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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).

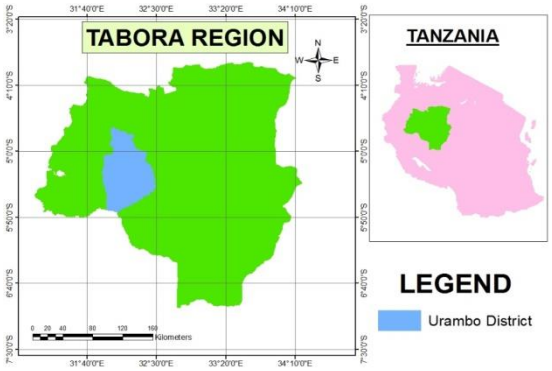

Fig. 1. Map of Tanzania, Tabora Region indicating the study area Urambo District.

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).

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

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

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

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).

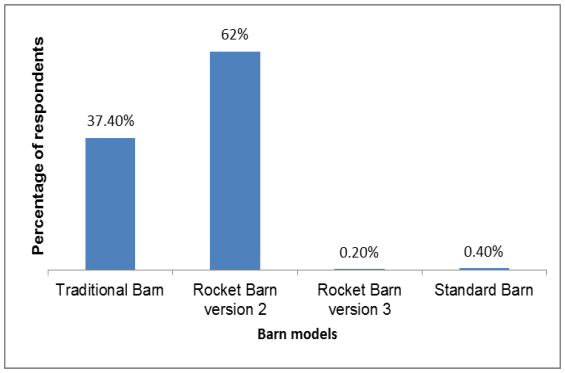

Fig. 2. Tobacco barn models adopted in Urambo district.

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 m^3 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.

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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.