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Contribution of Improved Charcoal Kilns to the Households Income in developing countries: The case of Kilindi District, Tanzania

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ABSTRACT

About ninety percent of the country's energy needs are satisfied through charcoal and firewood. This study was conducted to assess the contribution of improved charcoal kilns to the household income in Kilindi District, Tanzania. Simple random sampling was applied to select two wards from 21 wards, and one village from each ward. A total of 200 charcoal producers were randomly selected. The data collection tools were questionnaires and focus group discussion. The profit analysis was conducted using gross margins technique. The student t-test statistics was conducted to determine if there was statistically significant difference between the two values (improved and traditional kilns). The findings show that charcoal production activities contributed 82% of the total household income. The gross margin from using improved kilns was 52% while using traditional kilns was 26%. The *t*-test show that the difference in gross margin was statistically significant at p-value of 0.02 inferring that charcoal producers who used improved kilns in the study area generated more income than those who used traditional kilns. The study recommends that local governments should sensitise communities on advantages of using of improved charcoal kilns since it has shown a positive impact on the household income and reduces forest degradation.

Key words: charcoal production – forest - gross margin - household income – kilns.

INTRODUCTION

Charcoal production and other relating activities are expanding in scope and magnitude in many tropical catchments especially in Sub-Saharan African countries (Oguntunde *et al*. 2004, Glaser *et al*. 2002). Charcoal is one among the most important energy source in Tanzania (World Bank 2009). In 2017, 90% of the country's energy needs in Tanzania were satisfied either by charcoal (21%) or firewood (69%) as their main source of energy for cooking (URT 2019). The majority of the energy consumption (84% in 2002, 97% in 2017) comes from biofuels and waste (International Energy Agency, 2019). Charcoal consumption per day is approximately 2,650 metric tons which is equivalent to 1 million tons per year or approximately 1 m^3 of round wood per capita per year. The value of the entire charcoal sector in the country is approximately USD one billion (NBES 2014). The annual supply of wood needed for charcoal production is around 30 million cubic metres. In charcoal production it is estimated 160 000 earth kilns are used every year which is equivalent to 438 per day (Zulu and Richardson 2012).

From 2001 to 2010 charcoal used for cooking increased by 7% while in urban centres figure is higher than average (MNRT 2013). According to Word Bank (2009) demand for charcoal is expected to increase even further because of increase of population of about 3% per year, the rising of urban population and relatively high perceived price of alternatives source of energy (MNRT 2013).

The energy policies of many countries in Africa have been focusing on achieving the energy transition from biomass to electricity and fossil fuels, but it has not resulted in a transition away from biomass (Doggart et al. 2020). Many models have predicted decline in the relative importance of biomass consumption, but given the population increase and urbanization, charcoal is still gaining its relative importance while use of firewood is declining. Many households use multiple fuels where charcoal remains the cheapest (excluding firewood) and most widely used (Doggart and Sallu 2020). This implies charcoal production activities will continue to be profitable business for those who are involved. There is good evidence that involvement in the charcoal trade can generate substantial incomes for participants (Khundi *et al*. 2011, Minten *et al*. 2013). Despite of the growing urban charcoal demand and markets provides opportunities for income generation from production of charcoal in rural areas where it is often commercialized resources and thousands of rural and urban entrepreneurs earn vital income from charcoal production and trade, (Zulu and Richardson, 2012). Malimbwi and Zahabu (2007) claim that there is limited number of people who consider charcoal production to be their main economic activity and profits are used to be concentrated to few mainly transport agent and whole sellers while charcoal producers used to receive very small benefits among all player in the charcoal value chain. The authors besides, argue that small benefit earned among other factors is contributed by the use of highly inefficient use of traditional kilns with conversion efficiency of only 8% to 12%. Despite of the low efficiency rates most of producers use since these kilns presents practical, low investment options for poor producers.

Improved kilns have a potential of significantly contribution to efficient production and income to producers (Zulu and Richardson 2012). Despite this proven fact, most of charcoal producers in Tanzania still use traditional kilns in charcoal making with conversion efficiency of less than 20% which lose about 60 to 80% of the wood's energy (Neufeldt *et al*. 2015). Besides, advantages of improved kilns in environment and income their use have failed due to lack of capital for kiln construction, lack of awareness of their advantages and small producers find them to be incontinent since they are stationary while traditional kilns can be easily built from place to place where inputs are available (Zulu and Richardson, 2012).

According to Malimbwi and Zahabu (2007) there is no incentives for charcoal producers to adopt to efficient production technologies because of combination of reason including market failure, unrealistic fees and royalties, behaviour towards open access resources, and ignorance on advantages in terms of income and long-term effects on environment sustainability. Inefficient charcoal kilns make producers to use more wood to produce a unit of output due to a significant loss during the process. As a result, production using inefficient kilns not only causes depletion of wood resources, also charcoal producers loose significant portion of output which could result into higher profit if the loss is controlled. Also due to inefficiencies the radius of the area where materials are collected is increasing and therefore increases to transport cost due to distance which further squeezes the profit and therefore income (MNRT 2001).

Therefore, the objective of this paper is to explore the contribution of improved kilns to the households' incomes of those that are involved in charcoal production. The findings will show how much improved kilns are advantageous in terms of income generation when compared to traditional kilns. The findings shall be useful in convincing the producers in the study area and the entire country to adopt the improved charcoal kiln technology.

METHODOLOGY

The Study Area

The study was conducted in Kilindi district in Tanga region. The district is situated between 5.015^0 South and 6.005^0 South and longitude 37.05^0 East and 38.05^0 East. It has a total area of approximately 6443.52 km^2 with 21 wards and 102 villages. The district has a population of 236,833 with density of 37 per km^2 (National

Census 2012) The altitude of this area ranges from 1000m-2400m above the sea level. As Figure 1 shows, in the east the district is boarded by Handeni district, to the south-east by Bagamoyo, to the west by Mvomero and Gairo, to the north Kilindi is boarded by Simanjiro and Kiteto to the north-west. The climate ranges from hot and humid in dry plains to temperate in the mountains. The annual rainfall ranges between 500mm-800mm, the long rains are from February to May; and short rains from August to November (Hamilton 1989). The temperatures of the area range from 21^0C to 24^0C. Kilindi District is rich in indigenous and exotic tree species. It is characterized and dominated by woody plants, herbs, grasses and Miombo woodland respectively.

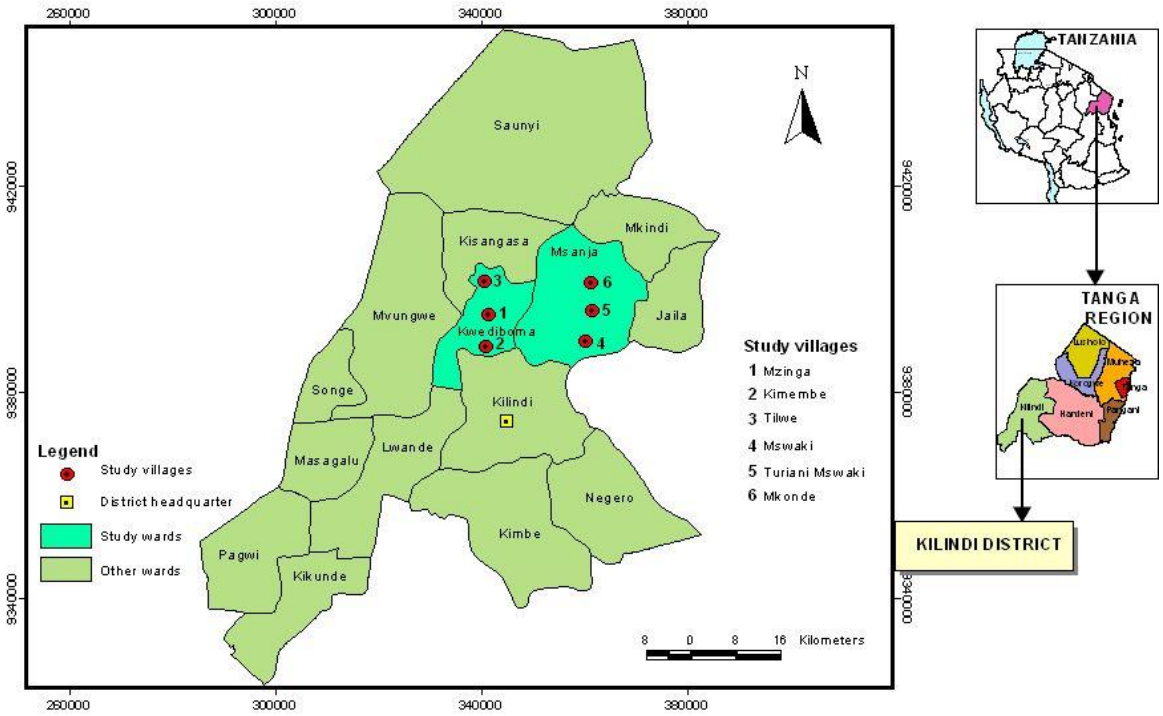

Figure 1: A map of the study area

Sample Size and Sampling Procedures

The cross-sectional design was used for this study because of its suitability. This design allows data collection at a single point of time from a large population therefore it is economic and flexible. The sample frame included charcoal producers in Kilindi district. Simple random sampling was applied to select two wards of Msanja and Kwediboma from the list of 21 wards. One village was then selected from each ward randomly from the. A total of 200 charcoal producers (both the users of improved and traditional kiln) were randomly selected for interview. The main data collection tools included questionnaire and focus group discussion.

Data Analysis

The descriptive analyses were used to analyse the general socio-economic data. For the contribution of improved charcoal kilns to the household income gross margins technique were used to compute the ratios i.e., gross profit that involved only the total revenue after removing the variable costs, against total collected revenue as to see how profitable was the business and to what extent was this compared between two types of the kiln used by producers. The gross margin of charcoal producers used improved kilns and traditional kiln was calculated separately and later compared to see if there is any statistical difference and then to find by how much the producers retains as profit from selling charcoal. The gross margin was

calculated by subtracting all the cost from the total revenue generated by the producer in their respective kilns. The formula that used for gross margin is shown in equation below.

$$G.M_k = \sum_i^j \left[\left(\frac{TR_{ik}-TC_{ik}}{TR_{ik}}\right)\right] x100 \qquad (1)$$

Where:

GM = Gross Margin,
TR = Total Revenue,
TC = Total Cost,
n = Number of producers,
i= ith charcoal producer,
k = 1 and 2, (where 1= Traditional Kiln and 2= Improved Kiln).

In computing gross margin, the charcoal total cost was computed by including all components of costs which were involved in production of charcoal per kiln. According to a study by Mndeme (2008) charcoal production cost involves equipment's such as axe, hoe, rake, spade and machete costs, and production costs such as tree cutting, log processing, logs collection, logs transportation, kiln preparations, kiln supervision, unloading and packing the charcoal. The total revenue was calculated by getting total sells of bags from each kiln which is computed by taking number of total charcoal bags produced multiplying by its respective price. After computing the gross margins of both improved kilns and traditional kilns, the comparison using student t-test statistics was conducted to determine if there is statistically significant difference between the two values.

RESULTS AND DISCUSSION

Charcoal Producers Socio-Economic Characteristics

Charcoal producers' characteristics by kiln type

Table 1 presents characteristics of charcoal producer categorised by the kiln type used in charcoal production. Majority (60.5%) of all charcoal producers used traditional kilns. The value of chi-square test of P=.050 shows existence of statistically significant difference between charcoal producer's experience in charcoal production and type of the kiln employed in producing charcoal. Also, the value of chi-square test of P=0.000 shows existence of statistically significant difference between training on charcoal production and type of the kiln employed in producing charcoal. Majority of charcoal producers who used traditional kilns and improved kilns had primary school education.

Table 1: Charcoal producers characteristics by type of kiln used in percentage

Variables	Traditional Kilns	Improved Kilns	N	$\chi 2$-test
Age				0.054
Less than 35 years	30.5	15	45.5	
35 years and above	30	24.5	54.5	
Sex				0.068
Female	22	10	32	
Male	38.5	29.5	68	
Marital Status				0.154
Single	9	8.5	17.5	
Married	51.5	31	82.5	
Education Level				0.988
No school	6.5	4.5	11	
Primary	48	31	79	
Secondary and above	6	4	10	
Experience in charcoal production				0.050*
Less than a year	5	2	7	*
1 to 5 years	46	23.5	69.5	

Variables	Traditional Kilns	Improved Kilns	N	χ^2-test
Above 5 years	9.5	14	23.5	
Training				0.000*
Charcoal producer did not receive	37	4.5	41.5	**
Charcoal producer received	23.5	35	58.5	
Total	60.5	39.5	100	

Kiln types and extent of use in the study area

In the study area as can be seen in Figure 2 about 60% of charcoal producers reported to use traditional kilns while 40% reported to improved kilns. This implies that in the area still a large number of people are using traditional kilns which are associated less efficiency and lower yields (BTG, 2010); and fewer producers uses improved kilns despite economic benefits that associate with them including less defiled charcoal and improved carbonisation which increase yield which translates to increased profit (Dobie *et al.*, 2015).This finding is similar to other studies such as Monela *et al.* (1999) and Chidumayo and Gumbo (2013) where in many places in a country producers uses traditional inefficient kilns with conversion rate ranging from 8 to 20 percent.

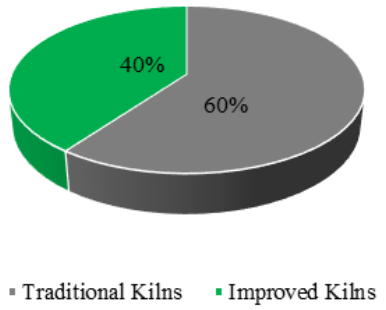

Figure 2: Charcoal kilns in the study area

Kiln shape

The main type of the kiln used in the study area is rectangular shape which is used with 95% producers while few about 2% and 3% uses pyramid and bottle shaped kilns as shown in Figure 3. These findings are similar to that of Monela *et al.* (1999) where similar proportions were found. Regardless the shape traditional kilns used to be earth mould and made by covering billets with earth followed by carbonization process under limited air supply while improved kilns in addition used to have wire mesh or metal sheet to reduce contamination of charcoal and chimney to enhance control of the carbonization process.

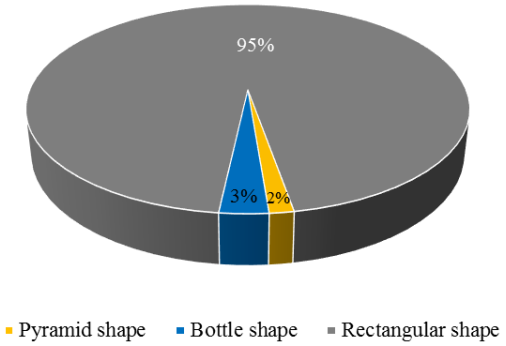

Figure 3: Kiln shapes

Kiln Volume

Volume of kilns as can be seen in Figure 4 are divided in three categories of large volume ranging from 50m^3 and above, medium volume ranging from 10m^3 to less than 50m^3 and small volume which is less than 10m^3. In the study area 29% of improved kilns and 56% of traditional kilns are of large volume; 33% of improved kilns and 24% of traditional kilns are of medium volume while 33% of improved kilns and 20% of traditional kilns are of small volume. According to KFS (2014) large volume used to involve high requirement of wood and transportation cost and when managed properly returns used to be high as well.

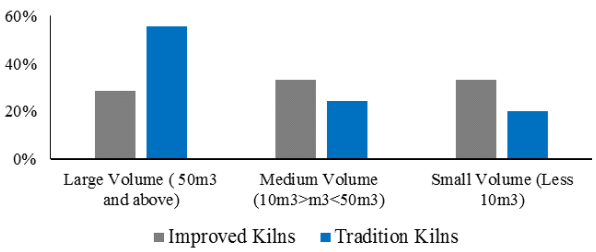

Figure 4: Kiln Volume

Tree types

As can be seen in Figure 5 there are various tree types used by charcoal producers in the study area. Approximately 29% of the producers in the study area use *Combretum molle*; according to Adeniji *et al.* (2015) apart from looking on factors such as availability, producers used to select these trees basing on the hardness of the wood where hardwoods used to give higher yield than softwood and charcoal produced from hardwoods used to be non-bristling which translates to higher profits.

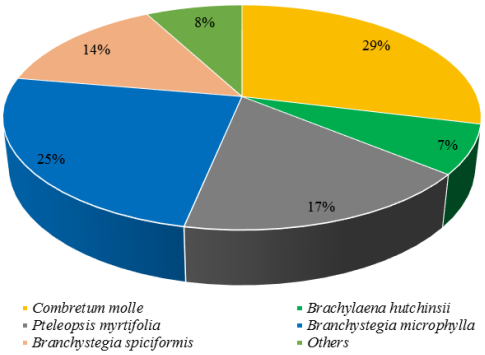

Figure 5: Type of trees used by charcoal producers

Contribution of Improved Charcoal Kilns to the Household Income

In the study area there were mainly five common sources of income to a household including income from charcoal production, income from own farm, income from wage labour, income from livestock and self-employment as shown in Figure 6. Charcoal production activities contributes about 82% of the total household income followed by income from own farm activity which contributes about 16%. Other economic activities including income from wage labour, income from livestock and income from self-employment contributes only 1% of the total household income. As can be seen from Figure 6 income from charcoal production contributes a large portion of the total household income.

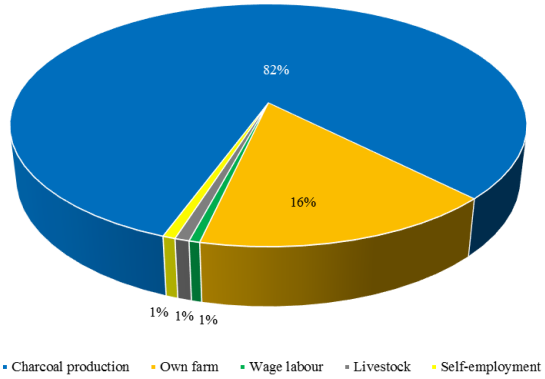

Figure 6: Income contribution from various household economic activities

In determining by how much actually the charcoal producer profits between each kiln type in the study area Table 3 presents results of gross margin analysis which was performed for producers who used improved kilns and producers who used traditional kilns separately followed by statistical comparison using *t*-test.

Table 3 show that average revenue from charcoal producers who used improved kilns is about 1.35 million TZS per kiln while average cost incurred during the process is around 450 000 TZS per kiln. The gross margin from using improved kilns in the study area is 52% implying that for each 10,000 TZS sells charcoal producer retains 5,200 TZS as a profit.

Similarly, for charcoal producers who used traditional kilns average revenue was approximately 730,000 TZS while the average cost was around 385,000 TZS. The gross margin from using traditional kilns in the area is 26% implying that for each 10,000 TZS sells charcoal producers retains 2,600 as profit.

According to t-test this difference in gross margin is statistically significant at p-value of 0.02 inferring that charcoal producers who used improved kilns in the study area generates more income from charcoal production compared to those who used traditional kilns. These finding concurs to several studies including that of Dobie *et al.* (2015), Liyama *et al.* (2014) and Kaale (2007in which traditional kilns are often inefficient with efficiency of only 9 to 15%

suggesting there is a biomass loss of 85 to 91% during the process; while improved kilns can reach efficiency up to 40% wood to charcoal conversion efficiency (Ishengoma and Ngaga, 2000).

Due to this significant loss in biomass producers who use traditional kilns tend to waste a lot of resources and efforts because of inefficiency which leads to lower returns since the large value of material invested in construction of traditional kilns are wasted unlike producers using improved kilns have relatively higher value of material invested being turned into output.

Table 2: Gross margin of improved kilns versus traditional kilns

Variables	Improved Kilns (n=79)	Tradition Kilns (n=121)	t-test
Revenue	1350000	730000	
Tools cost	20000	27500	
Kiln construction cost	360000	300000	
Food cost	27000	4000	
Cost of empty bags	40000	20000	
Average cost	450000	385000	
Gross Margin	52%	26%	0.024

CONCLUSION AND RECOMMENDATIONS

The findings show that large number of charcoal producers in the study area use traditional kilns despite advantages existing from using improved kilns. Producers in the study area have kilns of different sizes regardless the type of kiln whether traditional or improved kilns. The findings show that charcoal production is the main contributor to the income of the household in the study area and therefore charcoal production is very important to the livelihood of its producers in the study area compared to other economic activities such as farming, livestock keeping and other activities. Moreover, findings show that for producers who are using improved kilns in the study area slightly more than a half of sales to their income after deduction cost while for charcoal producers who used traditional kilns retain just a quarter of the sales to their income after deducting cost involved during production. Furthermore, the findings show that the charcoal producer's experience in charcoal production and training on charcoal production influenced the type of the kiln employed. Therefore, in the study area the use of improved kilns is more profitable compared to the use of traditional kilns. Charcoal producers should put more emphasis on the use of improved charcoal kilns since they have shown significant effects on the income of the households involved in charcoal production in the study area. Charcoal producers should be encouraged to form charcoal production social networks which will help to communicate and sharing various knowledge regarding charcoal production since social networks has shown to have significant effect on the decision of producer choice of improved kilns. Local governments through forests authorities should conduct training on advantages of using of improved charcoal kilns among charcoal producers in the study area since it has shown a positive influence towards using improved kilns for charcoal producers who received training.

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