, whereas the delay or lack of inputs reduces the cured tobacco production. These inputs include nitrogen fertilization, planting density, topping practices, sucker control, and harvesting practices (Henry *et al.*, 2019). Nitrogen fertilizer is essential for the high quality of cured tobacco (Nicotine production and accumulation). However, low crop densities and topping factors contribute to increased cured tobacco quality (nicotine accumulation). Moreover, the harvested ripen tobacco leaf from the field should immediately be cured without any delay. Otherwise, if they are stored for long time, they may be spoiled and heating up, destroying their qualities (Dasgupta *et al.*, 1991).

2.6 Mechanisms of tobacco curing

The curing operations distinguish the type of tobacco, the mode of consumption, local preference, convenience, market value and production economics (Zhang *et al.*, 2013). There are four types of tobacco production: flue-curing, air-curing, fire-curing and sun-curing (Krauss *et al.*, 2003). Tobacco curing management skills include understanding all stages that involve controlling airflow, temperature and humidity in a controlled environment (Sumner & Moore, 2009). This study based on Flue-Cured Tobacco because it is reported as wood intensive causing massive deforestation (Loker, 2005).

2.6.1 Flue-cured virginia tobacco (FCVT)

Flue-cured virginia tobacco is mainly grown in Argentina, Brazil, China, India, Tanzania, and the United States (Van-Liemt, 2001; Mackay *et al.*, 2002). Virginia Flue Cured (VFC) was first introduced in Urambo in the 1940s and subsequently spread to other areas of Tabora region, Kahama, Mpanda, Iringa and Chunya (Geist, 1999; Jew *et al.*, 2017; Ndomba, 2018). In Tanzania, Flue-Cured Virginia Tobacco accounts for 80% of all total tobacco production Mangora (2012b), as it has potential for the international market.

Harvested leaves of flue-cured tobacco are tied in sticks and hung in curing barns, followed by ignition of fire (fuel wood) for curing tobacco leaves. Heated air (steam) is generated by burning wood from the furnace to dry the leaves and to impart golden-yellow to deep-orange color (De-Godoy *et al.*, 2019). During the flue-curing, heat generated from the furnace is the one that dries the ripe tobacco leaves. The moisture dehydrated from tobacco by heated is removed from the barn through chimney and barn vents. Thus, for the drying of tobacco leaf heat is required and hence, a large quantity of wood fuel is required resulting in serious ecological effects (Dasgupta *et al.*, 1991). This is because it takes a long curing time ranging from 7 to 9 days (De-Godoy *et al.*, 2019).

2.6.2 Dark-fire cured tobacco (DFCT)

This type of tobacco leaf is cured by smoke (Bailey, 2006). In Tanzania, it was first introduced in Namtumbo, Ruvuma region, in the 1930s (Redmond, 1976; Ndomba, 2018). It is always cured when matured and not overripe. Dark Flue cured tobacco takes an average of three to ten days, depending on the level of matured leaves and environmental condition. The cured dark tobacco leaves have low sugar and high nicotine and they are always used as pipe tobacco, chewing tobacco, self-rolled cigarettes, and snuff.

2.6.3 Air-cured burley tobacco

Air-cured Burley tobacco has of minor commercial importance, grown only in Ruvuma, Kagera and Morogoro (Msigwa, 2019). This type of tobacco that is cured by ventilated barns under natural atmospheric conditions with little to no supplemental heat added - only air. Air cured tobacco can also be divided into 'Dark Air-Cured' (DAC) and 'Light Air-Cured' (LAC). Curing air-cured burley tobacco takes about three to twelve weeks resulting in deep brown leaf colour. They are used for cigar, moist snuff, snus, chewing, Roll-Your-Own (RYO), Make-

Your-Own (MYO), and water pipe products. This type of tobacco has higher nitrate content than flue-cured tobacco (Li *et al.*, 2017). For environmental conservation, the growing of air-cured tobacco could be of most importance in the country as it consumes no woods.

2.6.4 Sun-cured tobacco

Sun-Cured tobacco is a type of tobacco cured by exposing freshly harvested tobacco leaves directly to the sunlight. This type of tobacco leaves is highly grown in the area with a long season of dry season. Sun cured tobacco is grown traditionally and does not have a high demand in the international market (Tang *et al.,* 2020).

2.7 Procedures of tobacco harvesting and loading in curing barn

2.7.1 Tobacco leaves harvesting

Well-matured ripe leaf is harvested for the curing process in the tobacco barn. Ripe leaves have a greenish-yellow colour with a velvety feel and less sticky. Matured leaves lie horizontally or bend slightly down with tips slightly dry (TORITA, 2009). As a general rule, the leaves are harvested from the bottom priming slightly on the green side, and the middle leaves when they are ripe and the top leaves when they are fully ripe (Gong *et al.*, 2020). On average, not more than three leaves should be harvested at a time. Harvesting must be done on a clear weather day. Immediately after rains or irrigation, the crop should not be harvested and it is to be delayed by 2 - 3 days in such cases (TTB, 2019). Under normal condition, priming is done once a week. The leaves should be pluck against the direction of the sun for better judgment of matured leaf color. While picking, the midribs should be bent sideways, and a well-matured leaf will snap crisply with a characteristic sound (Tang *et al.,* 2020). The leaves are to be carried carefully without pressing in a wide basket with tips upward and shifted to tying shed immediately to minimize the possible wilting.

2.7.2 Tobacco leaf separation and barn loading

Despite the utmost care, tobacco green leaves should be separated before being tied to the stick to allow each stick to have uniform leave quality (TORITA, 2009). Tobacco leaves that should be put in the same stick include some immature leaves and over ripe leaves. Tying of the leaves on the stick should be done gently in a shaded place to avoid wilting and bruising (physical damage) of leaves (Bortolini *et al.*, 2019). Also, tied leaves should be distributed uniformly all over the length of the sticks to avoid overcrowding for easy drying (TORITA, 2020).

Loading of green tobacco leaves into the barn is done after tying the green tobacco leaves on the bundle of sticks (TORITA, 2009). During loading of the barn, stick with priming (un-ripped leaves) are placed on the top tiers, the yellowish-white (over-ripe leaves) on the bottom tiers and greenish-yellow (well-matured leaves) in the bulk of the intermediate tiers. The tiers on the bottom and intermediate should never be over loaded since they spoil more easily when curing process is low (Condorí *et al.*, 2020). During loading, the farmers ensure adequate air flow by loading the barn uniformly, which increases the quantity and quality of cures (TTB, 2019).

2.8 Necessity curing stages of flue tobacco

Harvested tobacco from the field contains 80% to 85% moisture, which has to be dried up to 0% before manufactured for different uses (Musoni *et al.*, 2013). The essence of drying ripe tobacco is to improving and preserving the potential quality, flavour and aroma of tobacco leaves. This can be indicated by achieving the desirable leaf colour (lemon and orange), which means specific chemical reactions have taken place. The curing process involves four stages; yellowing, fixing colour, leaf drying and midrib drying as shown in Fig. 1. During all stages of tobacco curing, monitoring of temperature and humidity is required. All four stages are classified as removing of moisture (dehydration process) and converting sugar into glucose. The early stage of flue-curing should permit continuing biological activity in the leaf, permitting the destruction of chlorophyll, the converting starch to simple sugars and leaf proteins to soluble nitrogenous constituents. These cellular reactions take place in fully turgid leaf cells in an aqueous medium, and for complete enzymatic reactions, thermal inactivation of these enzymes must be prevented (Wu *et al.*, 2020). This means maintaining high humidity and low temperature in the barn for these favourable reaction sequences (Condorí *et al.*, 2020).

During this period, the leaf turns yellow, containing high percentages of soluble sugars. At this juncture, further breaking up of sugars by respiratory enzymes must be prevented as cured leaf must contain high sugars. Browning reaction caused by polyphenol oxidase turning the yellow leaf to browns and bio-chemical conversion of soluble nitrogen to ammonia must be arrested as some of these transforms into aroma compounds at a later stage (Condorí *et al.*, 2020). These are achieved by thermal desiccation by progressively raising the barn's temperature and lowering relative humidity by ventilation adjustments. During subsequent stages, the abrupt change in temperature and humidity should not be done in the barn while curing. The whole process takes an average of 7-9 days, depending on the leaf position, environmental condition, and strand of tobacco (Siddiqui & Rajabu, 1996). During tobacco curing, tobacco farmers are advised to control temperature and relative humidity effectively for quality cured tobacco leaves. In developed countries, humidity is measured by using dry and wet bulb temperatures or relative humidity sensor. There are universal tobacco curing steps, but due to local factors such as weather condition, plant position, leaf maturity and disease prevalence a slight adjustment is necessary for almost every curing cycle. Furthermore, ripe tobacco grown on the same farm can be separated during curing because in each curing there should be a selection of temperature depending on the environment and curing experiences.

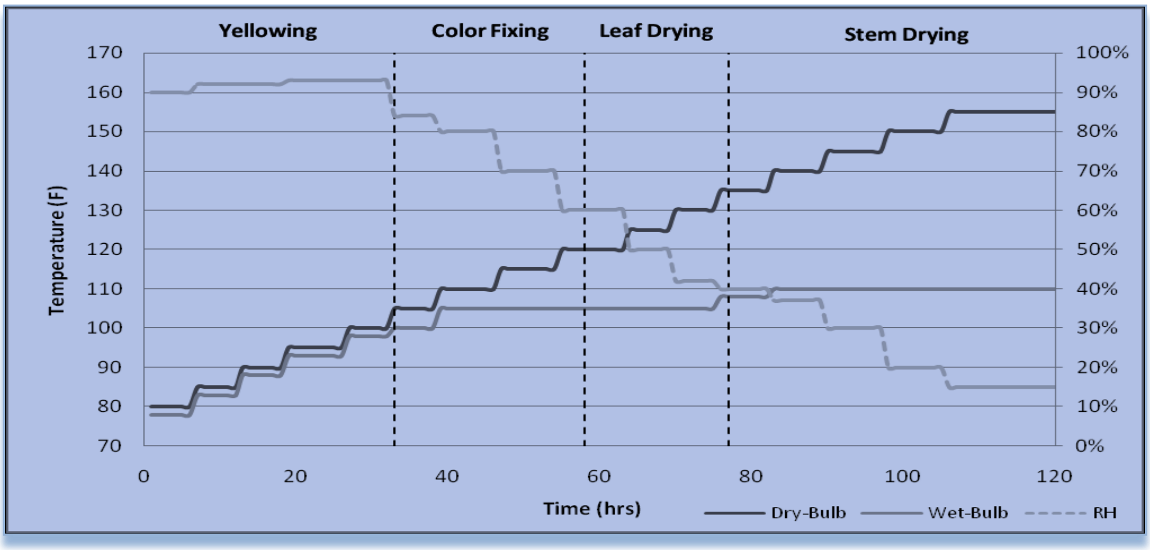

Figure 1: Tobacco curing process (Musoni *et al.*, 2013)

2.8.1 Yellowing stage

The yellowing stage (chemical conversion) is the first stage that converts starch in tobacco leaf into sugar, giving the fruity and colouring. The colors may be lemon, orange and mahogany, depending on the amount of nutrients applied during cultivation. This is achieved by heating slowly from 27 ^{0}C/80 ^{0}F to 44 ^{0}C/110 ^{0}F while maintaining the humidity of the indoor environment. During this stage, humidity control is essential to success and is controlled through the vent system by adjusting the fresh air exchange rate, which removes the moisture up to 20% (Sumner & Moore, 2009). The ventilators are either closed, partially closed or opened depending on barn types, speed of curing and loading capacity (Zou *et al.*, 2019). The first stage process takes an average of 24 hours to 72 hours to be completed. However, curing time of the first stage varies with stalk position of ripped leaves. For example, lower leaves such as primings, and lugs are yellowed in an average of 20 to 30 hours, while upper leaves are yellowed at an average of 60 or more hours (Sumner & Moore, 2009). The quality of certain varieties may be improved by extending the yellowing period. Certain varieties may sometimes yellow before starch is converted to sugar, resulting in pale, slick, immature tobacco (Benozic, 2020). This stage requires close monitoring since the price of the leaf is determined by its desirable colour.

2.8.2 Fixing color

The second stage is removing moisture (fixing color) by desiccation which is achieved by killing of stomata that prevent the gas exchange between air and stomata that stop change of color to undesirable. Denaturing of enzymes in the chlorophyll is achieved by rising of temperature from 44 ^{0}C/110 ^{0}F up to 55 ^{0}C/120 ^{0}F while decreasing the humidity (TTB, 2019). The temperature is increased by putting more fuel while humidity is reduced by opening of the ventilators (Zhao *et al.*, 2020).

2.8.3 Leaf drying

The third stage is leaf drying, which dries the lamina of tobacco. This is achieved by increasing temperature from 130 ^{o}F/55 ^{0}C to 140 ^{o}F/66 ^{o}C and closing bottom ventilators, while top ventilators are opened by 25%. The leaf drying stage takes about 24 hours to 36 hours depending, on the barn model and loading weather condition. During lamina drying, a lot of moisture is removed more than in other stages. To avoid moisture accumulation of in the barn, there should be a balance between heat, temperature and ventilation (Munanga *et al.*, 2014).

2.8.4 Midrib drying

The final stage is midrib drying (drying of the stem) which is achieved by increasing temperature from 150 ^{o}F/66 ^{o}C to 170 ^{o}F /77 ^{o}C, and all ventilators are closed (Banožić *et al.*, 2020). This stage takes 20 hours to 48 hours. For easy handling during removal from the sticks and market preparation, the vents and door of the barn are kept open for some time to allow little moisture 12% to 15% into dried leaves called the conditioning process (Wei *et al.*, 2018).

2.9 Types of barn models in Tanzania

Drying of the ripe tobacco leaves from farm needs energy input such as biomass, air and sun energy. The source of energy used to cure classifies the type of tobacco produced. Flue-cured tobacco is produced by burning wood at constant heat temperature for several days (7-9 days), hence it require large quantities of wood more than other types of curing. In Tanzania, there are two flue cued barns model: traditional barns and improved barns. The explanations of their design, differences, efficiencies and inefficiencies are explained in Table 2.

Table 2: Difference between traditional barns and improved barns

Building material	Traditional barn	Improved barn
Specific Fuel Consumption	14 kg/kg	4.5 kg/kg
Furnace	Farm brick furnace positioned outside the barn	Combustion chamber made with locally produced insulative ceramic bricks with 30 by 30 cm feed chamber, sunken Furnace
Chimney	Exhaust air outlets is positioned inside the barn with a small diameter.	Chimney made from galvanized iron sheets which allow preheating of incoming air into the barn
Conduits	Flue pipe covered by hessian cloth Length= 4 m Surface area=0.36 m2	bricks conduits, Zigzag Length 13 m Surface area=1.17 m2

Musoni *et al.* (2013)

2.9.1 Traditional barns (local barns)

These are the first barns to be used since the establishment of tobacco cultivation in Tanzania (TORITA, 2006). The commonly traditional barn is made of the muddy wall, corrugated iron roof or the thatch grass, vents placed near roof and wall, furnace placed outside and chimney for ventilation. The vents and chimney are used for the ventilation of the barn. Because of muddy wall, an unbaked brick, position of chimney and conduit length, much of the heat is lost through the wall porous, which makes the local barns inefficient. For example, unbaked bricks have a lower heat conductive capacity of about 588 W/m^2K, which causes flow of hot air, and hence air leaves the barn at the same rate of temperature barn (Musoni *et al.*, 2013). Also, the traditional barn is designed of conduit length (4 m) and small heat transfer area about (1.2 m^2). In contrast, the residence time for hot air is very minimal, hence unused heat exhaust into the atmosphere by chimney (Munanga *et al.*, 2014). Furthermore, the traditional barn is roofed by thatched grass that reduces the heat loss by moisture which helps during the curing process (Chirindo *et al.*, 2017).

The outside position of the furnace cause heat loss informs of radiation and conduction. Because of high heat loss more energy and time are required resulting in large amounts of wood being consumed (Munanga *et al.*, 2017). According to Mangora (2005) traditional barns consume up 23 m^3 of wood fuel to cure one hectare of ripened tobacco leaves. The inefficiencies of the traditional barns are resulting in long curing time (9 - 12 days) which, causes high fuel consumption and shortage of curing space as a result of continuous ripening of tobacco leaves in the fields (Chirindo *et al.*, 2017). In Tanzania, traditional barns include local and Malakis (TTB, 2019).

2.9.2 Improved barns

These are barns with high efficiency compared with traditional barns. According to TTB (2019), improved barns were first introduced in Tanzania since 2006 year. They were developed as the strategies to alleviate tobacco related deforestation and to increase tobacco production sustainability. In Tanzania, there are three models of improved tobacco barns which include standard barns (SB), rocket barn version two (RB2) and rocket barn version three (RB3). Also, in Zimbabwe, there are three improved barns known as rocket barn 1 (RB1), rocket barn 4 (RB4) and Kutsaga Counter-Current 1 barn (KCC1) (Song *et al.*, 2020). According to Scott (2008), and TORITA (2009), improved barns have energy efficiency up to 54.3% compared to traditional barns (Table 3). Furthermore, Munanga *et al.* (2017) reported that improved barn developed in Malawi reduce wood fuel consumption up 50% compared to the traditional barn.

Table 3: Trend of improved barn models adoption in Tanzania from 2014/15 to 2018/19

Season years	Local barns	Improved barns	Total number of barns	% of improved barn adoption
2014/2015	192850	54818	247668	22.1
2015/2016	137139	58943	196082	30.1
2016/2017	131991	73135	205126	35.7
2017/2018	103173	78343	181516	43.2
2018/2019	72741	134641	207382	64.9

TTB(2019)

Improved tobacco barns were developed by modification of traditional barns (Scott, 2008). These modifications included: sunken position of furnace to reduce heat loss by radiation and conduction, large conduit pipe and chimney to increase heat retention time (Munanga *et al.*, 2014). According to TORITA (2009), sunken and small size of the furnace limits usage of large trees, and only branches and agricultural remaining are used. Extensive works are still going on to modify tobacco barns regarding tobacco production volume, since the exiting from traditional to improved barns is fitted for small scale tobacco farmers. For example, in current developed Kutsaga Counter-Current 1 barn in Zimbabwe use 3.5 kg of wood fuel to produce a kilogram of cured tobacco leaves (Munanga *et al.*, 2014).

Zimbabwe's study concluded that improved barns are economically suitable for small scale tobacco farmers since they reduce wood fuel consumption while maintaining the quality and quantity of cured tobacco. Also, improved barns are reported to reduce curing time that reduces the rotting of ripe tobacco leaves since tobacco farmers lose thousands of dollars due to decay of over ripened tobacco leaf in the field due to barn space shortage (Chirindo *et al.*, 2017).

2.10 Specific fuel consumption for traditional and improved tobacco barn

Mass of fuel wood used to cure one kilogram of green tobacco leaf varies in each country depending on the type/model of curing barn used, local condition caloric energy of the fuel wood used and tobacco leaf position. The top position of tobacco leaf has low moisture content than bottom tobacco leaf hence requires a lower volume of wood fuel (Siddiqui & Rajabu, 1996). Also, for the improved barns, such as standard barn and rocket barn, wood consumption is very low compared to the traditional tobacco curing barn such as Brazilian barn (Munanga *et al.*, 2017). According to Chirindo *et al.* (2017), Tanzanian tobacco farmers use an average of 14 kg of wood fuel to produce a kilogram of cured tobacco for traditional barns. A study by Musoni *et al.* (2013) shows that an average of 4.5 kg of wood fuel is used to obtain one kilogram of cured tobacco when improved barns are used.

The adoption of improved barns in Tanzania is increasing (Table 3). For example, five years back, improved barns adoption increased by 64.92% from 54 818 barns in 2014/15 to 134 641 bans in 2018/19. Also, the numbers of local barns decrease from 192 850 barns in 2014/15 to 72 741 barns 2018/19. According to TTB (2019), approximately 60% to 70% of tobacco farmers have already adapted to the use of improved barns, and in 2020, traditional barns will be phased out. This effort reduces the massive clearance of forest woodland however; increase of tobacco production still remains a challenge as it increases the wood demand that results into the increase of deforestation and atmospheric carbon accumulation. This study estimated the quantity of wood consumed in 2018/19-crop season due to the tobacco curing process.

2.11 The role of forest woodland in sequestration

Forest woodland has an essential and complex role in the global carbon cycle. This is because, during wood land cellular respiration, carbon dioxide from the atmosphere is sequestred (IPCC, 2003; Williams *et al.*, 2008; Shirima *et al.*, 2011; FAO, 2016). For example, study done in tropical trees estimated that one hectare of pine or eucalyptus could sequester up to 10 tons of carbon dioxide per year (Myers & Goreau, 1991). The study that was conducted in southern Tanzania reported that miombo wood land store 19.2 tons of carbon per hectare with the exclusion of below ground carbon sinks (Munishi *et al.*, 2010). Furthermore, the study that was conducted in the Eastern Arc Mountains of Tanzania recorded higher carbon stock of miombo woodland per hectare (13–30 tons ha^{-1} of carbon) (Shirima *et al.*, 2011). This discrepancy might be due to the different model used, rainfall, temperature and soil characteristic of the region. Branches of miombo woodland have higher carbon content (60%) than the stem (40%). The miombo woodland species with a high carbon storage capacity include *Brachystegia spiciformis* and *Julbernardia globiflora* (Munishi *et al.*, 2010; Shirima *et al.*, 2011).

Newly planted trees in the tropics can remove up to 50 kilograms of CO_2 from the atmosphere for each year during its growth period of 20–50 years. On the other hand, a tree in temperate regions can take up to 13 kilograms of carbon dioxide per year (Brown *et al.*, 2008). Thus, due the highest temperature in the tropical region, increases the tree growth rate increases uptake of the carbon dioxide. The sustainable management of forest woodlands sequesters massive amounts of carbon and contributes to significant carbon pools during their growth (Jonson & Freudenberger, 2011). In addition, carbon continues to be stored in the wood products for extended periods as they are used and after disposal (Sawe *et al.*, 2014; Ribeiro *et al.*, 2015). IPCC (2007) stated that bio-sequestration through reforestation is among the best global carbon dioxide mitigations from the atmosphere. According to UN-REDD+, reducing of forest woodland-based greenhouse gases emissions is critical to limit global warming. Researches have estimated that forest woodland carbon storage is increasing by 139 million metric tons of carbon each year globally (Winjum *et al.*, 1998; Mandima, 2017). Developing countries are leading countries in conserving forest for carbon dioxide sequestration. Also, there many programmes on reducing the emission from deforestation and forest degradation through conserving, sustainable management of forests and enhancement of forest carbon stocks.

The tobacco curing process is among the contributors of carbon dioxide emission into the atmosphere and hindrance of bio-sequestration. This is through harvesting of wood fuel (deforestation) which stops the bio-sequestration process and also when the wood fuel combusted to emit carbon dioxide into the atmosphere. Estimation done by IPCC (2007) reported that deforestation of forest woodland contributes approximately 17% of global greenhouse gas emissions per year. In Tanzania tobacco farmers rely heavily on the wood fuel for curing of tobacco, which contributes to raising atmospheric levels of carbon dioxide (Siddiqui & Rajabu, 1996; Kagaruki, 2010; Mangora, 2012b).

Globally, there have been efforts in working with tobacco farmers to reduce carbon emissions. The goal was to reduce greenhouse gas emissions related to the tobacco curing process by 70% by 2020 compared to 2010 (Biesbroek *et al.*, 2014). In 2017, a 38% reduction of greenhouse gases; this was achieved by designing a more efficient barn that consumes little wood fuel. In 2017 alone, about 23 000 improved barns were adopted in Brazil, Indonesia, Italy, Malawi, Pakistan, the Philippines, Spain, and Tanzania since the beginning of the program in 2014 (Biesbroek *et al.*, 2014).

Moreover, in Tanzania, approximately 60% of tobacco farmers are now using improved tobacco barns (RB2) (TTB, 2019). However, these barns are still fueled with wood, which means deforestation and carbon emission due to tobacco curing still continue. The effort to replace wood fuel with clean and safe alternative energy is needed to protect the environment from greenhouse emission. Recently, many studies are ongoing to identify sustainable forest management practices capable of preserving forest woodland by finding alternative energy. One study proposed that carbon emission from tobacco curing can be mitigated through the use of solar drying (Kumar & Kandpal, 2005). In 2017, 36% of the flue-cured tobacco worldwide was cured with renewable fuels; as a result GHG emissions from tobacco curing activities were reduced by over 330 000 tCO2e (Biesbroek *et al.*, 2014).

However, in Tanzania, alternative energy to replace wood fuel is not yet started to be used, which means all farmers still depend wholly in wood fuel for tobacco curing (Mangora, 2012a). A previous study done in Tanzania estimated 4356 tons of CO_2 is produced in a season from the tobacco curing process alone (Siddiqui & Rajabu, 1996). This shows that the idea that the tobacco curing process contributes to global warming is not new. However, this study estimation based only on traditional barn (Malakis barn) use only, while currently, barn has been improved their furnace, configuration, and tobacco production has now increased. Hence this study will estimate the current amount of carbon emitted and the amount of carbon dioxide that has been inhibited from sequestered in the given wood land.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

This study was conducted at Urambo district, the leading tobacco producing district in the Tabora region and Tanzania (Waluye, 1994). It is located in the western part of Tanzania, covering an area of 21 199 km^2 and an elevation ranging from 1000 m to 1500 m above sea level at coordinates of -5°04'0.01" S 32°02'60.00" E. It is bordered by; the Kaliua district to the North, Uyui district to the East, Sikonge district to the southeast and the Katavi region to the southwest. The climate by average is warm with a daily mean temperature of 24 ^{o}C, 68% of humidity and over 1000 mm of rain annually. This climate supports the production of different crops such as tobacco, maize, beans and vegetables. According to TFS (2019), there are two forest reserves known as the North Ugara forest reserve and Ulyankuru forest reserve. The cured tobacco in Urambo district is increasing every season. For example, it increased from 5669.55 tons in 2017/18 to 7736.92 tons of cured tobacco in 2018/19 (TTB, 2019).

From an economic point of view, tobacco crop is the most important commercial crop in this district. This is because of high financial benefits to tobacco farmers and source of district income. Also, major Tobacco Companies such as Japan Tobacco International, Alliance One and Grand and Magefa tobacco companies are located in the Urambo district which guarantees buying of cured tobacco leaves at the highest price.

The numbers of registered tobacco farmers in the Urambo district change every year depending on the demand and availability of Tobacco Companies. Tobacco farmers are managed into groups called primary society; Urambo district has 38 active tobacco primary societies, whereas to each primary society, there are 400-700 tobacco farmers (TTB, 2019).

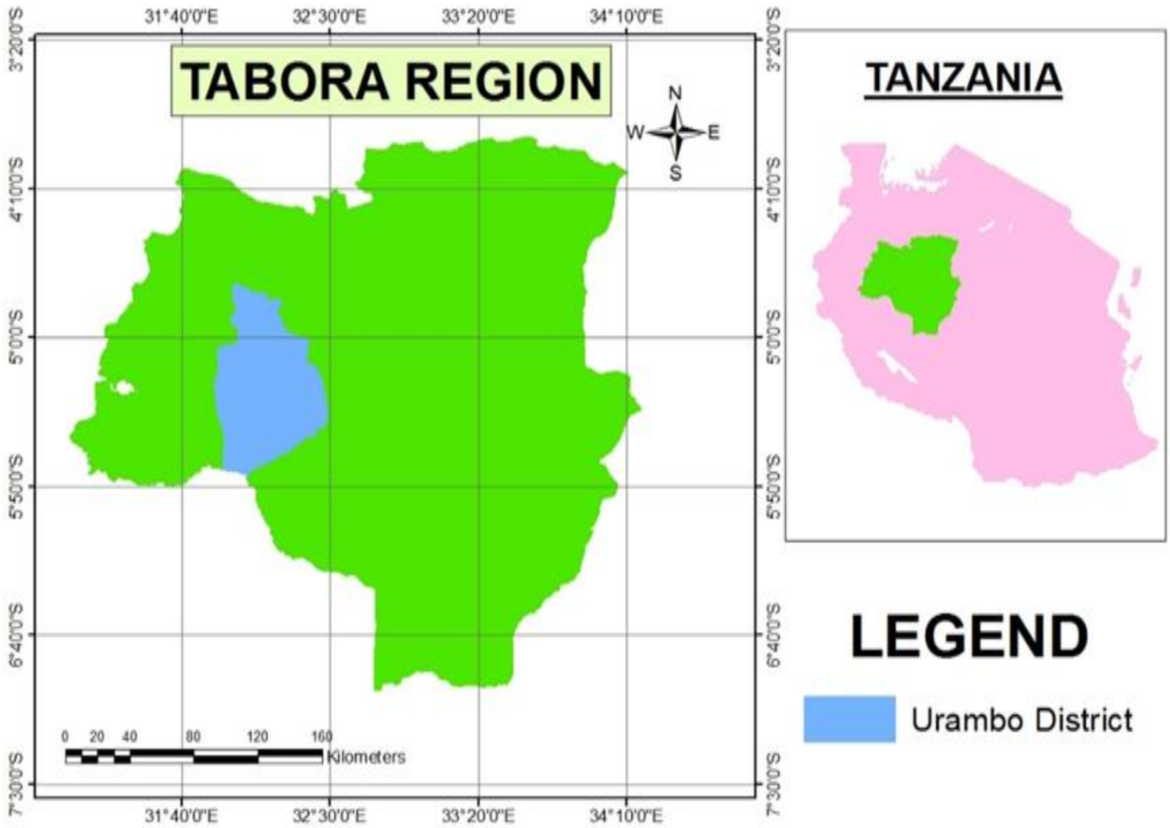

Figure 2: Map of Tanzania, Tabora Region indicating the study area in Urambo District

3.2 Data collection methods

In this study, the structured questionnaires and field observation methods were used to monitor closely the wood fuel consumption (kg) per cured tobacco leaves (kg).

3.2.1 Household survey

The structured questionnaires were prepared according to the study objective and administered to 892 tobacco farmers in the study area. The questionnaire contained four sections. The first section referred to the collection of the biographic information of the respondents. The second section was about tobacco production, barn model and wood fuel consumption. The third section referred to sustainable measures employed to avert tobacco related deforestation and the final section aimed at assessing the socio-economic factors.

Randomly selection was done to get 30% of Urambo district farmers as the sample survey representatives (Delice, 2010). This was achieved by stratified random sampling choosing three Tobacco Farmer Primary Cooperatives in each three-tobacco zones. Thus, resulted into 9 tobacco farmer primary cooperatives which are: Mirambo, Imalamakoye, Nsenda, Nsanjo, Kitete, Maendeleo, Katunguru, Ugala and ChapaJembe. Collectively, the number of respondents in this study was 892 tobacco farmers representing 30% of 2972 the total number of tobacco farmers in the Urambo district (Fig. 3). Prior information was sent to the villagers through their Tobacco Farmer Primary Cooperatives for preparedness.

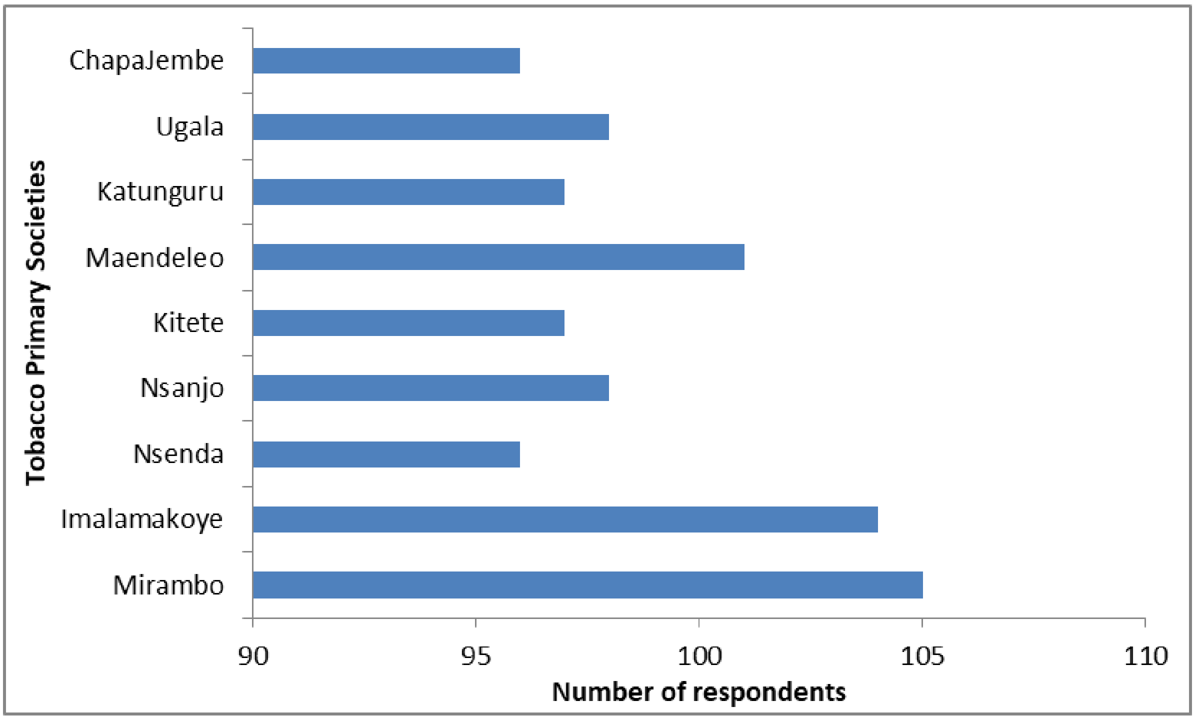

Figure 3: Study sample size. Field survey (2020)

3.2.2 Quantification of annual area of forest wood land cleared in 2018/19 season

Monitoring of four barn model was done to identify the exact Specific Fuel Consumption (SFC) in Tanzania. Those barns included a traditional barn, rocket barn (RB2 and RB3) and standard barn. Then, the average wood fuel to tobacco mass ratio was converted into total wood consumption per each barn by using the formula (Equation 1) adopted from the study of Musoni *et al.* (2013). After that, the quantities of wood fuel consumed for each barn were converted into area of forest woodland cleared in 2018/19 using the formula (Equation 2 and Equation 3).

$$\text{Tobbaco Mass Ratio (SFC)} = \frac{mass\ of wood\ fuel\ (kg)}{mass\ of curedtobacco\ (kg)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$Density\ of\ wood\ fuel = 500\frac{kg}{m^3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$1\ ha\ of\ wood\ land\ in\ a\ year = 21m^3\ of\ wood\ fuel \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

3.2.3 Quantification of annual atmospheric carbon dioxide accumulation in 2018/19 crop season

Wood fuel used for the tobacco curing process contains carbon content captured from the atmosphere during the photosynthesis process. Every one kilogram of dry wood fuel contains 50% carbon content (Huangfu *et al.*, 2014). Thus, using wood fuel during the tobacco curing contribute to the atmospheric carbon dioxide concentration in the atmosphere. This study used the formula (Equation 4) developed by County (2012) to quantify the amount of carbon dioxide that was emitted in the 2018/19 crop season.

Moreover, massive clearance of forest wood land for tobacco curing hinders the sequestration of carbon dioxide. This situation contributes to the accumulation of atmospheric carbon dioxide in the atmosphere. This study used the formula (Equation 5) developed by Munishi *et al.* (2010) to calculate the amount of carbon dioxide hindered by sequestration.

$$1\ kg\ of\ wood\ fuel = 50\%\ of\ carbon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$1\ ha\ of\ miombo\ woodland = 10\ tons\ of\ carbon\ dioxide \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

3.2.4 Economic assessment of tobacco curing

Net revenue per hectare is profit obtained directly by the farmer from cultivating one hectare of tobacco production. The method used to measure the economic profitability of given tobacco curing technology was Cost-Benefit Analysis (CBA). This involves the average net revenue earned and, or costs saved as the result of using a given tobacco barn technology. It helped to suggest the main requirements that a proposed alternative barn technology should require for easy adoptability by tobacco farmers. This study used the formula (Equation 6) to calculate the average net revenue of tobacco production per hectare and the formula (Equation 7) was used to estimate the average total revenue. The total cost of tobacco production was calculated by summing up all costs required for tobacco cultivation and tobacco curing process.

$$TR = p \times m \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Eq6$$

Whereas TR = Total Revenue per hectare, p =average selling price per hectare and m = average mass of tobacco production per hectare.

$$NR = TR - TC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Eq7$$

Whereas; NR=Net Revenue per hectare, TR= Total revenue per hectare, TC= Total cost per hectare

3.3 Data analysis

Data collected were analyzed using the content analysis method for open-ended questions that entailed open coding, thus line by line examination and axial coding identification of emergent narrative patterns. Besides, IBM Statistical Package for the Social Sciences (SPSS) program version 21 (IBM Corp 2013) was used to manage and analyze the collected data. Descriptive statistics, including frequencies and cross tabulations were generated by using Microsoft Excel. Significant differences in mass wood fuel consumption ratio were calculated by using One-way ANOVA (F-Statistics).

Also, Cost-Benefit Analysis was used to estimate the economic implication of the tobacco curing process in the Urambo district. In addition, quantifying the annual area of wood land cleared and carbon dioxide accumulation in the atmosphere were calculated using Microsoft Excel.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Impact of tobacco curing on the environment

Tobacco productions have an impact on the environment since it requires wood fuel for tobacco curing. Wood fuel needed for the tobacco curing is mainly harvested from forest woodland, hence resulted in deforestation. Also, during the tobacco curing by using wood fuel, carbon dioxide gas is emitted into the atmosphere, which results in global warming. This study estimated the amount of carbon dioxide emitted in the 2018/19 crop season, and the hectare of woodland forest cleared. Besides, the amount of carbon dioxide blocked from sequestration was estimated.

4.1.1 Annual area of forest woodland cleared for tobacco curing in 2018/2019 crop season

This study noted that 95% of all farmers obtain wood fuel from the woodlands such as Ulyankuru forest reserve, North Ugara forest reserves, and other forest woodlands, while only 5% harvest wood fuel was from the planted forest (woodlot) (Fig. 4). According to tobacco farmers, woodlot cannot accommodate the wood fuel for tobacco curing for all seasons, because of the long growth rate and lack of enough land for plantation. The current result agrees with other studies done in Tanzania and Zimbabwe which revealed that tobacco farmers rely heavily on wood fuel to cure tobacco which contributes to deforestation (Sauer & Abdallah, 2007; Mangora, 2012b).

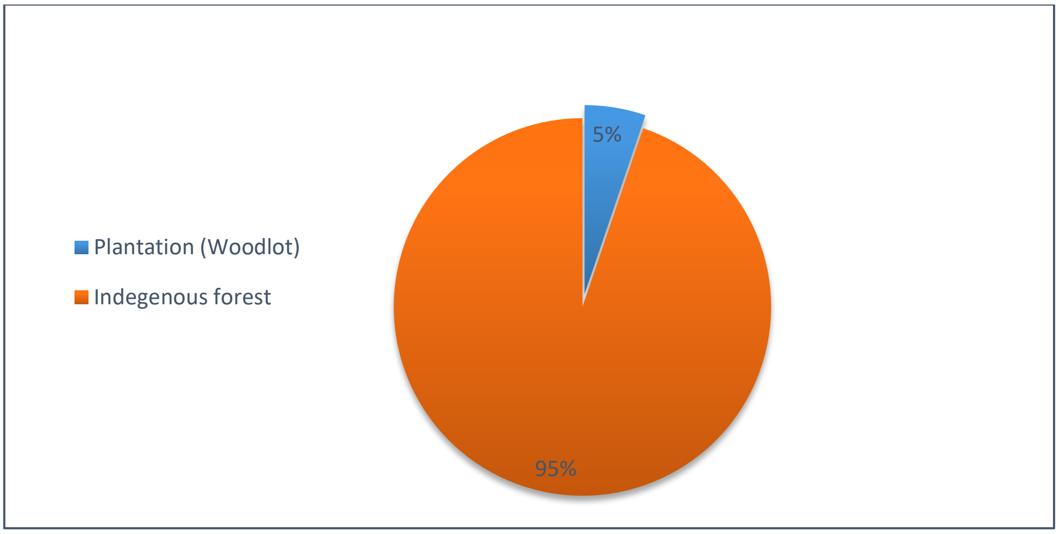

Figure 4: Source of wood fuel for tobacco curing process in Urambo District, Tanzania. Field survey data (2020)

Since 95% of wood fuel was harvested from natural woodland, based on Equation 2 Urambo district is estimated to lose 5 974.14 ha of natural forest woodland and 381.32 ha of woodlot plantation (Table 7). The current study indicates that the Urambo district harvested about 36.21% of the Tanzania forest area for curing tobacco out of the 16 500 ha of forest annually, as estimated by Kagaruki (2010). The research study by Jew *et al.* (2017) reported 4134 ± 390 ha to be cleared each year in the Urambo district for tobacco curing. The current study estimated 5974.14 ha of natural forest and 381.32 ha of planted woodlots were cleared for tobacco curing; these estimates were above than those reported by Jew *et al.* (2017) because of the increase in tobacco production. Furthermore, the global assessment of tobacco-related deforestation estimated 200 000 ha of natural forests woodlands are cleared for tobacco farming each year (Geist, 1999). This discrepancy might also be due to increased tobacco production from 60 000 tons in 2010 to 70.8 megatons in 2018. The estimated area of forest woodland cleared due to tobacco curing may seem negligible when compared to national scale. However, the magnitude is higher on the local scale. The TFS (2019) reported that in the Urambo district, the natural forest /woodlands are likely to be cleared if the current trend of tobacco production continues.

There is a correlation between wood fuel consumed and the annual area of woodland cleared for tobacco curing in the Urambo district (Table 4). The increase of wood fuel demand for tobacco curing resulted in massive destruction of forest woodland. Therefore, whenever tobacco production volume increased; the demand for wood fuel for tobacco curing also increased, and hence increased the rate of forest clearance. This study found that the rate of tobacco production volume related to deforestation depends on the type of tobacco curing barn used in the specific area/region (Mangora, 2012b). The traditional curing barn model users resulted in a high deforestation rate than those using RB2 rocket barn models (Table 5). Therefore, it is recommended for carrying out studies on alternative technologies to replace the wood fuel for tobacco production sustainability and forest conservation.

Table 4: Correlation between wood fuel consumption and area of the woodland cleared

	A	*B*	*c*	*d*	*e*	*f*	*g*	*h*	*I*	*j*
A	1***									
B	0.770***	1***								
C	0.69**	0.649**	1***							
D	0.544**	0.867***	0.183	1***						
E	0.69**	0.649**	1***	0.183	1***					
F	0.544*	0.867**	0.183	1***	0.183	1***				
G	0.69**	0.649*	1***	0.183	1***	0.183	1***			
H	0.544*	0.867***	0.183	1***	0.183	1***	0.183	1***		
I	0.69**	0.649**	1***	0.183	1***	0.183	1***	0.183	1***	
J	0.544*	0.867***	0.183	1***	0.183	1***	0.183	1***	0.183	1***

Field survey data (2020)

Correlations are significant at P ≤ 0.05 (where; *, **, and * are significant at P≤0.05, P≤0.01 and P≤0.001 Respectively.**

a-tobacco region, b-tobacco production (kg), c-mass (kg) of tobacco using traditional barn, d-mass (kg) of tobacco using rocket barn, e-mass (kg) of wood in consumed using traditional barn (annually) = 10.5*mass of wood fuel, d-mass (kg) of wood in consumed using rocket barn (RB2) annually = 6.2*mass of wood fuel, e-volume of wood fuel consumed by using traditional barn =mass(kg)/500(kg/m^3), h-volume (m^3) of wood fuel consumed by using rocket barn =mass(kg)/500(kg/m^3), i- estimated Area (ha) of woodland cleared annually by Traditional barn= volume of wood/21m^3, j-estimated area (ha) of woodland cleared annually by rocket barn = volume of wood/21m^3

4.1.2 Specific Fuel Consumption of each tobacco barn models in Tanzania

Table 5 indicates the average wood fuel-tobacco mass ratio of four tobacco barns models. The specific fuel consumption of different curing barn types is an excellent indicator to of deforestation and atmospheric carbon dioxide accumulation in the Tanzania atmosphere. According to TORITA (2020), there are four models of curing barn; traditional barn, rocket barn version 2 (RB2), rocket barn version 3 (RB3) and standard barn (Table 5).

Table 5: Average specific wood fuel consumption of different barn model

Type of Barn model	Mean wood fuel (kg) of of cured tobacco (kg)± SE
Traditional Barn	10.50 ±0.02a
Rocket Barn version 2	6.20 ± 0.01b
Rocket Barn version 3	4.60 ± 0.01d
Standard Barn	5.50 ± 0.05c
One-way ANOVA (F-Statistics)	**8267*** **

Field survey data (2020)

Data for specific fuel consumption obtained from close monitoring of the tobacco curing process done at TORITA in the 2019/20 crop season. Results showed that traditional curing barn consumed significantly (*P<0.001*) large quantities of wood fuel (10.5 kg) to cure a kilogram of tobacco green leaves compared to a standard barn, which consumed 5.50 kg of wood fuel to dry a kilogram of tobacco. The RB2 consumed significantly (*P<0.001*) large quantities of wood fuel (6.20 kg) to cure a kilogram of tobacco leaf in comparison with rocket barn version 3 (RB3), which consumed 4.6 kg of wood fuel to cure a kilogram of tobacco (Table 5). This indicates that rocket barn version three (RB3) is more saving energy efficient compared with the other three tobacco barns.

This study found that rocket barn (RB2), which consumes 6.20 kg of wood fuel to cure a kilogram of tobacco, is more adopted by most of tobacco farmers, accounting for 60% (Fig. 5). Then, it was followed by traditional barn (38%), standard barn (1.4%) and finally rocket barn 3 (0.6%). Thus, it indicates that tobacco farmers are very slow in adopting the use of improved curing barns. Therefore, the current study used traditional barn and rocket barn (RB2), which Urambo farmers mostly use, in estimation of deforestation and atmospheric carbon dioxide accumulation in 2018/19 crop season (Fig. 5).

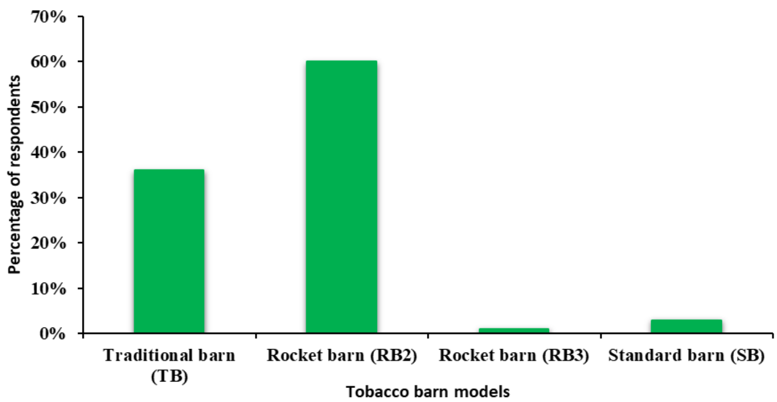

Figure 5: The adoption rate of tobacco barn models in Urambo district (Field survey, 2020)

4.1.3 Wood fuel consumed annually in the 2018/19 crop season

In the Urambo district, about 7736.92 tons of the cured tobacco were produced in the 2018/19 crop season in which 4363.62 tons of cured tobacco were produced by using traditional barn (TB) and 3373.3 tons of cured tobacco were produced by using rocket barn (RB2) (Table 6). This study estimated that, 45 818.03 tons and 20 914.44 tons of wood fuels were consumed by traditional barn and rocket barn version 2, respectively. In the Urambo district alone, an estimate of 0.067 megatons of wood fuel was consumed for the tobacco curing process compared with 0.31 megatons of wood fuel consumed in all the tobacco producing regions in Tanzania (Table 6).

Table 6: Wood fuel consumption per barn model in 2018/19 crop-season

Tobacco region	**A**	**b**	**c**	**d**	**E**
Tabora	9647.22	5431.39	4215.84	57029.54	26138.18
Urambo	**7736.92**	**4363.62**	**3373.3**	**45818.03**	**20914.44**
Kaliua	10139.72	5009.02	5100.28	52594.71	31621.72
Sikonge	6974.44	1841.25	5133.19	19333.15	31825.77
Kahama	11009.48	1321.12	9688.34	13871.95	60067.72
Mpanda	7144.03	3600.59	3543.44	37806.22	21969.33
Iringa	277.34	0	277.34	0	1719.51
Chunya	11923.07	2348.85	9574.23	24662.88	59360.21
Kigoma	4672.92	971.97	3700.95	10205.65	22945.9
Songea DFC	1247.77	0	1247.77	0	7736.17
Total	**70772.91**	**24841.29**	**45931.62**	**260833.55**	**284776.02**

Field survey data (2020)

a-Tobacco production (tons) in the region

b-Mass of tobacco (tons) cured using Traditional barns

c- Mass of tobacco (tons) cured using Rocket barns version 2

d-Mass of wood (tons) fuel consumed annually (10.5 x Mass of tobacco cured) using Traditional barns

e- Mass of wood (tons) fuel consumed annually (6.2 x Mass of tobacco cured) using Rocket barns 2

4.1.4 Annual area of forest woodland cleared in 2018/19 crop-season

In the Urambo district, 95% of total tobacco farmers harvest wood fuel from indigenous forest woodland and only 5% harvest wood fuel from plantations (woodlot) (Fig. 4). This study estimated the area of forest woodland cleared in the 2018/19 season from the quantity of wood fuel harvested for tobacco curing, where in Urambo district about 4 363.62 ha and 1 991.85 ha of forest land area were cleared when curing by using traditional and rocket barns, respectively (Table 7). Additionally, this study estimated that Tanzania loses 24 841.29 ha of woodland from traditional barns and 27 121.53 ha of woodland using rocket barn version 2 (RB2) (Table

7). Based on Equation 2, Urambo district alone lost about (2%) of the total woodland i.e. 6 355.47 ha of woodland due to the tobacco curing process, while the whole country lost a total of about 27 122 ha of woodland due to the tobacco curing process in Tanzania (Table 7).

Table 7: Forest woodland cleared per barn model in 2018/19 crop-season

Tobacco region	a	b	c	D
Tabora	114059	52276	5431	2489
Urambo	**91636**	**41829**	**4364**	**1992**
Kaliua	105189	63243	5009	3012
Sikonge	38666	63652	1841	3031
Kahama	27744	120135	1321	5721
Mpanda	75612	43939	3601	2092
Iringa	0	3439	0	164
Chunya	49326	118720	2349	5653
Kigoma	20411	45892	972	2185
Songea DFC	0	15472	0	736.8
Total	**521667**	**569552**	**24841**	**27122**

Field survey data (2020)

a-Volume of wood fuel (m^3) consumed using Traditional barns (Mass (Kg)/500 (Kg/m^3))

b-Volume of wood fuel (m^3) consumed using Rocket barns 2 (Mass (Kg)/500 (Kg/m^3))

c- Area of woodland cleared annually (ha) when Traditional barns is used = volume of wood/21m^3

d-Area of woodland cleared annually (ha) when Rocket barns 2 is used = volume of wood/21m^3

4.1.5 Carbon dioxide emitted through tobacco curing in 2018/19 crop-season

Table 8 show the estimated amount of carbon dioxide emitted during the tobacco curing process when traditional barn and rocket barn were used. The estimation amount of the carbon dioxide emitted was done using the amount of wood used during the tobacco curing process as described in section 3.2.3. In the Urambo district, the estimated amount of carbon dioxide emitted by using traditional and rocket barns were 22 909.02 and 10 457.2 tons, respectively. Furthermore, in Tanzania, the estimated amount of carbon dioxide emitted by using traditional and rocket barn was 130 416.78 tons and 142 388.01 tons, respectively.

Table 8: Carbon dioxide emitted through tobacco curing per barn model in 2018/19

a	b	C	d	E
Tabora	57029.54	26138.18	28514.77	13069.09
Urambo	**45818.03**	**20914.44**	**22909.02**	**10457.22**
Kaliua	52594712.08	31621.72	26297.36	15810.86
Sikonge	19333.15	31825.76	9666.57	15912.88
Kahama	13871.94	60067.72	6935.97	30033.86
Mpanda	37806.22	21969.33	18903.11	10984.66
Iringa	0	1719.51	0	859.75
Chunya	24662.88	59360.21	12331.44	29680.11
Kigoma	10205.65	22945.9	5102.83	11472.95
Songea DFC	0	7736.17	0	3868.08
Total	**260833.55**	**284776.03**	**130416.78**	**142388.01**

Field survey data (2020)

a- Tobacco region

b- Mass (tons) of wood consumed using traditional barn (TB)

c- Mass (tons) of wood consumed using rocket barn model (RB2)

d- Amount of Carbon (tons) emitted from tobacco curing using traditional barn model (TB) =50% of mass dry wood fuel

e- Amount of carbon (tons) emitted from tobacco curing using rocket barn model (RB2) =50% of mass dry wood fuel

The tobacco curing process is one of the contributors to carbon dioxide accumulation in the atmosphere. This occurs when wood fuel is used as an energy source during tobacco leaf drying stages and when clearing forest woodland (deforestation).

4.1.6 Carbon dioxide hindered from sequestration in 2018/19 crop-season

The amount of carbon dioxide that was rendered from sequestration annually in the 2018/19 crop season is shown in Table 9. The results showed that 4363.62 ha was cleared when curing using traditional barn (TB), which hinders about 43 636.2 tons of carbon dioxide from the atmosphere. In addition, when rocket barn (RB2) is used, about 1991.85 ha of woodland was cleared, which hindered about 19 918.51 tons of carbon dioxide from the atmosphere (Table 9).

Table 9: Annual carbon dioxide hindered from sequestration in 2018/19 crop-season

a	B	c	d	E
Tabora	5431.38	2489.35	54313.85	24893.5
Urambo	**4363.62**	**1991.85**	**43636.22**	**19918.51**
Kaliua	5009.02	3011.59	50090.2	30115.93
Sikonge	1841.25	3031.03	18412.52	30310.25
Kahama	1321.14	5720.74	13211.38	57207.36
Mpanda	3600.59	2092.32	36005.92	20923.17
Iringa	0	163.76	0	1637.63
Chunya	2348.85	5653.35	23488.45	56533.53
Kigoma	971.97	2185.32	9719.67	21853.23
Songea DFC	0	736.78	0	7367.78
Total	**24841.29**	**27121.53**	**248412.91**	**271215.26**

Field survey data (2020)

a- Tobacco region

b- Estimated Area (ha) of woodland cleared annually by TB

c- Estimated Area (ha) of woodland cleared annually by RB2

d- Amount of CO_2 (megatons) hindered from sequestration per year using traditional barn model (TB) =hectares of tree cleared*10 tons

e- Amount of CO_2 (megatons) hindered from sequestration per year using rocket barn model (RB2) =hectares of tree cleared*10 tons

Based on the Equation 3, the total amount of carbon emitted from the tobacco curing process in the Urambo district was 0.03 megatons. This was far less than reports which revealed that 4 356 tons of CO_2 were produced in a given season from the tobacco curing process alone (Siddiqui & Rajabu, 1996).

Furthermore, forest woodland traps atmospheric carbon dioxide, but the moment they are cleared down, carbon dioxide in that area can no longer be absorbed as it was before (Abrams & Rue, 1988). Thus, the study estimated about 4363.62 ha of forest woodland was cleared for wood fuel when using traditional barn (TB), which could cause hindrances of about 43 636.22 tons of carbon dioxide. Comparably, rocket barn version 2 (RB2) usages contributed about 1 991.85 ha of woodland clearances for wood fuel during tobacco curing, which might hinder approximately 1 9918.51 tons of carbon dioxide (Table 9).

Based on the Equation 1 and 2 about 6355.47 ha of forest woodland were cleared for tobacco curing in the Urambo district, which could have absorbed 63 554.7 tons of carbon dioxide from the atmosphere in the 2018/19 crop season (Table 9). Carbon dioxide emitted from the tobacco curing process combines with oxygen to produce atmospheric carbon dioxide. Atmospheric carbon dioxide absorbs the long wavelength radiation that leads to global warming when it is emitted. The current study has shown the impact of tobacco cultivation on forest or woodland clearance, resulted into carbon dioxide accumulation in the atmosphere and contributing to the global warming. Therefore, further research is recommended in future to extend the impact studies of tobacco on quantifying soil erosion volume caused by deforestation. There is a lack of information on how the tobacco curing process contributes to atmospheric carbon accumulation in local settings as the available information and only estimating 17% of carbon dioxide to be emitted from the tobacco related deforestation (IPCC, 2007).

4.2 Social and economic aspect of tobacco curing

This subsection reports the social and economic aspects related to tobacco curing in the Urambo district, especially in 2018/19 crop season.

4.2.1 Social aspects of tobacco curing

The social aspects associated with tobacco curing were assessed and reported in Fig. 6. Major aspects that were assessed included the labour intensity, tedious work, and food insecurity, school drop-out of students and disruption of the forest social services. On the labour intensive, farmers complained that the tobacco curing process requires a large amount of labour to produce a quality of flue-cured tobacco leaf. The workforce is needed in all process from harvesting, leaf-tiring, loading of green tobacco leaf to the barn, off-loading cured tobacco, grading etc. These activities are laborious and time consuming and agree with the research results reported by Arcury and Quandt (2006). During the tobacco curing process, many laborers are required associated with labor costs that reduce net revenue to the tobacco farmers. The 23% of Urambo district respondents reported that farmers need to invest long time from harvesting to grading stage since the process takes about 12 to 20 days. The long time required for tobacco curing makes tobacco growing family to only depend on tobacco production. The long time spent to the tobacco curing process was also reported by Hendlin and Bialous (2020).

This study found that most tobacco farmers in the Urambo district cannot afford to pay costs to the higher number of labourers, and hence on some occasion, they use children as cheap labour. In some cases, it results in students stopping going to school in respect of their parents (Kibiki, 2017). Thus, increase number of illiterate in tobacco-growing regions. Studies in Kenya showed that family members in the tobacco-growing areas are involved in the tobacco curing process (James, 2018). In Tanzania, the worst forms of child labour, including curing tobacco day and nights, were identified in the tobacco agricultural sector, mainly in the Urambo district (URT, 2017). A research study by Masiaga (2015) in tobacco crop pinpointed that the tobacco curing process is the major factor for most students to have poor attendance in school by engaging in tobacco curing.

School drop-outs of students due to tobacco curing were also reported by many tobacco farmers in the Urambo district (Fig. 6). Tobacco curing involves many activities starting from harvesting, tying tobacco leaves, and loading tobacco leaves to the curing barn. These activities require extensive, and most small scale farmers cannot afford to pay for laborers, hence they always use their children as labourers TTB (2019); Personal communication with the Chairman for Milambo Primary Society).

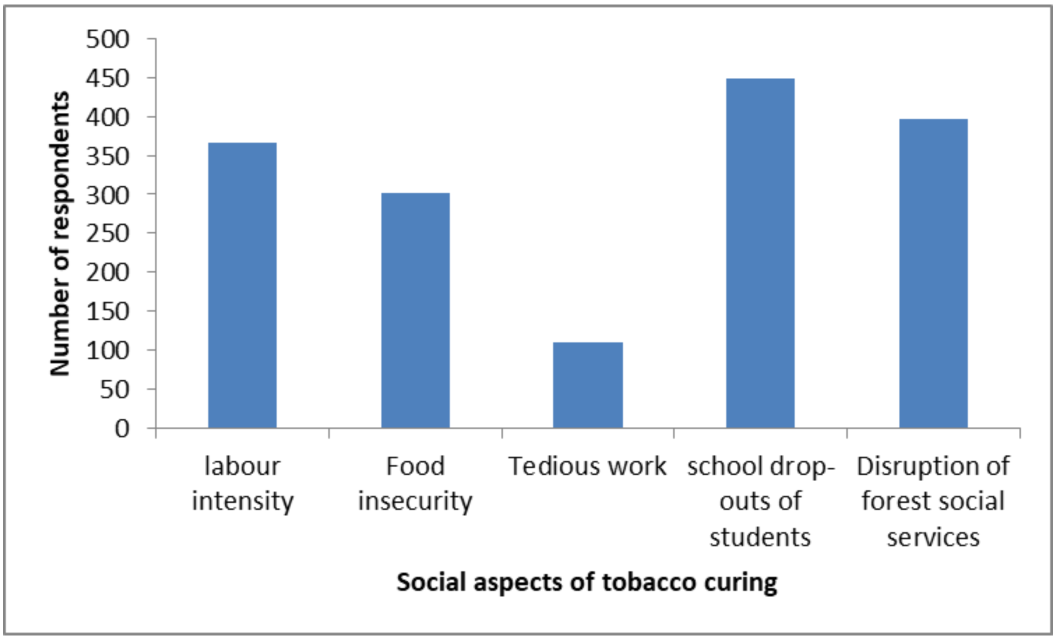

Figure 6: Social aspects of tobacco curing (Field survey, 2020)

Tobacco production contributed to food insecurity in the Urambo district, whereas there is no reliable access to a sufficient quantity of affordable and nutritious food. The majority of tobacco farmers reported that the food insecurity in the Urambo district is due to the depletion of soil nutrients by tobacco production. Tobacco is widely known to be a nutrient heavy feeder crop for nitrogen, phosphorus and potassium and, hence reduces soil fertility and resulting in low production to the subsequent food crops (Cavlek *et al.*, 2006; Henry *et al.*, 2019; Reed *et al.*, 2019; Lisuma *et al.*, 2020). Furthermore, tobacco-related deforestation (for curing tobacco) contributes to soil erosion and degradation of the arable land and low food production (Novotny *et al.*, 2015).

Most tobacco farmers (95%) reported severe deforestation problem that leads to disruption of forest social services in Urambo district (Fig. 6). The disrupted forest social services mentioned by tobacco farmers in the Urambo district included; recreation services, spiritual services, collection of medicinal plants and aesthetics. It was revealed that many people in the Urambo district used natural woodland forests for different activities and had strong cultural and spiritual attachments to the forests. Therefore, forest destruction undermines the capacities of these people to survive culturally and spiritually. Njana *et al.* (2013) reported that forest woodland is vital for social service since 5% of rural people depend on medicinal collection, but also people use it for praying.

4.3 Economic aspects of tobacco curing

Figure 7 indicates the average selling price of the cured tobacco per kilogram. The majority of tobacco farmers (82%) sell one kilogram of cured tobacco at 3000-3999 TZS. About 15% of farmers sell their cured tobacco at 2000-2999 TZS per kilogram, and the remaining 2% sell at 4000-4999 TZS per one kilogram of cured tobacco. According to Tanzania Tobacco Board, the average selling price of one kilogram of cured tobacco in the 2018/19 season was 3565 TZS. Thus, most of tobacco farmers (82%) in the Urambo district got the national average price of 3565 TZS/kg of purchased tobacco.

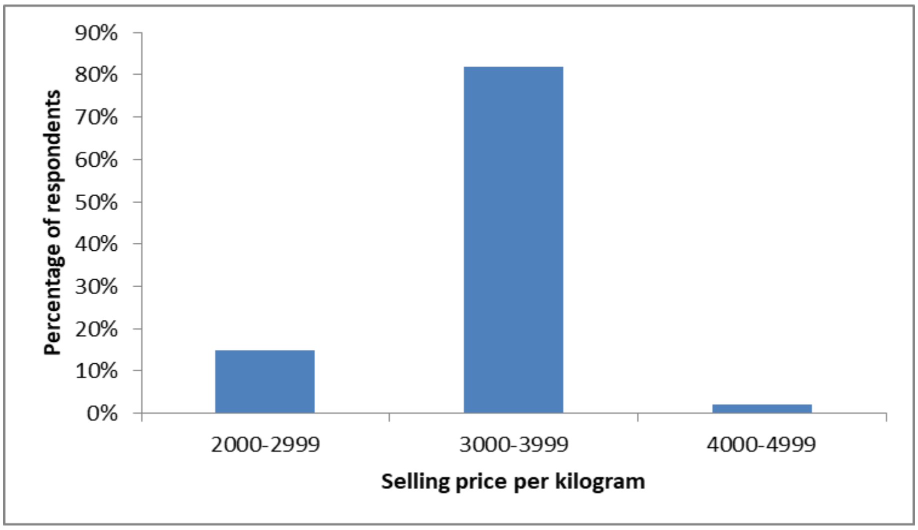

Figure 7: Response to selling price per kilogram of cured tobacco in 2018/19 season (Field survey 2020)

The research results indicate that the tobacco production in the Urambo district is rapidly increasing, and the majority of farmers producing about 1500 – 2000 kg of tobacco per hectare (Table 10). The increase in tobacco production is attributed to increased tobacco demands from the tobacco buying companies and tobacco prices per kilogram. In the Urambo district, the tobacco volume production increased from 5669.55 tons in 2017/18 to 7736.92 tons in the 2018/19 season (Table 1). Moreover, the increase in tobacco production is correlated to the increase in price per tobacco kilogram. In this study, it was found that the average price of 1 kg of tobacco for the 2018/19 season was 5750 TZS while the best leaf fetched price was 6536.6 TZS and the lowest price was 1490.4 TZS (TORITA, 2020). The results concur with other studies that declared that the selling price factor leads to increased tobacco production in Tanzania (Temu, 1980; Waluye, 1994; Mangora, 2012a). Temu (1980) reported that increased selling price per kilogram from 900 TZS in 1987 to 1500 TZS in 1990 attracted farmers from Kigoma, Mpanda and Shinyanga shift to the Urambo district for tobacco farming. This suggests that tobacco production increases due to the rise in price and economic importance to the Urambo district.

Table 10: Quantity of cured tobacco produced per hectare in 2018/19 crop-season

Tobacco production per hectare (kg/ha)	Percentage of respondents
Below 1500 kg	7.1
1500 – 2000 kg	91.8
above 2000 kg	1.1

Field survey data (2020)

According to TTB (2019), tobacco farmers are willing to produce any quantity of tobacco required by tobacco companies (buyers) as long as there is assured demand of tobacco from the tobacco companies. For instance, in the 2017/18 season, 5282 registered farmers produced 5669.55 tons of tobacco, while in the 2018/19 season, 2972 registered farmers produced 7736.92 tons of tobacco as demanded by tobacco buyers. Thus, when tobacco demand increases from the tobacco buyers, the volume of tobacco produced also increased, and is not directly related to the increased number of farmers. The tobacco curing process involves a process that either adds profit or reduces profits depending on either compliance or not for curing tobacco. These processes are categorized as the direct and indirect processes that affect the social and economic related to tobacco production.

The tobacco crop is one of the most profitable cash crops for both large-scale and smallholder farmers (Keyser, 2002) and is the first crop to earn foreign exchange (Cleland & Doherty, 2016;

BOT, 2020). This study revealed that tobacco production provides high net revenue for all tobacco barn users in the Urambo district. Furthermore, this study suggests that tobacco remains the most attractive agricultural activity to all farmer's scale even in under progressively tricky market conditions.

4.3.1 Tobacco production costs

Tobacco production involves many costs, including; land preparation, infrastructures maintenance costs, loading green leaf to the barn costs, curing costs, off-loading cured leaf costs, grading costs and baling costs. These costs were categorized into two stages, namely tobacco-growing cost and tobacco curing cost (Table 11). The costs of tobacco cultivation were the same for each barn as curing barn model is only functional to the curing of harvested tobacco leaf. This study estimated the tobacco curing cost of each tobacco model per hectare. The variable cost was of traditional barn model is higher (400 850 TZS) as compared to other improved barn model. Majority of farmer reported that traditional barn model require high quantity of wood fuel which increase the variable costs while improved barn model have consume low quantity of wood fuel (Table 11).

Table 11: The total costs, total revenue and net revenue of each tobacco barn model in 2018/19

Barn model	Variable cost	Fixed cost	Additional cost	Total cost	Total revenue	Net revenue
Traditional barn (TB)	4 000 850	725 282	820 709	5 546 841	5 650 525	103 684
Rocket barn (RB2)	3 957 150	736 782	820 709	5 514 641	5 650 525	135 884
Rocket barn (RB3)	3 934 150	844 882	820 709	5 599 741	5 650 525	50 784
Standard barn (SB)	3 945 650	849 482	820 709	5 615 841	5 650 525	34 684

Field survey data (2020)

NOTE: VARIABLE COST (Nursery 175 352 TZS; inputs 142 209TZS; Field costs 1 358 150 TZS; inputs 1 130 749 TZS; fuel wood 595 309 TZS; transport 70 840 TZS: Therefore, AVEREGE TOTAL VARIABLE COSTS is 4 000 850 TZS. FIXED COST (such as watering can, hoe, axle, barn thermometers, construction and repair of curing barns, grading, baling. cost about 844 882 TZS) Therefore, AVEREGE TOTAL FIXED COST is 844 882 TZS. ADDITIONAL COSTS (labourers, medicals, food and accommodation is 820 709 TZS. Therefore, AVEREGE TOTAL ADDITIONAL COST is 820 709 TZS.

This study estimated the total cost of the tobacco curing process of each barn model. The cost of tobacco curing differs from one barn model to another. This is due to different inputs of wood fuel costs, barn installation and health cost. The total tobacco production costs per hectare for traditional barn (TB), rocket barn (RB2), rocket barn (RB3) and standard barn (SB) was 5 546 841, 5 514 641, 5 599 741 and 5 615 841 TZS, respectively (Table 11). The results of this study indicate that tobacco production seems to be very high, with high up-front costs that smallholder farmers may not be able to afford. A research study by Keyser (2002) indicated that the overall cost of tobacco production is very high and become a barrier to most cash-poor smallholders to persist longer in tobacco production.

Tobacco farmers in the Urambo district depend wholly on wood fuel consumption for tobacco curing (Mangora, 2012b). According to TORITA (2020), there is no adopted alternative energy source so far. The cost of using wood fuel for the traditional barn model was observed to be more expensive (595 309 TZS per hectare) compared with other tobacco barn model (Table 11). The difference in wood fuel cost was due to the different in the energy efficiency of improved tobacco barn models. High wood fuel consumption by using traditional barn was also revealed by Siddiqui and Rajabu (1996). According to them, the traditional ban model consumes a large quantity of wood fuel (10.5 kg) that result in the high costs. Research study by Hendlin and Bialous (2020) showed the higher energy efficiency of rocket barn than the conventional barn. From these studies, it can be concluded that higher energy efficiency of the tobacco barn model signifies lower wood fuel cost, and lower energy efficiency indicates a higher cost of wood fuel.

Tobacco barn model installation and maintenance costs also correlate highly with total cost (Table 11). This study showed that standard barn model and rocket barn model (RB3) cost were significantly ($P<0.001$) higher than any other barn model. The TORITA (2020) explained that the lower cost for building traditional barn model was because many building materials are found within the area and many tobacco farmers build traditional barn model by themselves without building expert. The rocket barn and standard barn models require exotic installation materials and construction expert which causes rising of installation and maintenance cost. Rocket barn model version three (RB3) has high installation cost (820 000 TZS) compared to other tobacco barns in Tanzania. That cost results were lower compared to cost of installation in Zimbabwe which was estimated to be about 1 750 000 TZS. The differences in cost might be due to the size of the barn and the cost of building materials. For this reason traditional barn and rocket barn version two (RB2) are highly adopted in Urambo district as compared to standard barn and rocket barn version three (RB3).

Most of the tobacco farmers in Urambo district devote an average of 1 ha to 3 ha per season while each hectare requires three barn models (TORITA, 2020). A minimum of 3 barn models are built for those devoting one hectare and a maximum of 9 barn models for those devoting three hectares. The increase of area for cultivation increases the numbers of tobacco barns which increases the tobacco curing cost. However, Milambo Cooperative Union reported that most of the farmers cannot afford to build three tobacco barn models for every hectare resulting in the decay reaped tobacco leaves, hence reducing the quantity and quality of cured tobacco which reduced the net revenue. Kibwage *et al.* (2014) revealed that tobacco production requires occupation and extensive labor which increasing the total costs of production and hence net revenue reduction. Also, the study conducted by Makoka *et al.* (2017) found that sometimes tobacco farmers ends up in loss due to extensive labor work needed during tobacco production.

The majority of tobacco farmers in the Urambo district harvest wood fuel far from the curing site; hence they incur a cost to transport wood fuel. The wood fuel obtained near the curing site has a lower cost, while wood fuel obtained from far incurs higher cost. This study observed that currently woodland near the curing site has been totally cleared; hence farmers have to move long distance to harvest wood fuel. Our results agree with Waluye (1994) study, which reported that Urambo district farmers often move distance to harvest wood fuel for tobacco curing. Also, our findings are in agreement with the study by Lawrence *et al.* (2020) who found that many forest woodlands near the homestead have been cleared than those far from the homestead. This results in increases in the wood fuel cost.

4.3.2 Revenue of tobacco production

The total revenue per hectare depends on the quantity of cured tobacco produced per hectare and the selling price per kilogram. There are some changes in tobacco price per kilogram and yields per hectare in every season (Table 10). However, Keyser (2002) revealed that tobacco production would remain relatively profitable, even if prices fell considerably. The majority of farmers in the Urambo district sell a kilogram of cured tobacco at an average of 3565 TZS (Fig. 7), compared to 5635 TZS per kilogram in Zimbabwe (Scoones *et al.*, 2018). The difference in tobacco selling price might be due to a given country's economic status, levies and taxes imposed in tobacco crop (Drope *et al.*, 2017).

Most of respondents produce 1500 – 2000 kg of cured tobacco in one hectare. The average mass of cured tobacco in a one acre is 1 585 kg. From the Equation 6, estimated total revenue per hectare was equal to 5 650 525 TZS (Table 11). This is higher revenue than other crops such as tea hence tobacco production is considered highly profitable for all small and large scale tobacco farmers (Keyser, 2002).

4.3.3 Net revenue of tobacco production

Tobacco is among the cash crops which play a key role in the economic development of the Urambo district TTB (2019), as a result of this, high net revenue obtained from tobacco farming. Based on Equation 7, tobacco farmers gained average net revenue of 103 684, 135 884, 50 784, 34 684 TZS from one hectare for using the traditional barn, rocket barn (RB2), rocket barn (RB3) and standard barn (SB) respectively in 2018/19 season. The net revenue of RB2 barn is higher (135 884 TZS) followed by traditional barn (103 684 TZS), justifying the adoption of these curing barns by the majority of the Urambo district farmers (Fig. 4). This means that rocket barn (RB2) was more profitable than other barn models due to lower wood fuel cost and installation cost. Our results concur with the study of Scott (2008), who reported that there is an increase of 10% of financial benefit when the rocket barn model (RB2) is used for tobacco curing.

This study indicates that the standard barn model was more expensive in terms of installation cost than other ban models resulting in low benefits (Table 11). Farmers have motives in gaining benefits and will choose affordable infrastructures but, with high profit margin. Therefore, traditional barn and rocket barn (RB2) models have high net revenue per hectare compared with standard barn and rocket barn (RB3) models. Due to this reason, RB2 barns were easily adopted by smallholder farmers in the Urambo district than RB3 barns (Fig. 4). A study by Maw *et al.* (1985) showed similar results that improved RB2 barn models might save up to 690 000 TZS per curing season compared to the traditional barn models. The differences in net revenue might be due to the long time spent and higher installation cost for the traditional barn, which reduces the net revenue compared to the improved RB2 barn, which increased revenue due to the lower cost of wood fuel.

Thus, the study signifies that the net revenue is the motive factor for the RB2 and traditional tobacco barn adoption in the Urambo district. Therefore, higher net revenue from tobacco production is attractive to farmers and keeps them in a loop for production continuity (Moyo, 2014). This was also revealed in Malawi, whereby the price is the motive factor for increasing tobacco production (Manyanhaire & Kurangwa, 2014).

4.3.4 Correlation between the total costs and net benefits

The correlation between the total costs and the net benefits are shown in Table 12. The installation cost of tobacco barn increased with the modification done in the furnace, channel and chimney. This study found that the installation cost for a traditional barn was cheaper because there was no modification in the furnace, channel and chimney. At the same time, improved barns have higher modifications in furnace, channel and chimney hence higher installation costs. Furthermore, this study found that rocket barn version 3 (RB3) has high installation costs because of higher modifications that make it more energy efficiency than other tobacco barns. That is why the lower wood fuel cost of the rocket barn version 3 (RB3). In summary, it can be concluded that installation cost increases inversely with an increase of wood fuel cost. Because as the installation cost increases, the barn is more energy efficient and hence lower wood fuel consumption.

Table 12: Correlation between the installation cost, wood fuel cost, maintenance cost, and net benefits

	A	*B*	*C*	*D*
A	1			
B	-0.822**	1		
C	0.923***	-0.796**	1	
D	0.985***	-0.715**	0.913***	1

Field survey (2020)

Correlations are significant at P ≤ 0.05 (where; *, **, and *** are significant at P≤0.05, P≤0.01 and P≤0.001, Respectively

Note: A-Installation cost, B-Wood fuel cost, C-Maintenance cost, D-Net benefit

The installation cost also correlates with the maintenance cost (Table 12). The installation cost of the tobacco barn model increase, increases the maintenance cost hence increase of the total cost of tobacco production. Standard barn and rocket barn version three have higher total cost due to higher installation cost as compared to traditional and rocket barn version two lower (Table 12). According to the tobacco farmers, the higher installation cost is due to the materials needed for construction and expert to construct a barn from outside the Urambo district. Hence, even during the repairing of the improved barn the experts and materials have to be transported to the site, which leads to higher makes maintenance costs.

4.4 Challenges faced by tobacco farmers during tobacco curing and proposed solutions

Challenges faced by tobacco farmers in the Urambo district during the tobacco curing are shown in Fig. 8. Challenges facing tobacco farmers during the curing differ among the farmers as they have different skills since areas are not the same. However, the curing stage's major challenges encountered were grouped into two, the effect of long rainfall season associated with the lower heat distribution to the curing barn and the poor design of channels.

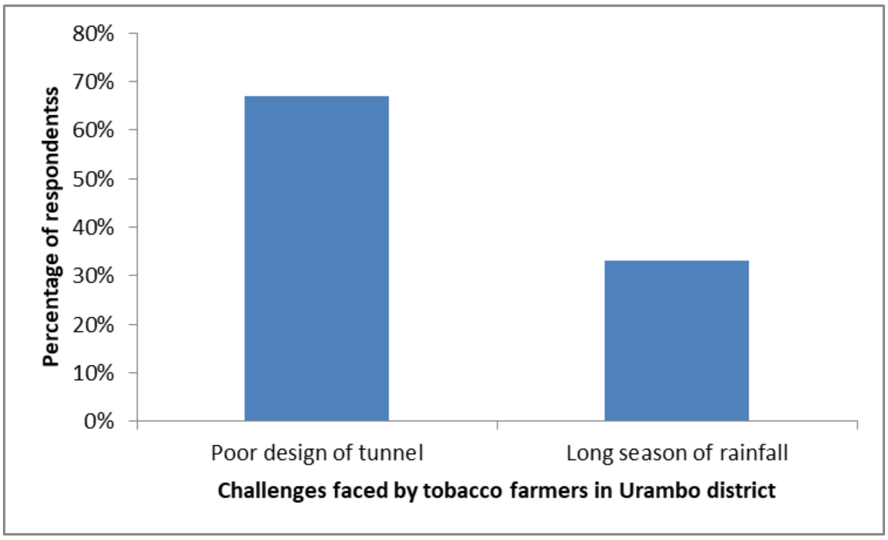

Figure 8: Challenges of tobacco curing in Urambo district (Field survey 2020)

Research findings observed that curing tobacco leaf during the long rainfall season, heat generated in a furnace intended to flow inside the channel towards the curing barn is lost outside the furnace. Thus farmers are forced to use more wood fuel quantities to cure the tobacco, and hence the big challenge to them is the reduction of the net revenue as the cost of wood fuel is increase. During the longer rainfall season the wood fuel consumption is much higher as most of the channels have been designed and constructed poorly with leakages and hence heat loss.

Farmers were allowed to propose solutions to the challenges encountered during the tobacco curing stage. The findings indicate that most tobacco farmers (79%) suggested providing of cheap and affordable alternative curing sources of energy to replace wood fuel (Fig. 9) as sourcing and loading wood fuel to the furnace is very laborious and time consuming. Research studies by Cole and Cole (2006) and Nayak (2013) revealed that most tobacco farmers are still using wood fuel instead of coffee husks because of wood availability, easy to store and require no modification of tobacco barn. However, the need for alternative curing energy apart from wood, is of most important; because some of impacts of using wood fuels are not realized at the time of usage, but their occurs in future to cause global warming, disappearance of forest extinction tree species and soil erosion (Owusu & Asumadu-Sarkodie, 2016). Thus, Lawrence *et al.* (2020) advised that the government to support the efforts to design the alternative tobacco curing technologies and conserving the forest woodland for deforestation mitigation and climate change.

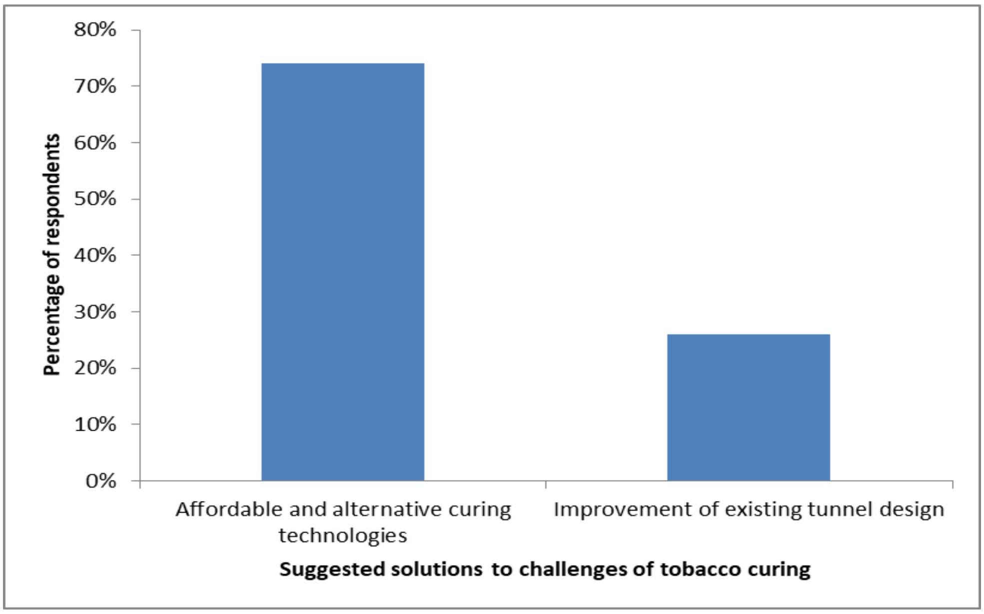

Figure 9: Suggested solutions to challenges of tobacco curing (Field survey 2020)

There is a green light for the Urambo district to use alternative energy source to cure tobacco. TORITA (2020) research finding using RB2 curing barn in the testing possibility of two sources, briquettes from organic materials (rice husks) and coal to cure green tobacco leaf, showed promising results. About 56 204 kg of organic briquettes with the calorific value of 3133 cal/g cured 1585 kg of tobacco at the cost of 2 604 192 TZS per hectare. The coal observed to have a higher calorific value (4462.97 cal/g) and used 4105 kg of coal to cure 1585 kg of tobacco, but at very high cost of 4 210 300 TZS per hectare compared with 9510 kg of wood fuel with the calorific value of 4218 cal/g to cure the same volume of tobacco at the cost of 626 158 TZS per hectare. Despite having a high calorific value for coal in curing tobacco, the use of coal was not recommended in the tobacco sector for the sustainability of tobacco based on three facts. First, the use of coal in curing tobacco was very costly to be affordable by farmers. Second, coal is a non-renewable resourced and hence can be used to cure tobacco sustainably. Third, the use of coal emits carbon dioxide that contributes to global warming, thus not recommended.

Despite the reasonable efforts made by TORITA on research for alternative sources of curing tobacco, there is a need to improve the calorific value of organic briquettes by mixing with other organic materials of high calorific value to reduce the costs in curing tobacco. However, tobacco farmers should be fairly involved from the start to the end to increase the adaptability of any new curing source technology Kurangwa *et al.* (2015).

Therefore, to mitigate the encountered challenges faced by farmers during the curing of tobacco, we propose the following strategies; first, further research is required to look for the most probable, affordable alternative curing energy source in collaboration with the farmers for the sustainability of tobacco crop. Secondly, the tobacco sector should look for the funds and support tobacco farmers to repair or improve the channels design that allow efficiently flow of heat into the curing barns with minimal heat loss. Finally, farmers should be supplied with protective gears from the fieldwork towards the curing stage as they are exposed to danger when loading wood fuel to the furnace.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The present study indicates that tobacco is a cash crop of economic importance in the Urambo district. The tobacco crop requires wood fuel for curing tobacco leaf; about 95% of the farmers outsource wood fuel from the forest reserve and only a few (5%) from planted woodlots. Most of the Urambo district farmers are using rocket barn version 2 (RB2) and traditional barn (TB). These barns observed to consume much significantly wood fuel 6.20 and 10.50 kg of wood fuel to cure a kilogram of tobacco than rocket barn version 3 (RB3) and standard barn (SB), which consumed 4.60 and 5.50 kg of wood fuel to cure a kilogram of tobacco leaf. In the 2018/19 crop season about, 5974.14 and 381.32 ha of forest reserve and woodlots plantations are estimated to be cleared for curing tobacco, respectively, in the Urambo district and hindered 63 554.73 tons of atmospheric carbon dioxide from sequestration. During the curing time of tobacco leaf, the study estimated 33 366.24 tons of carbon dioxide released into the atmosphere to cause global warming.

The study further assessed the social aspects associated with all stages of tobacco production which explored tobacco as labor-intensive, disruption of forest services, student drop-out from school, tedious work, time consuming crop, and leave little time for other food crops and food insecurity. Social aspects observed the tobacco farmers to spend more time on tobacco production, which later exacerbated the illiteracy and poverty as children were mostly used in farming operations. Following the impacts of tobacco curing using wood fuel on the environment, the current study proposed developing alternative sources of energy to replace wood fuel usage; hence, reduce deforestation and carbon dioxide accumulation in the atmosphere.

5.2 Recommendations

(i) For the conservation of forest woodland, this study suggests developing alternative curing technologies to replace wood fuel. Thus, it will speed up the conservation of woodland forest and reduce global warming.

(ii) Since tobacco is the first earner crop for foreign exchange in Tanzania, the government should put policies that govern forest woodland conservations and strictly impose laws and regulations to anyone harvesting forest trees without a permit.

(iii) The current research has pinpointed the impact of growing tobacco on deforestation and the accumulation of carbon dioxide in the atmosphere following curing tobacco using wood fuel. Therefore, further studies are recommended to study the tobacco production's impacts impact on the agrochemicals use to its residuals in soils.

(iv) The majority of the tobacco farmers are subjected to high risk on their health following using agrochemicals in fields and exposure to the heat during the curing tobacco, but do not have protective gears. Therefore, the current study recommends that personal protective equipment's (PPE) be given to farmers as package with agrochemicals and instructing farmers on how to use the PPE.

(v) Tobacco is grown as a monocrop leaving unprotected upper soil against wind and water runoff causing soil erosion. Thus, further research is required to establish tobacco production's impact on soil loss through erosion and propose affordable solutions to soil loss.

REFERENCES

Abrams, E. M., & Rue, D. J. (1988). The causes and consequences of deforestation among the prehistoric Maya. *Human Ecology*, *16*(4), 377-395. https://link.springer.com/article/ 10.1007/BF00891649

Alibhai, N. (1968). Tobacco marketing in Tanzania. *Rural Development Research*, *397*(63), 2-13. https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/1451

Arcury, T. A., & Quandt, S. A. (2006). Health and social impacts of tobacco production. *Journal of Agromedicine*, *11*(3-4), 71-81. https://doi.org/10.1300/J096v11n03_08

Bailey, A. (2006). Harvesting, curing, and preparing dark firecured tobacco for market. AGR-152. Service, *University of Kentucky, Lexington*, *8*(12), 1-96. http://www2.ca.uky .edu/agcomm/ pubs/agr/agr152/agr152.pdf

Bank, W. (2017). *Agriculture for Jobs and Growth in the Western Balkans: A Regional Report. World Bank*. http://hdl.handle.net/10986/32204

Banožić, M., Aladić, K., Jerković, I., & Jokić, S. (2020). Volatile organic compounds of tobacco leaves versus waste (scrap, dust, and midrib): Extraction and optimization. *Journal of the Science of Food and Agriculture*, *2*(7), 1-65. https://doi.org/10. 1002/jsfa.10796

Benozic. (2020). Carbohydrates—Key Players in Tobacco Aroma Formation and Quality Determination. *Molecules*, *25*(7), 1-13. https://doi.org/10.3390/molecules25071734

Biesbroek, S., Bueno-de-Mesquita, H. B., Peeters, P. H., Verschuren, W. M., van der Schouw, Y. T., Kramer, G. F., Tyszler, M., & Temme, E. H. (2014). Reducing our environmental footprint and improving our health: greenhouse gas emission and land use of usual diet and mortality in EPIC-NL: A prospective cohort study. *Environmental Health*, *13*(1), 27

Banožić, M., Aladić, K., Jerković, I., & Jokić, S. (2020). Volatile organic compounds of tobacco leaves versus waste (scrap, dust, and midrib): Extraction and optimization. *Journal of the Science of Food and Agriculture*, *2*(7), 1-9. https://doi.org/10.1186/ 1476-069X-13-27

Blomley, T., & Iddi, S. (2009). *Participatory forest management in Tanzania: 1993-2009: Lessons learned and experiences to date*. http://hdl.handle.net/123456789/60

Bortolini, M., Gamberi, M., Mora, C., & Regattieri, A. (2019). Greening the tobacco flue-curing process using biomass energy: A feasibility study for the flue-cured Virginia type in Italy. *International Journal of Green Energy*, *16*(14), 1220-1229. https://doi.org/ 10.1080/15435075.2019.1671397

BOT. (2020). *Annual report 2019/20 Bank of Tanzania.* https://www.bot.go.tz/ Publications /Regular/Annual%20Report/en/2020123112264444.pdf

Brown, L. R., Larsen, J., Dorn, J. G., & Moore, F. C. (2008). Time for Plan B. *Earth Policy Institute*, *2008,* 1-12. http://www.earth-policy.org/mobile/releases/80by2020

Burgess, N. D., Bahane, B., Clairs, T., Danielsen, F., Dalsgaard, S., Funder, M., Hagelberg, N., Harrison, P., Haule, C., & Kabalimu, K. (2010). Getting ready for REDD+ in Tanzania: a case study of progress and challenges. *Oryx*, *44*(3), 339-351. https://doi.org/10.1017/ S0030605310000554

Campbell, J. S. (1995). Tobacco and the environment: the continuous reduction of worldwide energy source use for green leaf curing. *Beiträge zur Tabakforschung International/Contributions to Tobacco Research*, *16*(3), 107-117. https://doi.org/ 10.2478/cttr-2013-0637

Cavlek, M., Tursic, I., & Cosic, T. (2006). Study of growing flue-cured tobacco in Croatia under various conditions of irrigation and nitrogen nutrition. *Beiträge zur Tabakforschung International/Contributions to Tobacco Research*, *22*(2), 125-132.

Chaves, L. S. M., Fry, J., Malik, A., Geschke, A., Sallum, M. A. M., & Lenzen, M. (2020). Global consumption and international trade in deforestation-associated commodities could influence malaria risk. *Nature Communications*, *11*(1), 1-10. https://doi.org/10. 1038/s41467-020-14954-1

Chirindo, N. C. J., Daniel, R., Peter ,C., Zvirevo, B. (2017). Development of an efficient low cost emergency obacco curing barn for small scale tobacco growers in Zimbabwe. *Journal of Basic and Applied Research International*, *2017,* 244-256. https://www. researchgate.net/publication/315661124

Clark, M., Magati, P., Drope, J., Labonte, R., & Lencucha, R. (2020). Understanding Alternatives to Tobacco Production in Kenya: A Qualitative Analysis at the Sub-National Level. *International Journal of environmental Research and Public Health*, *17*(6), 1-14. https://doi.org/10.3390/ijerph17062033

Cleland, G., & Doherty, E. (2016). *Monthly economic review: November 2016. 1-33*. https://www.bot.go.tz/Publications/Regular/Monthly%20Economic%20Review/sw/20 20021122483223286.pdf

Condorí, M., Albesa, F., Altobelli, F., Duran, G., & Sorrentino, C. (2020). Image processing for monitoring of the cured tobacco process in a bulk-curing stove. *Computers and Electronics in Agriculture, 168,* 1-2. https://doi.org/10.1016/j.compag. 2019.105113

Danny de Vries, M. (2000). Africare's Ugalla Community Conservation Project (UCCP)-Tabora: History, observations and analysis of the natural resource baseline. *Africare, 6*, 1-84. https://doi.org/10.13140/RG.2.1.2746.7768

Dasgupta, D., Rao, T. P., Vithal, P., & Kapur, P. (1991). Flue curing of Virginia tobacco by a tube-in-basket (TiB) burner using rice husk as fuel and barn insulation. *Resources, Conservation and Recycling*, *5*(1), 47-60. https://doi.org/10.13140/RG.2.1.2746.7768

De Leite Ribeiro, L. S., & da Conceição Pinto, V. (2020). Discrepancies in the Brazilian tobacco production chain: raw inputs, international trade and legal cigarette production. *Tobacco Control*, *29*(5), s310-s318. https://doi.org/10.1136/tobacco control-2019-055265

Delice, A. (2010). The Sampling Issues in Quantitative Research. *Educational Sciences: Theory and Practice*, *10*(4), 2001-2018. https://files.eric.ed.gov/fulltext/EJ919871.pdf

Dhungana, B. (2020). *Marketing in regulated industry: Study of Tobacco Industry.* http://urn. fi/URN:NBN:fi:amk-2020101721389

Drope, J., Li, Q., Araujo, E. C., Harimurti, P., Sahadewo, G. A., Nargis, N., Durazo, J., Witoelar, F., & Sikoki, B. S. (2017). *The Economics of Tobacco Farming in Indonesia*. https://tobacconomics.org/files/research/654/indonesia-economics-of-tobacco-farming.pdf

FAOSTAT. (2017). *The State of Food Security and Nutrition in the World 2020.* http://www.fao.org/3/i9836en/I9836EN.pdf

Geist, H. J. (1999). Global assessment of deforestation related to tobacco farming. *Tobacco Control*, *8*(1), 18-28. https://doi.org/10.1136/tc.8.1.18

Giannetti, B., Agostinho, F., Eras, J. C., Yang, Z., & Almeida, C. (2020). Cleaner production for achieving the sustainable development goals. *Journal of Cleaner Production*, *271*, 1-9. https://doi.org/ 10.1016/j.jclepro.2020.122127

Gong, D., Chen, M., Sun, Y., Zhang, Y., Zhang, X., & Xu, X. (2020). Fine mapping of QTLs for resistance to Phytophthora nicotianae in flue-cured tobacco using a high-density genetic map. *Molecular Breeding*, *40*(5), 1-13. https://doi.org/10.1007/s11032-020-01126-8

Gwenzi, W., Ncube, R. S., & Rukuni, T. (2020). Development, properties and potential applications of high-energy fuel briquettes incorporating coal dust, biowastes and post-consumer plastics. *SN Applied Sciences*, *2*, 1-14. https://doi.org/10.1007/s42452-020-2799-8

He, F., Wei, F., Ma, C., Zhao, H., Fan, Y., Wang, L., & Wang, J. A. (2021). Performance of an Intelligent Biomass Fuel Burner as an Alternative to Coal-Fired Heating for Tobacco Curing. *Polish Journal of Environmental Studies*, *30*(1), 131-140. https://doi.org/10. 15244/pjoes/122164

Hendlin, Y. H., & Bialous, S. A. (2020). The environmental externalities of tobacco manufacturing: A review of tobacco industry reporting. *Ambio*, *49*(1), 17-34. https://doi.org/10.1007/s13280-019-01148-3

Henry, J. B., Vann, M. C., & Lewis, R. S. (2019). Agronomic Practices Affecting Nicotine Concentration in Flue-Cured Tobacco: A Review. *Agronomy Journal*, *111*(6), 3067-3075. https://doi.org/10.2134/agronj2019.04.0268

Hopkinson, N. S., Arnott, D., & Voulvoulis, N. (2019). Environmental consequences of tobacco production and consumption. *National Library of Medicine*, *394*(10203), 1007-1008. https://doi.org/10.1016/S0140-6736(19)31888-4

Hu, B. B., Lin, Z. L., Chen, Y., Zhao, G. K., Su, J. E., Ou, Y. J., Liu, R., Wang, T., Yu, Y. B., & Zou, C. M. (2020). *Evaluation of biomass briquettes from agricultural waste on industrial application of flue-curing of tobacco. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*. https://doi.org/10.1016/j.scitotenv.2016.11.025

Hu, T. W., & Lee, A. H. (2015). Commentary: tobacco control and tobacco farming in African countries. *Journal of Public Health Policy*, *36*(1), 41-51. https://doi.org/10. 1057 /jphp.2014.47

Huangfu, Y., Li, H., Chen, X., Xue, C., Chen, C., & Liu, G. (2014). Effects of moisture content in fuel on thermal performance and emission of biomass semi-gasified cookstove. *Energy for Sustainable Development*, *21*, 60-65. https://doi.org/10.1016/j.esd.2014.05.007

ILO. (2016). *ILO cooperation with the tobacco industry in the pursuit of the Organization'ssocial mandat*e. https://www.ilo.org/wcmsp5/groups/public/---africa/---ro-abidjan/---ilo-dar_es_salaam/documents/publication/wcms_517519.pdf

IPCC. (2003). *Sequestration and phytosequestration*. https://www.ipcc.ch/site/ assets/uploads /2018/02/ipcc_wg3_ar5_chapter11.pdf

IPCC. (2007). *Climate Change and Land*. https://www.ipcc.ch/site/assets/uploads/2019/11/ SRCCL-Full-Report-Compiled-191128.pdf

James, M. M. (2018). *Impacts of Tobacco Farming on forest cover in Bukira West/Bukira East location, Migori country, Kenya*. https://www.researchgate.net/publication/32751 0833

Jew, E. K., Dougill, A. J., & Sallu, S. M. (2017). Tobacco cultivation as a driver of land use change and degradation in the miombo woodlands of south-west Tanzania. *Land Degradation and Development*, *28*(8), 2636-2645. https://doi.org/doi.org/10. 1002/ldr.2827

Jew, E. K., Dougill, A. J., Sallu, S. M., O'Connell, J., & Benton, T. G. (2016). Miombo woodland under threat: Consequences for tree diversity and carbon storage. *Forest Ecology and Management*, *361*, 144-153. https://doi.org/10.1016/j.foreco.2015.11.011

Jimu, L., Mataruse, L., Musemwa, L., & Nyakudya, I. W. (2017). The miombo ecoregion up in smoke: The effect of tobacco curing. *World Development Perspectives*, *5*, 44-46. https://doi.org/10.1016/j.wdp.2017.03.007

John, R. M., Sinha, P., Munish, V. G., & Tullu, F. T. (2021). Economic Costs of Diseases and Deaths Attributable to Tobacco Use in India, 2017–2018. *Nicotine and Tobacco Research*, *23*(2), 294-301. https://doi.org/10.1093/ntr/ntaa154

John, R. M., Sung, H., & Max, W. (2009). Economic cost of tobacco use in India, 2004. *Tobacco Control*, *18*(2), 138-143. https://doi.org/10.1136/tc.2008.027466

Jonson, J., & Freudenberger, D. (2011). Restore and sequester: estimating biomass in native Australian woodland ecosystems for their carbon-funded restoration. *Australian Journal of Botany*, *59*(7), 640-653. https://doi.org/doi.org/10.1071/BT11018

Kagaruki, L. K. (2010). Community-based advocacy opportunities for tobacco control: experience from Tanzania. *Global Health Promotion*, *17*(2), 41-44. https://doi.org/ 10.1177/1757975910363932

Katundu, M., & Mwaseba, D. (2009). The Role of Co-Operative Organizations in Implementing Reforestation Programs: The Case of Tanzania Tobacco Traders" Reforestation Program in Urambo District. *Journal of Co-operative and Business Studies, Tanzania. Journal of cooperative Business Studies, 4*(2), 1-4. https://directresearch publisher.org/drjsses/files/2018/11/Ojimba-et-al.pdf.

Keyser, J. C. (2002). The costs and profitability of tobacco compared to other crops in Zimbabwe. *World Bank, Washington*, *67*(6), 1-29. http://hdl.handle.net/10986/13654

Kibiki, J. M. (2017). *The Relationship Between Family Composition and Child Labour in Tanzania: A Case of Urambo District [The Open University of Tanzania]*. http://repository.out.ac.tz/id/eprint/1954

Kibwage, J. K., Netondo, G. W., Odondo, A. J., Momanyi, G. M., Awadh, A. H., & Magati, P. O. (2014). Diversification of household livelihood strategies for tobacco small-holder farmers: a case study of introducing bamboo in South Nyanza region, Kenya. 1-98. http://hdl.handle.net/123456789/466

Kumar, A., & Kandpal, T. C. (2005). Solar drying and CO2 emissions mitigation: potential for selected cash crops in India. *Solar Energy*, *78*(2), 321-329. https://doi.org/10. 1016/j.solener.2004.10.001

Kurangwa, W., Katsaruware, R. D., & Hunduza, S. (2015). E*ffect of Training on Yield and Quality of Tobacco (Nicotiana Tabaccum): A Comparative Study of Trained and Untrained Farmers in Mazowe District, Zimbabwe.* https://www.semanticscholar. org/paper/Effect-of-Training-on-Yield-and-Quality-of-Tobacco-Hunduza-Kurangwa / e5d6f5eb358d1470e02528ecb72800b7a2e1b34d

Lawrence, M., Tapiwa, K. A., Lovemore, M., & Michael, M. (2020). Smallholder Tobacco Farmers and Forest Conservation in Mutasa District, Zimbabwe. *Ecology and Evolutionary Biology*, *5*(1), 6-12. https://doi.org/10.11648/j.eeb.20200501.12

Layden, J. E., Ghinai, I., Pray, I., Kimball, A., Layer, M., Tenforde, M. W., Navon, L., Hoots, B., Salvatore, P. P., & Elderbrook, M. (2020). Pulmonary illness related to e-cigarette use in Illinois and Wisconsin. *New England Journal of Medicine*, *382*(10), 903-916. https://doi.org/10.1056/NEJMoa1911614

Lecours, N., Almeida, G. E., Abdallah, J. M., & Novotny, T. E. (2012). Environmental health impacts of tobacco farming: a review of the literature. *Tobacco Control*, *21*(2), 191-196. https://doi.org/10.1136/tobaccocontrol-2011-050318

Lencucha, R., Moyo, T., Labonte, R., Drope, J., Appau, A., & Makoka, D. (2020). Shifting from tobacco growing to alternatives in Malawi? A qualitative analysis of policy and perspectives. *Health Policy and Planning*, *35*(7), 810-818. https://doi.org/10.1093 /heapol/czaa057

Li, Y., Shi, H., Yang, H., Zhou, J., Wang, J., Bai, R., & Xu, D. (2017). Difference between burley tobacco and flue-cured tobacco in nitrate accumulation and chemical regulation of nitrate and TSNA contents. *Journal of Chemistry*, *2017,* 1-13. https://doi.org/ 10.1155/2017/4357456

Lisuma, J., Mbega, E., & Ndakidemi, P. (2020). Influence of tobacco plant on macronutrient levels in sandy soils. *Agronomy*, *10*(3), 1-15. https://doi.org/10.3390/agronomy 10030418

Loker, W. M. (2005). The rise and fall of flue-cured tobacco in the Copán Valley and its environmental and social consequences. *Human Ecology*, *33*(3), 299-327. https://doi.org/10.1007/s10745-005-4141-x.

Mackay, J., Eriksen, M., & Eriksen, M. P. (2002). *The Tobacco Atlas. World Health Organization.* https://www.who.int/tobacco/media/en/title.pdf

Makoka, D., Drope, J., Appau, A., Labonte, R., Li, Q., Goma, F., Zulu, R., Magati, P., & Lencucha, R. (2017). Costs, revenues and profits: an economic analysis of smallholder tobacco farmer livelihoods in Malawi. *Tobacco Control*, *26*(6), 634-640. https://doi.org/10.1136/tobaccocontrol-2016-053022

Mandima, L. (2017). T*he impact of deforestation on the miombo woodland regeneration. A case of* [Madziva Communal Area BUSE]. *Forest Service*, 2(9), 33-89. https://doi.org/10.1136/forestservice-2016-053022

Mangasini, A. (2007). *Evaluation of the association of Tanzania tobacco traders' reforestation programme: The case of Urambo District* [Sokoine University of Agriculture (SUA)]. 1-128. http://www.taccire.suanet.ac.tz/xmlui/handle/123456789 /373?show=full

Mangora, M. M. (2005). Ecological impact of tobacco farming in miombo woodlands of Urambo District, Tanzania. *African Journal of Ecology*, *43*(4), 385-391. https://doi.org/10.1111/j.1365-2028.2005.00603.x

Mangora, M. M. (2012a). Shifting cultivation, wood use and deforestation attributes of tobacco farming in Urambo District, Tanzania. *Journal of Social Sciences*, *4*(2), 135-140.

Mangora, M. M. (2012b). Shifting Cultivation, Wood Use and Deforestation Attributes of Tobacco Farming in Urambo District, Tanzania. *Journal of Social Sciences*, *7*(3), 1-77. http://hdl.handle.net/20.500.11810/1726

Manyanhaire, I. O., & Kurangwa, W. (2014). Estimation of the impact of tobacco curing on wood resources in Zimbabwe. *International Journal of Development and Sustainability,* 3(7), 1455-1467. https://doi.org/2168-8662.ijds.

Masiaga, M. R. (2015). *Child labour among tobacco growing communities: An exploratory study on the effect of child labour on pupil's schooling in Kaliua district*. 1-128 http://hdl.handle.net/11192/430

Masvongo, J., Mutambara, J., & Zvinavashe, A. (2013). Viability of tobacco production under smallholder farming sector in Mount Darwin District, Zimbabwe. *Journal of Development and Agricultural Economics*, *5*(8), 295-301. https://doi.org/10. 5897/JDAE12.128

Maw, B., Butts, C., Garner, J., & Sumner, P. (1985). Estimating Reductions in Energy Consumption During Tobacco Curing as a Result of Improved Tobacco Barn Maintenance. *Applied Engineering in Agriculture*, *1*(2), 84-86. https://tobacco. caes uga.edu/content/dam/caes-subsite/tobacco/docs/retrofit/ archive/ est-energy-tob-main. pdf

Mergos, G. (2001). T*obacco: Supply, Demand, and Trade Projections, 2005-2010*. Prepared fortheFAO. https://ec.europa.eu/health/archive/ph_determinants/life_style/ tobacco/ documents/world_bank_en.pdf

Mganilwa, Z., Mbilinyi, B., Kweka, A., & Msilanga, B. (2009). Environmental impact of cereal-tobacco farming system in Miombo Woodlands: A case study of Uyui District, Tabora Region, Tanzania. *Tanzania Journal of Forestry and Nature Conservation*, *79*(1), 39-46. https://www.ajol.info/index.php/tjfnc/article/view/57440

Misana, S. (1999). D*eforestation in Tanzania: A development crisis. The Experience of Kahama District.* https://www.amazon.com/Deforestation-Tanzania-development-experience-District/dp/B00069WWBK

Mitchell, D., & Baregu, M. (2012). The tanzania tobacco sector: How market reforms succeeded. *African agricultural reforms: The Role of Consensus and Institutions*, *23*(50), 271-289. https://www.jstor.org/stable/23644949

Mohan, P., Lando, H. A., & Panneer, S. (2018). Assessment of tobacco consumption and control in India. *Indian Journal of Clinical Medicine*, *9*, 1199-5928. https://doi.org/10. 4103/0019-509X.147479.

Moyo, M. (2014). *Effectiveness of a contract farming arrangement: A case study of tobacco farmers in Mazowe district in Zimbabwe Stellenbosch*: [Stellenbosch University]. http://www.globalbioenergy.org/uploads/media/moyo_effectiveness_% 20%202014.pdf

Msigwa, F. J. (2019). *Impacts of Tobacco Production on Forest Resources Management in Kasulu District, [Tanzania The Open University of Tanzania]*. http://www.fao. org/uploads/media/moyo_effectiveness_%20%202014.pdf

Munanga, W., Mugabe, F., Kufazvinei, C., & Dimbi, S. (2017). Development of a low cost and energy efficient tobacco curing barn in Zimbabwe. *African Journal of Agricultural Research*, *12*(35), 2704-2712. https://doi.org/10.5897/AJAR2017.12413

Munanga, W., Mugabe, F., Kufazvinei, C., & Svotwa, E. (2014). Evaluation of the curing efficiency of the rocket barn in Zimbabwe. *International Journal of Agriculture, Innovations and Research*, *3*(2), 436-441. https://www.researchgate.net/publication/ 320187650

Munishi, P., Mringi, S., Shirima, D., & Linda, S. (2010). *The role of the Miombo Woodlands of the Southern Highlands of Tanzania as carbon sinks*.1-67 http://www.academic journals.org/jene

Munthali, G. N. C., & Xuelian, W. (2020). The Future of Tobacco Industry Amidst of COVID-19-A Case of Malawi Producing Country. *Biomedical Journal of Science, Technology and Research [Internet]*, *7*(5), 21104-21109. https://doi.org/10.26717/ BJSTR. 2020.27.004566

Musoni, S., Nazare, R., Manzungu, E., & Chekenya, B. (2013). Redesign of commonly used tobacco curing barns in Zimbabwe for increased energy efficiency. *International Journal of Engineering Science and Technology*, *5*(3), 1-9. https://doi.org/10.1.1. 303.2087

Myers, N., & Goreau, T. J. (1991). *Tropical forests and the greenhouse effect: A management response. In Tropical forests and climate, Springer.* https://doi.org/10. 1007/978-94-017-3608-4_22

Nayak, N. S. (2013). *Tobacco curing and fuel efficiency in Karnataka, India. SANDEE*. http://www.sandeeonline.org/uploads/documents/publication/1007

Ndomba, H. H. (2018). *A history of peasant tobacco production in Ruvuma Region, Southern Tanzania, c. 1930-2016 [Stellenbosch: Stellenbosch University]*. http://hdl.handle.net/ 10019.1/103264

Ngarava, S. (2020). Impact of the Fast Track Land Reform Programme (FTLRP) on agricultural production: A tobacco success story in Zimbabwe? *Land Use Policy*, *99*, 10-5000. https://doi.org/10.1016/j.landusepol.2020.105000

Njana, M. A., Kajembe, G. C., & Malimbwi, R. E. (2013). Are miombo woodlands vital to livelihoods of rural households? Evidence from Urumwa and surrounding communities, Tabora, Tanzania. *Forests, Trees and Livelihoods*, *22*(2), 124-140. https://doi.org/doi.org/10.1080/14728028.2013.803774

Novotny, T. E., Bialous, S. A., Burt, L., Curtis, C., Costa, V. L. d., Iqtidar, S. U., Liu, Y., Pujari, S., & Tursan d'Espaignet, E. (2015). The environmental and health impacts of tobacco agriculture, cigarette manufacture and consumption. *Bulletin of the World Health Organization*, *93*, 877-880. https://doi.org/10.2471/BLT.15.152744

Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, *3*(1), 116-7990. https://doi.org/10.1080/23311916.2016.1167990

Ramadhani, T., Otsyina, R., & Franzel, S. (2002). Improving household incomes and reducing deforestation using rotational woodlots in Tabora district, Tanzania. *Agriculture, Ecosystems and Environment*, *89*(3), 229-239. https://doi.org/10.1016/ S0167-8809(01)00165-7

Redmond, P. M. (1976). The NMCMU and tobacco production in Songea. *Tanzania Notes and Records*, *79*, 65-98. https://www.africabib.org/rec.php?RID=188760776

Reed, T. D., Johnson, C. S., Wilkinson, C. A., & Barts, S. (2019). 2019. *Flue-cured tobacco production guide*. http://hdl.handle.net/10919/92603

Ribeiro, N. S., Syampungani, S., Matakala, N. M., Nangoma, D., & Ribeiro-Barros, A. I. (2015). Miombo woodlands research towards the sustainable use of ecosystem services in Southern Africa. *Biodiversity in Ecosystems—Linking Structure and Function*, *7*, 12-30. https://doi.org/10.5772/59288

Rubhara, T. T., Mudhara, M., Oduniyi, O. S., & Antwi, M. A. (2020). Impacts of Cash Crop Production on Household Food Security for Smallholder Farmers: A Case of Shamva District, Zimbabwe. *Agriculture*, *10*(5), 188. https://doi.org/10.3390/agriculture 10050188

Sauer, J., & Abdallah, J. M. (2007). Forest diversity, tobacco production and resource management in Tanzania. *Forest Policy and Economics*, *9*(5), 421-439. https://doi. org/10.1016/j.forpol.2005.10.007

Sawe, T. C., Munishi, P. K., & Maliondo, S. M. (2014). *Woodlands degradation in the Southern Highlands*, Miombo of Tanzania: Implications on conservation and carbon stocks. 1-92. https://doi.org/10.5897/IJBC2013.0671

Scoones, I., Mavedzenge, B., Murimbarimba, F., & Sukume, C. (2018). Tobacco, contract farming, and agrarian change in Zimbabwe. *Journal of Agrarian Change*, *18*(1), 22-42. https://doi.org/10.1111/joac.12210

Scott, P. (2008). *Development of improved tobacco curing barn for small holder farmers in Southern Africa.* http://stoves.bioenergylists.org/scott_tobacco08

Sheya, M. S., & Mushi, S. J. (2000). The state of renewable energy harnessing in Tanzania. *Applied Energy*, *65*(1-4), 257-271. https://doi.org/2000:i:1-4:p:257-271

Shirima, D. D., Munishi, P. K., Lewis, S. L., Burgess, N. D., Marshall, A. R., Balmford, A., Swetnam, R. D., & Zahabu, E. M. (2011). Carbon storage, structure and composition of miombo woodlands in Tanzania's Eastern Arc Mountains. *African Journal of Ecology*, *49*(3), 332-342. https://doi.org/10.1111/j.1365-2028.2011.01269.x

Siddiqui, K., & Rajabu, H. (1996). Energy efficiency in current tobacco-curing practice in Tanzania and its consequences. *Energy*, *21*(2), 141-145. https://doi.org/10.1016/0360-5442(95)00090-9

Siddiqui, K. M. (2001). Analysis of a Malakisi barn used for tobacco curing in East and Southern Africa. *Energy Conversion and Management*, *42*(4), 483-490. https://doi.org/10.1016/S0196-8904(00)00066-2

Song, Z., Wei, F., Su, X., Wang, Y., Fan, Y., & Wang, J. A. (2020). Application of automatic control furnace for combustion of biomass briquette fuel for tobacco curing. *Thermal Science*, (00), 148-148. https://doi.org/10.2298/TSCI191115148S

Sumner, P. E., & Moore, J. M. (2009). Harvesting and curing flue-cured tobacco. *Coooperative Extension*, *16*, 1-6. https://athenaeum.libs.uga.edu/bitstream/handle/10724/12062/B884.pdf

Tang, Z., Chen, L., Chen, Z., Fu, Y., Sun, X., Wang, B., & Xia, T. (2020). Climatic factors determine the yield and quality of Honghe flue-cured tobacco. *Scientific Reports*, *10*(1), 1-12. https://doi.org/10.1038/s41598-020-76919-0

Temu, A. B. (1980). *Miombo woodland inventory design a response to fuel wood scarcity in Tabora, Tanzania, University of Dar es Salaam*, 1-120. http://41.86.178.5:8080/xmlui/handle/123456789/1903?show=full

TFS. (2019). *Forest_Ecosystems in theTransition to a green economy and the role of REDD*. https://www.tfs.go.tz/index.php/en/resources/category/publications-and-reports/P24

TORITA. (2006). T*he political economy of the Tanzanian science granting council. 2-39.* http://www.asti.cgiar.org/tanzania/directory/tobacco-research-institute-tanzania-torita

TORITA. (2009). *Review of food and agricultural policies in the United Republic 2-90.* https://www.torita.or.tz/uploads/publications/en-1595315352-Evaluation%20of %20Minjingu%20fertilizers%20in%20tobacco%20production,%20June%202019.pdf

TORITA. (2020). *Encouraging investment in agro-industries, 290.* https://www.torita.or.tz/uploads/ publications/en-1595314412-Determination%20of%20a%20siutable%20combination%20of%20farmyard%20manure%20and%20NPK%2010-18-24%20 in%20tobacco%20production.pdf

TTB. (2019). *Tanzania Tobacco Board, 23-84.* https://doi.org/https://www.tobaccoboard.go.tz/index.php/en/tobacco-exports

URT. (2017). *Tanzania Seasonal Rainfall Patterns, 1-53*. http://www.ipcinfo.org/fileadmin/user_upload/ipcinfo/docs/IPC_Tanzania_AFI_Situation_2018Feb.pdf

Van Liemt, G. (2001). *The world tobacco industry: Trends and Prospects. ILO, 125-198.* https://doi.org/993525813402676

Waluye, J. (1994). *Environmental impact of tobacco growing in Tabora/Urambo, Tanzania. Tobacco Control*, *3*(3), 1-252.https://europepmc.org/articles/PMC1759341

Wang, J. A., Zhang, Q., Wei, Y. W., Yang, G. H., & Wei, F. J. (2019). Integrated furnace for combustion/gasification of biomass fuel for tobacco curing. *Waste and Biomass Valorization*, *10*(7), 2037-2044. https://doi.org/10.1007/s12649-018-0205-1

Wei, S., Tan, F., Gao, Y., Wu, W., Li, H., Fang, M., & Song, Z. (2018). Drying kinetics of tobacco leaves based on Weibull function during stem drying stage and its color parameters. *Journal of Southern Agriculture*, *49*(2), 333-339. http://www.nfnyxb.com/EN/Default.aspx

Welter, C. A., Farias, J. A. D., Silva, D. A. D., Rech, R. D. S., Teixeira, D. D. S., & Pedrazzi, C. (2019). Consumption and Characterization of Forestry Biomass Used in Tobacco Cure Process. *Floresta e Ambiente*, *26*(SPE2). https://doi.org/10.1590/2179-8087.043818

WHO. (2013). WHO report on the global tobacco epidemic, 2013*: Enforcing bans on tobacco advertising, promotion and sponsorship*. World Health Organization.

WHO. (2017). *World Health Organization*. https://www.google.com/search?q=WHO+tobacco+production&oq=WHO+tobacco+production&aqs=chrome..69i57j0i390l5.32110j0j7&sourceid=chrome&ie=UTF-8

WHO. (2020). *World Health Organization. 1-9.* https://www.statista.com/statistics/192022/top-10-tobacco-producing-us-states/

Williams, M., Ryan, C., Rees, R., Sambane, E., Fernando, J., & Grace, J. (2008). Carbon sequestration and biodiversity of re-growing miombo woodlands in Mozambique. *Forest Ecology and Management*, *254*(2), 145-155. https://doi.org/10.1016/ j.foreco.2007.07.033

Winjum, J. K., Brown, S., & Schlamadinger, B. (1998). Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science*, *44*(2), 272-284. https://www.cabdirect.org/cabdirect/abstract/19980612532

Wu, S., Guo, Y., Joan, H. I., Tu, Y., Adil, M. F., Sehar, S., Zhao, D., & Shamsi, I. H. (2020). iTRAQ-based comparative proteomic analysis reveals high temperature accelerated leaf senescence of tobacco (Nicotiana tabacum L.) during flue-curing. *Genomics*, *112*(5), 3075-3088. https://doi.org/10.1016/j.ygeno.2020.05.019

Xiao, X., Li, C., Ya, P., He, J., He, Y., & Bi, X. T. (2015). Industrial experiments of biomass briquettes as fuels for bulk curing barns. *International Journal of Green Energy*, *12*(11), 1061-1065. https://doi.org/10.1080/15435075.2014.891119

Xinfeng, W., Guizhuan, X., Bailiang, Z., Youzhou, J., Haifeng, L., & Baoming, L. (2015). Application of tobacco stems briquetting in tobacco flue-curing in rural area of China. *International Journal of Agricultural and Biological Engineering*, *8*(6), 84-88. https://doi.org/10.1016/j.rser.2009. 06.025

Yuan, S., & Peng, S. (2017). Trends in the economic return on energy use and energy use efficiency in China's crop production. *Renewable and Sustainable Energy Reviews*, *70*, 836-844. https://doi.org/10.1016/j.rser.2016.11.264

Zhai, Z. J. (2011). *The Use of Biomass in High Efficiency Tobacco Curing for Small Holding Farmers in Bangladesh* [Architectural Engineering]. https://www.semanticscholar.org/paper/The-Use-of-Biomass-in-High-Efficiency-Tobacco-for-Zhai/fdc47ba2902700 c0 420fb9636f95ef64fa771837

Zhang, H., Jiang, X., & Chen, S. (2013). Intelligent tobacco curing control based on color recognition. *Research Journal of Applied Sciences, Engineering and Technology*, *5*(8), 2509-2513. https://doi.org/10.19026/rjaset.5.4688

Zhao, Z., Sakai, S., Wu, D., Chen, Z., Zhu, N., Gui, C., Zhang, M., Umemura, K., & Yong, Q. (2020). Investigation of synthesis mechanism, optimal hot-pressing conditions, and curing behavior of sucrose and ammonium dihydrogen phosphate adhesive. *Polymers*, *12*(1), 216. https://doi.org/10.3390/polym12010216

Zou, C., Hu, X., Huang, W., Zhao, G., Yang, X., Jin, Y., Gu, H., Yan, F., Li, Y., & Wu, Q. (2019). Different yellowing degrees and the industrial utilization of flue-cured tobacco leaves. *Scientia Agricola*, *76*(1), 1-9. https://doi.org/10.1590/1678-992x-2017-0157

APPENDICES

Appendix 1: Structured questionnaire

Background information

My name is Domitius Katatwile, a Master student at Nelson Mandela Institution of Science and Technology (NM-AIST). I am doing a research on **Assessment of the Impact of Tobacco Curing on Forest Woodland and Need for Alternative Curing Technologies**. All the information to be collected from this survey will be used for academic purposes and will be treated with privacy and confidentiality. Your response to this questionnaire will be greatly appreciated in this research.

Questionnaire No …….

Date ../../ 2020

I. Demographic Data

1. Sex: ☐Male ☐Female
2. Age : ☐ 18-30 ☐31-40 ☐41-50 ☐ 51-60 ☐60+
3. Education level attained: ☐Primary ☐Secondary ☐tertiary ☐ others
4. Marital status:
   ☐ Single, never married ☐ Married or domestic partnership ☐ Widowed
   ☐ Divorced ☐ Separated
5. What is your main source of income?
   ☐Formally employed ☐ Tobacco farming ☐ Both

Objective 1: To quantify and qualify cleared woodland area for tobacco curing in Urambo district

II. Tobacco production and Barn wood usage

6. Are you a registered tobacco farmer? …… if yes when did you venture into tobacco farming? ☐ 19 1991-2000 ☐ 2001-2010 ☐2011-2020
7. How many hectares do you devote toward tobacco cultivation?
   ☐≤ 3ha ☐ 3-7ha ☐ +8ha
8. What is the average yield per hectare?
   ☐ ≤ 500kg ☐600-800kg ☐900-1100kg ☐ 1200-1400kg
9. Which barn do you use to cure tobacco?
   ☐ Brazilian barn ☐Rocket barn ☐ Standard barn

10. What source of energy do you use for curing? ………….
11. If is wood, from where do you get it?

☐ Woodlot (plantation) ☐ Indigenous forest

12. Approximately how much fuel wood did you use to cure tobacco this season (kg per hectare)? How do you estimate?

…………………………………………………………………………………….

13. From which time do you start and finish curing (Time per hectare)? ....
14. Are you facing any problems during curing? If yes what are those?……………
15. Possible solutions do you thing can reduce those problems? ....

III. Sustainable Measures Employed to avert tobacco related deforestation

16. From the time you have been here, what is your comment about indigenous plant population within this area? Is it **Constant** or **Declined** or **Serious Declined**
17. Which tree species are most favourable to use as wood fuel?................................
18. What sustainable measure are you implementing as tobacco farmer to avert deforestation?........
19. What role is being played by statutory bodies such as TORITA, TTB, Environmental Management Agency and Forest Commission in sustainable use of forest?...
20. What do you think needs to be done so as to ensure sustainable tobacco production?.............................
21. What do you see as challenges to sustainable forest resource utilization in tobacco curing?..

Objective 2: To evaluate socio-economic benefit on adaptability of alternative tobacco curing technology

IV. Economic evaluation, benefit and adaptability

22. How much did you use to install the barn currently in use? …………………..
23. Do you buy wood fuel for tobacco curing? ....
24. If YES, what are the charge rates of the firewood per hectare (TSH)…………………
25. How much cost do you incur in all process of curing (TSH per hectare)?..
26. What is the selling price of your tobacco per kilogramme? ………………………….

22\. What is quantity of cured tobacco reach the recommended standards for one hectare?...

23. What are the challenges to attain the recommended standard? What should be done?..
24. When alternative curing technology is introduced, how do you think you will be affected?.......

RESEARCH OUTPUTS

Published paper

Katatwile, D., Marwa, J., Mtei, M. K. (2021). Effect of tobacco curing process toward environmental degradation in Urambo district. *Journal of Biodiversity and Environmental Science, 18*(1), 88-95. https://www.innspub.net/wp-content/uploads/2021/ 06/JBES-Vol-18-No-1-p-88-95.pdf

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RESEARCH PAPER OPEN ACCESS

Effect of tobacco curing process toward environmental degradation in Urambo district

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Abstract

This study assessed the effect of deforestation and atmospheric carbon dioxide accumulation caused by tobacco curing process in 2018/2019 season. The objective was achieved through structured questionnaire and close monitoring of Specific Fuel Consumption (SFC). Structured questionnaires were administered to 892 tobacco farmers from nine Primary Tobacco Farmer Cooperatives in Urambo district. Analysis of structured questionnaire was done using IBM SPSS version 21 using the descriptive statistics. In additional SFC data were employed to estimate annual woodland area cleared, carbon emission and carbon dioxide hindered from sequestration. The results showed that 94% of all tobacco farmers harvested wood fuel from forest wood land. This caused tobacco related deforestation of 6355.47 ha in 2018/2019 that hindered 63554.73 tons of atmospheric carbon dioxide from sequestration. Also, the emission of 33366.24 tons of carbon dioxide was recorded during the curing process. It is evident that increased tobacco production lead to increased demand for wood fuel which positively contribute to deforestation and increased atmospheric carbon dioxide.

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Introduction

Tobacco (*Nicotiana tabacum*. L.) is grown in 120 countries around the world of which Eighty percent (80%) of global tobacco production are majorly grown in ten countries: China, Brazil, India, United States of America, Malawi, Indonesia, Argentina, Pakistan, Zimbabwe and Tanzania Sacchetto (2012) while the remaining 20% is grown in the other 110 countries (FAOSTAT, 2017).

In Africa Tobacco is largely produced in Malawi, Zimbabwe, and Tanzania (FAOSTAT, 2017). In Tanzania, tobacco is mainly grown in Tabora, Iringa, Mbeya, Shinyanga and Rukwa regions (TTB, 2020). According to Tanzania Tobacco Board (TTB) in 2018/2019, Tabora region contributed 39% while Urambo district contributed to 11% of the total production within the country. Tanzania produces two types of tobacco: Flue Cured and Dark Flue Varieties. The Flue Cured Variety (FCV) is grown by 80% farmers while the Dark Flue Cured variety is estimated at 20% (Tanzania Tobacco Board, 2019).

Economically, tobacco production contributes towards: tax revenue, employment and income especially cash income that reduces household poverty and contribute to foreign exchanges (Chacha, 1996)). Globally, tobacco production is valued approximately US$20 billion (WHO Tobacco Atlas). In Tanzania, 98% of tobacco produced is exported contributing over $ 364 million per annum of foreign exchange (BoT, 2018). Furthermore, tobacco production contributes to 17% of agricultural Growth Domestic Product (GDP) (Friedrich, 2017). According to ILO, (2013) paid employment in tobacco manufacturing contributed to 4.3% of total labor force in Tanzania.

Despite the economic importance of tobacco, the environmental degradation issue remains a contentious issue in relation to production and curing of tobacco (T.-w. Hu & Lee, 2015). Since 1970s nearly 1.5 billion of hectares of forests have been cleared for tobacco production in the world causing 20% of carbon dioxide emission annually (WHO, 2017).

It is estimated that tobacco production contribute to 84 megatons carbon dioxide equivalent globally causing global warming (Hopkinson, Arnott, & Voulvoulis, 2019). In Tanzania studies have consistently shown that tobacco production contributes to severe deforestation (Sauer & Abdallah, 2007; Mangora, 2005; Yanda, 2010). Approximately, 16500 ha of forest woodland are cleared down annually in Tanzania due to tobacco curing alone contributing to 4% of total deforestation (Kagaruki, 2010).

Thus, considering the table 1 below from Food and Agriculture Organization Statistics (FAOSTAT) the information describes the past, present and the future of wood usage for curing by indicating the significant increase of tobacco farming and production and in terms of mass

Table 1 above illustrates increasing tobacco production trends in Tanzania from 1961 to 2017 whereby tobacco production increased from 2701 tons to 104471 tons. The rapid increase of tobacco production directly correlates to more wood fuel required for the curing process resulting to increase deforestation that directly relates to accumulation of atmospheric carbon dioxide. Various practices such as afforestation and reafforestation have been done to avert deforestation and carbon accumulation due to tobacco curing process (TORITA, 2020). For example, Association of Tanzania Tobacco Traders (ATTT) supported projects in Urambo district which initiated and implemented a "Tree Planting Policy" in 2001 in order to provide firewood that would be sufficient for tobacco curing (Katundu & Mwaseba, 2009). Also, Ugalla Community Conservation Project (UCCP) (funded by Africare) was introduced in Tabora with aim of reduce clearance of miombo woodlands (Danny de Vries, 2000). Despite implementation of tree planting promotion program, the response is very low since it requires commitment of tree planting and maturity of tree takes time and a quest for forest sustainability (Mangasini, 2007).

Similarly, different statutory organizations such as Tanzania Forest Reserve (TFS), Tobacco Research

Institute (TORITA) and Tanzania Tobacco Board (TTB) have implemented tree planting policies in protecting the forest woodland from tobacco related deforestation but with little success (Blomley & Iddi, 2009). Currently, improved barns have been developed to reduce deforestation and carbon emission (Musoni, Nazare, Manzungu, & Chekenya, 2013; Sauer & Abdallah, 2007; Tippayawong, Tantakitti, & Thavornun, 2004).These barns were reported of high energy efficiency compared to traditional barns as the result they reduce quantity wood fuel consumption per kilogram of cured tobacco leaves (Munanga, Mugabe, Kufazvinei, & Dimbi, 2017; Munanga, Mugabe, Kufazvinei, & Svotwa, 2014; Musoni *et al.*, 2013). High energy efficiency of improved barn was achieved through modification of structural elements traditional barns including sunken position of furnace to reduce heat loss by radiation and conduction, large conduit pipe and chimney to increase heat retention time (Munanga *et al.*, 2014). In Tanzania, improved barn were first introduced in 2006 and they include standard barn (SB), rocket barn version 2 (RB2) and rocket barn version three (RB3) (TORITA, 2020).

Tanzania Tobacco Board (TTB) report shows that almost 55% of improved barns are now adopted by tobacco farmers in Tanzania.

Table 1. Tobacco production trend in Tanzania from 1961 to 2017.

Range of years	Tobacco production trend (Tons)	Increase in% of Tobacco production	Types of barn used
1961-1970	2701-11971	77.44	
1971-1980	14154-16771	15.60	Traditional
1981-1990	17200-16459	-4.50	barns
1991-2000	23322-26384	11.61	
2001-2010	24522-60000	59.13	Improved barn
2011-2017	13000-104471	98.76	and traditional barn

Source: Faostat, 2017

In spite of this huge improvement, they are still powered by wood fuel and where increasing trend of tobacco production cause increase of wood fuel demand that contribute positively to environmental degradation such as deforestation and atmospheric carbon dioxide accumulation (B.-B. Hu *et al.*, 2020; Tippayawong *et al.*, 2004). (Kagaruki, 2010; Mangora, 2012) studies estimated tobacco curing related deforestation in Tanzania. However, they did not include improved barns and atmospheric carbon dioxide accumulation was not estimated. Therefore, this study was undertaken to assess the effect of tobacco curing process toward environmental degradation in Urambo district.

Material and methods

Study area

This study was conducted at Urambo district one of the largest producer of tobacco in Tabora region and Tanzania at large (Mangora, 2012; Waluye, 1994). The district is located in the western part of Tanzania covering an area of 21,199 km² at elevation ranging from 1,000m to 1,500m above sea level at coordinates of -5°04'0.01" S 32°02'60.00" E. It is bordered to the North by the Kaliua district, to the East by the Uyui district, to the Southeast by the Sikonge district and to the Southwest by the Katavi region as illustrated (Fig. 1). The climate by average is warm with daily mean temperature of 24°C, 68% humidity and over 1,000mm of rain annually.

This climate support production of different crop such as tobacco, maize, beans and vegetables. According to Tanzania Forest Service (TFS), there are two forest reserves in Urambo district known as North Ugara forest reserve and Uryankuru forest reserve. These forest reserves in Urambo district are dominated by miombo woodland (Mangora, 2012).

Total cured tobacco production is increasing every season (TTB, 2020). For example, in Urambo district tobacco production increased from 5669553.84kg in 2017/2018 to 7736919kg of cured tobacco in 2018/2019- season (TTB, 2020).

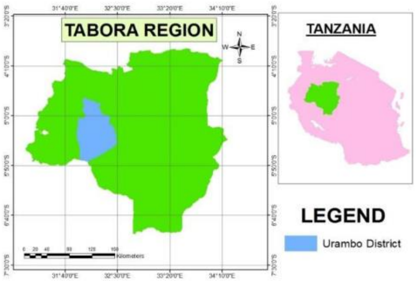

Fig. 1. Map of Tanzania, Tabora Region indicating the study area Urambo District.

Data collection

Household survey

Random selection was done to get 30% of all farmers in Urambo district as the sample survey representatives (Delice, 2010). This was achieved by randomly choosing three Tobacco Farmer Primary Cooperatives in each three-tobacco region. This resulted to 9 Tobacco Farmer Primary Cooperatives which are: Mirambo, Imalamakoye, Nsenda, Nsanjo, Kitete, Maendeleo, Katunguru, Ugala and ChapaJembe. The total number of respondents in this study was 892 tobacco farmers representing 30% of 2972 total tobacco farmers in Urambo district (Table 2). Prior information was sent to the villagers through their Tobacco Farmer Primary Cooperatives for preparedness.

Table 2. Study sample size.

Tobacco Farmer Primary Cooperatives	Number of respondents
Mirambo	105
Imalamakoye	104
Nsenda	96
Nsanjo	98
Kitete	97
Maendeleo	101
Katunguru	97
Ugala	98
ChapaJembe	96
Total number of respondents	892

Quantification of annual wood fuel consumed and area of forest wood land cleared in 2018/2019 season

Monitoring of four barn models were done to identify the exact Specific Fuel Consumption (SFC) in Tanzania. These barns included traditional barn, rocket barn (RB2 and RB3) and standard barn. Then, the average wood fuel to tobacco mass ratio was converted into total wood consumption per each barn by using formula (Eq 1) adopted from the study of Musoni *et al.* (2013). Thereafter, the quantities of wood fuel consumed for each barn were converted into area of forest woodland cleared in 2018/2019 using formula (Eq 2 and Eq 3) from Siddiqui and Rajabu (1996).

$$\text{Tobbaco Mass Ratio (SFC)} = \frac{mass\ of wood\ fuel(kg)}{mass\ of curedtobacco(kg)} ..(1)$$

$$Density\ of\ wood\ fuel = 500\frac{kg}{m3}..(2)$$

$$Iha\ of\ wood\ land\ in\ a\ year = 21m^3\ of\ wood\ fuel..(3)$$

Quantification of annual atmospheric carbon dioxide accumulation in 2018/2019-year season

Wood fuel used for tobacco curing process contains carbon content captured from atmosphere during photosynthesis process. Every one kilogram of dry wood fuel contain 50% carbon content (Huangfu *et al.*, 2014). Thus, using wood fuel during tobacco curing contribute to atmospheric carbon dioxide concentration in the atmosphere. This study used formula (Eq 4) developed by County (2012)to quantify the amount carbon dioxide that was emitted in 2018/2019-year season.

Moreover, massive clearance of forest wood land for tobacco curing hinders sequestration of carbon dioxide. This situation contributes to accumulation of atmospheric carbon dioxide in atmosphere. This study used formula (Eq 5) developed by Munishi, Mringi, Shirima, and Linda (2010)to calculate the amount of carbon dioxide hindered from sequestration.

$$1\ kg\ of\ wood\ fuel = 50\%\ of\ carbon \ldots(4)$$

$$Iha\ of\ miombo\ woodland = 19.2\ tons\ of\ carbon\ dioxide \ldots(5)$$

Data analysis

The data obtained from household survey were analyzed by using IBM Statistical Package for the Social Sciences (SPSS) program version 21 (IBM Corp 2013) using the descriptive statistics by means of frequencies and percentages. In addition, different formulas from equation 1 to equation 5 were used to quantify of annual area of wood land cleared and carbon dioxide accumulation in the atmosphere.

Results and discussion

Specific Fuel Consumption of tobacco barn models in Tanzania

The aim of monitoring average specific fuel consumption was to estimate deforestation and atmospheric carbon dioxide accumulation contributed by adopted tobacco barns models in Tanzania. According to Tobacco Research Institute in Tanzania (TORITA), there are four model of barn that includes: traditional barn, rocket barn version 2, rocket barn version 3 and standard barn. However, majority of tobacco farmers use traditional barn (TB) and rocket barn version 2 (RB2) compared to rocket barn (RB3) and standard barn (Fig. 2).

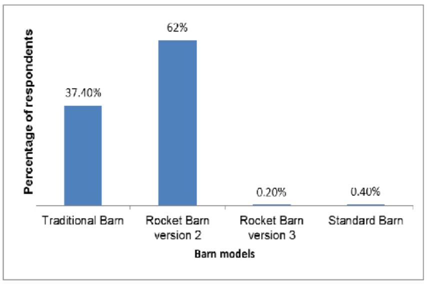

Fig. 2. Tobacco barn models adopted in Urambo district.

The results of table 3 above indicate the average wood fuel-tobacco mass ratio of four tobacco barns model. These were obtained from close monitoring of tobacco curing process done at Tobacco Research Institute in Tanzania (TORITA) in 2020.

According to table 3 above, traditional barn usage requires large quantity of wood fuel (10.5kg) to produce a kilogram of cured tobacco leaves compared to rocket barn version 3 (RB3) usages that require low quantities of fuel (4.6kg) to flue cure one kilogram of tobacco. This indicates that rocket barn version three (RB3) was more energy efficiency than the other three tobacco barns. However, this study used traditional barn and rocket barn (RB2) in estimation of deforestation and atmospheric carbon dioxide accumulation since they were the most used by Urambo tobacco farmers in 2018/2020-year season (Fig. 2).

Table 3. Average Specific Fuel Consumption of different barn model.

Type of barn	Mean Wood fuel (Kg)/Leaves of Tobacco cured (Kg)± SE
Traditional Barn	10.50±0.02a
Rocket Barn version 2	6.20±0.01b
Rocket Barn version 3	4.60±0.01d
Standard Barn	5.50±0.05c
One-way ANOVA (F-Statistics)	8267***

Annual wood fuel consumed and area of forest wood land cleared in 2018/2019 season

Forest woodland continues to be cleared since all tobacco farmers depend wholly in wood fuel to cure green tobacco leaf (TTB, 2020).

In Urambo district, about 7736919kg of cured tobacco were produced in 2018/2019 season in which 4363622kg of cured tobacco was produced by using traditional barn and 3373296.7kg of cured tobacco was produced by using rocket barn (RB2) (Table 4).

This study estimated that, 45818034kg and 20914439kg of wood fuel were consumed by traditional barn and rocket barn version 2 respectively. In Urambo district alone, an estimate of 66732474kg of wood fuel was consumed for tobacco curing process compared with 310859380kg of wood fuel consumed in all tobacco producing regions in Tanzania (Table 4).

This study noted that, 94% of all farmers get the wood fuel from the woodlands such as Uryankuru forest reserve, North Ugara forest reserves and other forest wood lands while only 6% harvest wood fuel from planted forest (woodlot).

This result are in agreement with other studies done in Tanzania (Mangora, 2012; Sauer & Abdallah, 2007) which revealed that, tobacco farmers rely heavily on the wood fuel for curing of tobacco which contribute to deforestation. This study estimated the area of forest woodland cleared in 2018/2019 season from quantity of wood fuel harvested for tobacco curing where in Urambo district about 4363.62 ha and 1991.85 ha of forest land was cleared using traditional and rocket barns respectively.

Table 4. Wood fuel consumed and area of forest woodland cleared during tobacco curing process in 2018/2019 season.

Tobacco region	a	b	c	d	e	F	g	h	i	j
Tabora	7400	9647220	5431385	4215835	57029541	26138178	114059	52276	5431	2489
Urambo	2972	7736919	4363622	3373297	45818034	20914439	91636	41829	4364	1992
Kaliua	4744	10139717	5009020	5100278	52594712	31621721	105189	63243	5009	3012
Sikonge	3000	6974440	1841252	5133188	19333148	31825765	38666	63652	1841	3031
Kahama	5096	11009480	1321138	9688342	13871945	60067723	27744	120135	1321	5721
Mpanda	7569	7144032	3600592	3543440	37806217	21969327	75612	43939	3601	2092
Iringa	19	277340	0	277340	0	1719508	0	3439	0	164
Chunya	6000	11923073	2348845	9574228	24662877	59360211	49326	118720	2349	5653
Kigoma	1909	4672918	971967	3700951	10205653	22945897	20411	45892	972	2185
Songea DFC	1912	1247769	0	1247769	0	7736168	0	15472	0	736.8
Total	40621	70772908	24841291	45931617	260833552	284776027	521667	569552	24841	27122

Source: Field survey data (2020)

a-Number of tobacco farmers in the region

b-Tobacco production (Kg) in the region

c-Amountof tobacco (Kg) cured using Traditional barns

d- Amount of tobacco (Kg) cured using Rocket barns version 2

e-Amount of wood (Kg) fuel consumed annually (10.5 x Mass of tobacco cured) using Traditional barns

f- Amount of wood (Kg) fuel consumed annually (6.2 x Mass of tobacco cured) using Rocket barns 2

g-Volume of wood fuel (m^3) consumed using Traditional barns (Mass (Kg)/500 (Kg/m^3))

h-Volume of wood fuel (m^3) consumed using Rocket barns 2 (Mass (Kg)/500 (Kg/m^3))

i- Area of woodland cleared annually (ha) when Traditional barns is used = volume of wood/21m^3

j-Area of woodland cleared annually (ha) when Rocket barns 2 is used = volume of wood/21m^3

Additionally, this study estimated that Tanzania lose a total of 24841.29 ha of wood land from using traditional barns and 27121.53 ha of woodland by using rocket barn version 2 (RB2). Urambo district alone lost about (2%) of the total woodland i.e. 6355.47 ha of woodland due to tobacco curing process while the whole country lost a total of about 295962.29 ha of woodland due to Tobacco curing process in Tanzania. Since 94% of wood fuel was harvested from natural woodland, Urambo district is estimated to lose 5974.14 ha of natural forest woodland and 381.32 ha of plantation (woodlot). Our results were as higher as compared to estimation done by Kagaruki (2010) who reported that Tanzania loses more than 16,500 ha of forests annually. This discrepancy might be due to increase of tobacco production from 60,000 tons in 2010 to 70,772,908 tons in 2018. The estimated area of forest woodland cleared due to tobacco curing may seem to be negligible when compared in national scale but the magnitude is higher in local scale. Tanzania Forest Service (2019) reported that, in Urambo district, the woodlands are likely to be totally cleared if the current trend of tobacco production continues. Majority of tobacco farmers proposed of alternative technologies to replace the wood fuel for tobacco production sustainability and forest conservation.

Carbon emitted annually and carbon dioxide hindered from sequestration

Tobacco curing process is one of contributor of carbon dioxide accumulation into the atmosphere. This occurs when wood fuel is used as the source of energy during tobacco leaf drying stages and when clearing forest woodland (deforestation) (B.-B. Hu *et al.*, 2020; Tippayawong *et al.*, 2004; Yan, Ohara, & Akimoto, 2006).This study estimated the amount of carbon emitted annually and carbon dioxide hindered from sequestration in 2018/2019 season. In Urambo district, about 22909.02 tons of carbon was emitted when traditional barns and 10457.22 tons of carbon when rocket barns were used during tobacco curing process. The total amount of carbon emitted from tobacco curing process in Urambo district was 3066.24 tons. This was far less than reports that revealed 4356 million m³ of CO_2 is produced in a given season from tobacco curing process alone (Siddiqui & Rajabu, 1996).

Furthermore, forest woodland trap atmospheric carbon dioxide, but the moment they are cleared down, carbon dioxide in that area can no longer be absorbed as it was before (Abrams & Rue, 1988). This study estimated about 4363.62 ha of forest woodland was cleared for wood fuel when using traditional barn (TB) which could cause hindrances of 83781.5 tons of carbon dioxide. Comparably, rocket barn version 2 (RB2) usages contributed about 1991.85 ha of woodland clearances for wood fuel during tobacco curing which might hinder approximately 38243.5 tons of carbon dioxide. The total amount 6355.47 ha of forest wood land was cleared for tobacco curing in Urambo district which was to absorb 63554.73 tons of carbon dioxide from atmosphere in 2018/2019 year. Carbon emitted from tobacco curing process combine with oxygen to produce atmospheric carbon dioxide. Atmospheric carbon dioxide absorbs the long wavelength radiation that lead to global warming when they are emitted. There is lack of information on how tobacco curing process contributes to atmospheric carbon accumulation in local settings. Many studies have been estimating tobacco related deforestation worldwide for example Intergovernmental Panel on Climate Change (IPCC) in 2007 estimated that 17% of carbon dioxide was emitted from tobacco related deforestation.

Conclusion

This study assessed the effects of tobacco curing process towards environmental degradation in Urambo district. The study findings showed that use of wood fuel for tobacco curing is a long-term threat to environment through deforestation and global warming. This study concludes, current tobacco production trends relate to increase of wood fuel demand which quest for tobacco production sustainability and environmental conservation. Majority of tobacco farmers harvest wood fuel from indigenous forest rather than plantation (woodlot) which indicate that indigenous forest such Uryankuru and North Ugara forest reserve are at risk of deforestation. On bases of these study findings, it is recommended that clean, safe and affordable development of alternative curing technologies is required. This will reduce the pressure on wood resources and increase tobacco production sustainability.

Acknowledgment

The authors are grateful to the Tanzania Commission for Science and Technology project (COSTECH) number FA.403/489/55/4 and the African Development Bank (AfDB) for financing this study. We thank all tobacco stakeholders in Urambo district including Tanzania Tobacco Board (TTB), Tobacco Research Institute in Tanzania (TORITA), Tanzania Forest Service (TFS), Milambo Cooperative Union, Agricultural Research Institute (TARI) –Tumbi center and various tobacco companies. We acknowledge the willingness of the tobacco farmers to be involved in the study by responding to our questions and allowing us to visit their farms.

Reference

Abrams EM, Rue DJ. 1988. The causes and consequences of deforestation among the prehistoric Maya. Human ecology **16(4),** 377-395.

Blomley T, Iddi S. 2009. Participatory forest management in Tanzania: 1993-2009: Lessons learned and experiences to date: URT: Ministry of Natural Resources and Tourism, Forestry and Beekeeping.

Chacha B. 1996. Killing Trees to Cure Tobacco: Tobacco and Environmental Change in Kuria District, Kenya 1969-1999.

County B. 2012. How to calculate the amount of CO2 sequestered in a tree per year: Obtenido de https://www. broward. org/ Natural Resources/ Climate Change.

Danny de Vries M. 2000. Africare's Ugalla Community Conservation Project (UCCP)-Tabora: History, observations and analysis of the natural resource baseline.

Delice A. 2010. The Sampling Issues in Quantitative Research. *Educational Sciences:* Theory and Practice **10(4),** 2001-2018.

Hopkinson NS, Arnott D, Voulvoulis N. 2019. Environmental consequences of tobacco production and consumption (vol **394,** pg 1007, 2019).

Hu B-B, Lin Z-L, Chen Y, Zhao G-K, Su J-E, Ou Y-J, Zou C-M. 2020. Evaluation of biomass briquettes from agricultural waste on industrial application of flue-curing of tobacco. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects 1-12.

Hu T-w, Lee AH. 2015. Commentary: tobacco control and tobacco farming in African countries. Journal of public health policy **36(1),** 41-51.

Huangfu Y, Li H, Chen X, Xue C, Chen C, Liu G. 2014. Effects of moisture content in fuel on thermal performance and emission of biomass semi-gasified cookstove. Energy for Sustainable Development **21,** 60-65.

Kagaruki LK. 2010. Community-based advocacy opportunities for tobacco control: experience from Tanzania. Global Health Promotion, 17(2_suppl), 41-44.

Katundu M, Mwaseba D. 2009. The Role of Co-Operative Organizations in Implementing Reforestation Programs: The Case of Tanzania Tobacco Traders" Reforestation Program in Urambo District. Journal of Co-operative and Business Studies, Tanzania. Journal of cooperative business studies (JCPS) Vol **1.**

Mangasini A. 2007. Evaluation of the association of Tanzania tobacco traders' reforestation programme: the case of Urambo District. Sokoine University of Agriculture (SUA).

Mangora MM. 2012. Shifting Cultivation, Wood Use and Deforestation Attributes of Tobacco Farming in Urambo District, Tanzania.

Munanga W, Mugabe F, Kufazvinei C, Dimbi S. 2017. Development of a low cost and energy efficient tobacco curing barn in Zimbabwe. African Journal of Agricultural Research **12(35),** 2704-2712.

Munanga W, Mugabe F, Kufazvinei C, Svotwa E. 2014. Evaluation of the curing efficiency of the rocket barn in Zimbabwe. Int J Agric Innovations Res **3(2),** 436-441.

Munishi P, Mringi S, Shirima D, Linda S. 2010. The role of the Miombo Woodlands of the Southern Highlands of Tanzania as carbon sinks.

Musoni S, Nazare R, Manzungu E, Chekenya B. 2013. Redesign of commonly used tobacco curing barns in Zimbabwe for increased energy efficiency. International Journal of Engineering Science and Technology **5(3),** 609.

Sacchetto C. 2012. The impact of tobacco-growing on deforestation: Assessment of the situation based on independent publicly available information: Rome: UNITAB and FETRATAB.

Sauer J, Abdallah JM. 2007. Forest diversity, tobacco production and resource management in Tanzania. Forest Policy and Economics **9(5),** 421-439.

Siddiqui K, Rajabu H. 1996. Energy efficiency in current tobacco-curing practice in Tanzania and its consequences. Energy **21(2),** 141-145.

Tippayawong N, Tantakitti C, Thavornun S. 2004. Energy and emission based performance of an experimental tobacco bulk-curing barn. Chiang Mai Univ. J **3(1),** 43-52.

Waluye J. 1994. Environmental impact of tobacco growing in Tabora/Urambo, Tanzania. Tobacco Control **3(3),** 252.

Yan X, Ohara T, Akimoto H. 2006. Bottom-up estimate of biomass burning in mainland China. Atmospheric Environment **40(27),** 5262-5273.

Poster presentation

Effect of tobacco curing process toward environmental degradation in Urambo district

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1. Introduction

- Despite the efforts that have been employed to reduce tobacco curing related deforestation in many countries including Tanzania.
- The economic importance of tobacco production on employment creation and foreign exchange makes production continue to increase which increases the demand for wood fuel that results in deforestation.
- Solar energy is considered as the most abundant among renewable energy sources with high-potential to address the challenges arising from environmentally problematic energy sources such as fossil fuels.

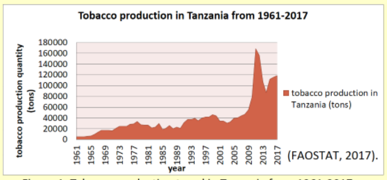

Figure 1: Tobacco production trend in Tanzania from 1961-2017

2. Materials and Methods

- This study was conducted in Urambo district shown in (Fig. 2). From an economic point of view, tobacco crop is the most important commercial crop in this district.
- This is because of high financial benefits to tobacco farmers and source of district income. Also, major Tobacco Companies such as Japan Tobacco International, Alliance One and Grand and Magefa tobacco companies are located in the Urambo district which guarantees buying of cured tobacco leaves at the highest price.

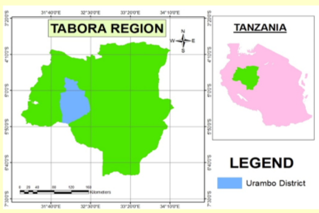

Figure 2: Map of Tanzania, Tabora Region indicating the study area in Urambo District

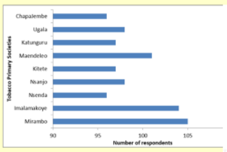

Figure 3: Study sample size

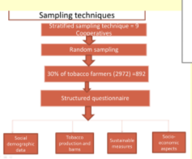

Figure 4: sampling techniques

- **Activity 1**: Monitoring of wood tobacco consumption ratio of each tobacco barn model.

$$SFC = \frac{Mass\ of\ fuel\ (kg)}{Mass\ of\ cured\ tobacco\ (kg)} \ldots\ldots\ldots\ldots\ldots Eq1$$

(Musoni *et al.*, 2013).

$$1ha\ of\ protected\ woodland\ forest\ =\ 21m^3\ of\ \frac{wood}{year}\ \ldots\ldots Eq2$$

(Musoni *et al.*, 2013).

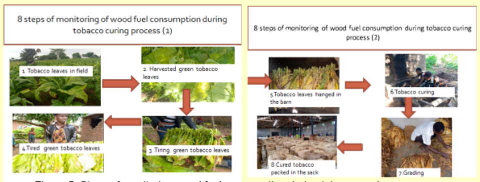

Figure 5: Steps of monitoring wood fuel consumption during tobacco curing process

- **Activity 3:** Determining the weight of CO_2 emission during tobacco curing process.

$$Carbon\ dioxide\ emitted\ = mass\ of\ wood\ fuel \times 50\%. Eq3$$

(County, 2012).

- **Activity 4:** Determining amount CO_2 hindered from sequestration.
- $$1ha\ of\ woodland\ forest\ = 19.2 tons\ of\ CO_2 \ldots\ldots\ldots. Eq4$$

(Munishi *et al.*, 2010).

3. Results

- The results show that **94%** of all tobacco farmers have been harvesting wood fuel from forest woodland. This caused tobacco related-deforestation of **6355.47** ha in 2018/2019 that hindered **63554.73** tons of atmospheric carbon dioxide from sequestration.
- Also, the emission of **33366.24** tons of carbon dioxide was recorded during the curing process.

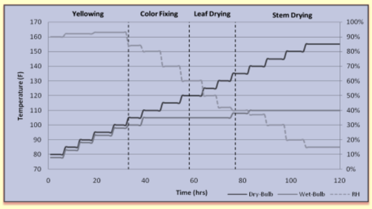

Figure 6: Tobacco curing process

Table 1: Average Specific Fuel Consumption of different barn mode

Type of barn model	SFC
Traditional Barn	10.50±0.02a
Rocket Barn version 2	6.20±0.01b
Rocket Barn version 3	4.60±0.01d
Standard Barn	5.50±0.05c
One-way ANOVA (F-Statistics)	**8267*****

Source: Field survey data, (2020).

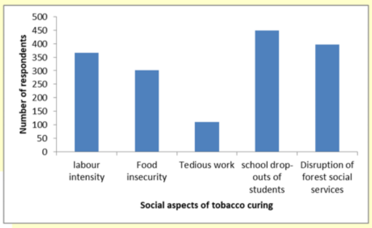

Figure 7: Social aspects of tobacco curing

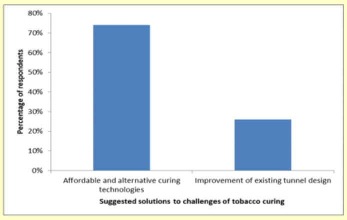

Figure 8: Suggested solutions to challenges of tobacco curing

Economic assessment of tobacco curing

Table 2: The cost, revenue and net benefit of each tobacco barn model in 2018/2019

1	2	3	4	5	6	7	8	9	10	11
Traditional barn (TB) *1000	50	100	400	540	120	65	50	1,325	2275	930
Rocket barn (RB2) *1000	50	100	400	600	60	65	55	1,330	2275	950
Rocket barn (RB3) *1000	50	100	400	820	45	65	70	1,550	2275	710
Standard barn (SB) *1000	50	100	400	750	50	65	75	1,490	2275	785

Source: Field survey data, (2020).

Note: 1-Type of barn model, 2-Land preparation cost, 3-Seed cost, 4-Fertilizer and pesticide cost, 5-Installation cost, 6-Wood fuel cost, 7-Grading cost, 8-Maintenance cost, 9-Total cost, 10-Total revenue, 11-Net benefit

4. Conclusion

- The present study indicates that tobacco is a cash crop of economic importance in the Urambo district. The tobacco crop requires wood fuel for curing tobacco leaf; about 95% of the farmers outsource wood fuel from the forest reserve and only a few (5%) from planted woodlots.
- Most of the Urambo district farmers are using rocket barn version 2 (RB2) and traditional barn (TB). These barns observed to consume much significantly wood fuel 6.20 and 10.50 kg of wood fuel to cure a kilogram of tobacco than rocket barn version 3 (RB3) and standard barn (SB), which consumed 4.60 and 5.50 kg of wood fuel to cure a kilogram of tobacco leaf.
- In the 2018/19 crop season about, 5974.14 and 381.32 ha of forest reserve and woodlots plantations are estimated to be cleared for curing tobacco, respectively, in the Urambo district and hindered 63554.73 tons of atmospheric carbon dioxide from sequestration. During the curing time of tobacco leaf, the study estimated 33366.24 tons of carbon dioxide released into the atmosphere to cause global warming.
- The study further assessed the social aspects associated with all stages of tobacco production which explored tobacco as labor-intensive, disruption of forest services, student drop-out from school, tedious work, time consuming crop, and leave little time for other food crops and food insecurity. Social aspects observed the tobacco farmers to spend more time on tobacco production, which later exacerbated the illiteracy and poverty as children were mostly used in farming operations.
- Following the impacts of tobacco curing using wood fuel on the environment, the current study proposed developing alternative sources of energy to replace wood fuel usage; hence, reduce deforestation and carbon dioxide accumulation in the atmosphere.

5. Recommendations

- For the conservation of forest woodland, this study suggests developing alternative curing technologies to replace wood fuel. Thus, it will speed up the conservation of woodland forest and reduce global warming.
- The current research has pinpointed the impact of growing tobacco on deforestation and the accumulation of carbon dioxide in the atmosphere following curing tobacco using wood fuel. Therefore, further studies are recommended to study the tobacco production's impacts impact on the agrochemicals use to its residuals in soils.
- The majority of the tobacco farmers are subjected to high risk on their health following using agrochemicals in fields and exposure to the heat during the curing tobacco, but do not have protective gears. Therefore, the current study recommends that personal protective equipment's (PPE) be given to farmers as package with agrochemicals and instructing farmers on how to use the PPE.

6. Funding

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7. References

Blomley, T., & Iddi, S. (2009). Participatory forest management in Tanzania: 1993-2009: Lessons learned and experiences to date.
Chirindo, N. C., et al. (2017). Development of an efficient low cost emergency tobacco curing barn for small scale tobacco growers in zimbabwe. Journal of Basic and Applied Research International, 244-256.
Wang, J. A., et al. (2019). Integrated furnace for combustion/gasification of biomass fuel for tobacco curing. Waste and Biomass Valorization, 10(7), 2037-2044.
Yuan, S., & Peng, S. (2017). Trends in the economic return on energy use and energy use efficiency in China's crop production. Renewable and Sustainable Energy Reviews, 70, 836-844.

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