Tanzania Forest Conservation Group
Shirika la Kuhifadhi Misitu ya Asili Tanzania

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

TFCG Technical Paper 47

Assessment of the Potentials for Sustainable Charcoal Production from Wood Waste Using Efficient Technologies in Village Land Forest Reserves in Tanzania

Zahabu, E & Madadi, L

2020

This report was prepared by:

Zahabu, E, Department of Forest Resources Assessment and Management, College of Forestry, Wildlife and Tourism, Sokoine University of Agriculture (SUA), P.O. Box 3013, Morogoro.

Madadi, L. Mpingo Conservation &Development Initiative (MCDI), Monitoring and Research Department, P.O. Box 49, Kilwa Masoko.

On behalf of the project:

Conserving Forests through sustainable, forest-based Enterprise Support in Tanzania' – CoForEST.

The goal of the project is to achieve a sustainable, pro-community natural forest management that transforms the economics and governance of the forest products value chains and contributes to climate change mitigation and adaptation.

The project is designed to achieve its overall goal through three inter-related Outcomes:

Outcome 1: The capacity of national, regional and local authorities and community members is strengthened to implement and scale-up CBFM in ways that diversify livelihoods and reduce deforestation.

Outcome 2: A supportive policy framework and financing mechanism for community based forest management and sustainable natural forest based enterprises is in place

Outcome 3: Research and learning institutions in Tanzania are generating new knowledge about enterprise oriented CBFM and are integrating this in student learning.

The project is financed by the Swiss Agency for Development and Cooperation and is implemented by the Tanzania Forest Conservation Group in partnership with the Tanzania Community Forest Conservation Network (MJUMITA)

Recommended citation: Zahabu, E. & L. Madadi 2020. Assessment of the Potentials for Sustainable Charcoal Production from Wood Waste Using Efficient Technologies in Village Land Forest Reserves in Tanzania. TFCG Technical Paper 47. p. xx

Table of Contents

Abbreviations and Acronyms

CBFM	Community-Based Forest Management
CoForEST	Conserving Forests through sustainable, forest-based Enterprise Support in Tanzania
Dbh	Diameter at Breast Height
DC	District Council
DED	District Executive Director
DFO	District Forest Officer
DFM	District Forest Manager
FBD	Forestry and Beekeeping Division
FMU	Forest Management Unit
FORVAC	Forestry and Value Chains Development programme
GN	Government Notice
GoT	Government of Tanzania
GPS	Global Positioning System
ha	hectare
IBEK	Improved Basic Earth Kiln
Kg	Kilogram
LGA	Local Government Authority
MJUMITA	Mtandao wa Jamii wa Usimamizi wa Misitu Tanzania
MNRT	Ministry of Natural Resources and Tourism
MoU	Memorandum of Understanding
PFM	Participatory Forest Management
PO RALG	President's Office for Regional Administration and Local Government
RS	Regional Secretariat
SDC	Swiss Agency for Development and Cooperation
SUA	Sokoine University of Agriculture
TAFORI	Tanzania Forestry Research Institute
TaTEDO	Tanzania Traditional Energy Development Organisation
TFCG	Tanzania Forest Conservation Group
TFS	Tanzania Forest Services Agency
TShs	Tanzania Shillings
TTCS	Transforming Tanzania's Charcoal Sector project
URT	United Republic of Tanzania
VC	Village Council
VEO	Village Executive Officer
VLFR	Village Land Forest Reserve
VLUM	Village Land Use Management
VLUP	Village Land Use Plan
VNRC	Village Natural Resources Committee

Executive Summary

Research on Charcoal Production from Wood Waste in Village land Forest Reserves (VLFRs) in Tanzania was formulated as part of the project 'Conserving Forests through sustainable, forest-based Enterprise Support in Tanzania' – CoForEST that is implemented by the Tanzania Forest Conservation Group (TFCG) in partnership with the Tanzania Community Forest Conservation Network (MJUMITA). The research was identified following the implementation of the Transforming Tanzania's Charcoal Sectors (TTCS) project in 30 supported villages. This present study aims to explore the potentials of utilizing wood waste from timber off-cuts and other wastes in the forests as a source of raw material for charcoal production. It is envisaged that charcoal production using wood waste from harvested timber in natural forests can provide another potential opportunity for improving utilization rate of raw material from timber production and therefore enhancing efficiencies of forests use, reduce the amount of wood wastes and providing additional income source which can stimulate local economic development.

The research is approached in two phases to evaluate if it is economically viable to produce charcoal using wood wastes, and if so, using which feasible charcoal production techniques while observing the governing regulations. The first phase involves desk review of literature while the second phase will involve field trials of the potential improved charcoal production technologies from wood wastes. This working paper concerns the first phase of the study.

In order to determine the economic viability of charcoal production, the volume of standing timber harvested in each of the village forest was determined. Then the amount of wood left as logging waste and timber off-cuts and slabs at the sawmill centre was computed from the harvested total standing tree volume. The costs involved in the production of charcoal using the different technologies were determined and the profit computed. The profit ranges from TShs 105,060 to TShs 3,995,978 when the charcoal is made from logging waste using improved earth mound kilns. When the charcoal is made from sawmill waste using half orange brick kiln, the profit ranges from TShs (-209,982) to TShs 901,731 meaning that seven villages which currently have small amount of sawmill waste (<25 m^3) cannot break even by producing charcoal using the half orange brick kiln. However, a field study is required to authenticate all the data and assumptions made in these computations.

There are three common charcoal production methods: earth kilns, brick and metal kilns. Apart from its limitation when used inside the forest, the half orange brick kiln is suitable for timber off-cuts centralized at some selected single points where sawmills are located. On the other hand Improved Earth Mound Kiln with better kiln management could be a better option for the scattered wood waste left in the forest due to its high wood-to-charcoal conversion efficiency and improved quality of charcoal produced.

There exist policies, strategies and legal frameworks that support charcoal production from standing wood which also apply to production of charcoal from wood wastes. Currently, there is 'A Guide to Sustainable Harvesting and Trade of Forest products from natural Forests of 2015'. In addition to the instructions given in the 2007 Guideline, this guide provides the procedures for harvesting wood for charcoal making. A person involved in charcoal production needs to be registered by the village government and get a licence from the Forestry Officer or the District Forest Manager which currently costs TShs 256,000/- per year. Other required charges include a royalty of TShs 12,500/- per 50 kg charcoal bag and tree planting fees which is 5% of the royalty. However, in practice the charcoal

business is done through charcoal dealers who go directly to the producers; buy the charcoal and transport it after obtaining a transit pass from the District Forest Officer. With this arrangement, the dealer will be required to pay: the royalty, district and village fees charged on per bag basis. It is at this stage where royalty may be charged twice if the dealer is not made aware that royalty is already charged to the timber dealers. However, this is an opportunity for the villages to sell their charcoal from wood waste at a normal kiln site price plus royalty (i.e TShs 7,000/- + 12,500/- = 19,500/-). However, good price negotiation and stakeholders consultation skills are needed in order to make this happen.

This study revealed that, 10 out of 11 villages break even when producing charcoal from the wood waste. This suggests that the utilization of wood waste is by itself enough and it should not be supplemented by felling additional trees. This is because most of the timber tree species in the miombo woodlands are also preferred charcoal species. While harvesting trees for timber requires a minimum tree size of 45 cm Dbh, charcoal harvesting utilizes even small diameter trees and hence jeopardizing timber production.

The study recommends carrying out field trials on wood waste charcoal production using efficient technologies of Improved Earth Mound Kiln and Built-in Kilns (Half-orange or Casamanse Kiln). In collaboration with MCDI, TaTEDO and TFCG, field visits to the MCDI villages in Kilwa district will be done to assess not only the amount and composition of wood wastes but also how appropriate the waste is for the production of charcoal. The on-going experience of producing charcoal from wood wastes in the MCDI project area will also be assessed. These assessments will form a basis for the identification of potential charcoal production technologies to be trialled for the timber off-cuts (centralized) and other wood waste/branches (scattered in the forest). The trials will involve training of charcoal producers on a particular technology and field demonstrations on its use.

Further, during the field visits legal issues identified during the literature review in relation to charcoal production using wood waste from timber harvesting will be further explored. This will go hand in hand with the further assessment of the minimum annual timber harvesting quota as threshold for village to qualify for charcoal production from timber off-cuts/wood waste.

1. Introduction

1.1 Background

This research on Charcoal Production from Wood Waste in Village land Forest Reserves (VLFR) in Tanzania is formulated as part of the project 'Conserving Forests through sustainable, forest-based Enterprise Support in Tanzania' – CoForEST that is implemented by the Tanzania Forest Conservation Group (TFCG) in partnership with the Tanzania Community Forest Conservation Network (MJUMITA). The research was identified as a priority in consultation with Mpingo Conservation and Development Initiatives (MCDI), Tanzania Traditional Energy Development and Environment Organization (TaTEDO) and Tanzania Forest Service Agency (TFS) during designing of Phase 3 of the project.

The research is guided by a technical committee involving representatives from the President's Office Regional Administration and Local Government (PORALG), the Forestry and Beekeeping Division (FBD), Tanzania Forestry Research Institute (TAFORI), Traditional Energy Development Organization (TaTEDO), MCDI, Tanzania Forest Service (TFS) and TFCG. The first technical committee meeting was held on 23rd September 2020. The planning meeting was convened for the purpose of discussing and agreeing on the research objectives and approach, deliverables for the research. The committee agreed on the modalities on how the research can be implemented and the way forward. The technical team also agreed on the proposed research theme to be: "***Charcoal production from wood waste in CBFM sites".*** The research objectives are as follows

i. Examine economic viability of charcoal production using timber off-cuts (centralized) and other wood waste / branches (scattered in the forest),
ii. Examine feasible charcoal production techniques using timber off-cuts and other wood waste from timber harvesting,
iii. Explore/examine legal issues in relation to charcoal production using wood waste from timber harvesting, and
iv. Provide recommendations on the minimum annual timber harvesting quota as threshold for village to qualify for charcoal production from timber off-cuts/wood waste.

The technical meeting also agreed that the expected deliverable for this assignment will be;

Phase 1 (up to 30th Nov 2020)

- Inception report – including information on objectives, scope, methods, sampling, research tools, analysis plan and reporting.
- Preliminary findings from the literature review / working paper that will inform the second phase of the research on the important areas to concentrate

Phase 2 (up to Feb 2021)

- Research report providing a detailed write-up of the objectives, methods, results and discussion. The report should also include recommendations for research in year 2.
- At least 1 policy paper summarizing the research and highlighting the relevance of the research to policy makers, particularly in the context of the on-going development of the National Forestry Strategy.

- Research summary providing an overview of the objectives, methods, results and conclusions. These should be clearly written for a non-specialist audience.

This working paper is part of Phase 1.

1.2 Rationale

In Tanzania fuel wood (firewood and charcoal) is the major energy source accounting for approximately 90% of total energy consumption (National Bureau of Statistics, 2013). While firewood is mostly used in rural areas, charcoal is the single largest source of household cooking energy in urban areas, as it is considered affordable, available and easy to transport, distribute, and store. Firewood and charcoal production are identified to be among the major direct causes of uncontrolled deforestation and forest degradation in the country (VPO, 2013). However, wood harvesting for charcoal most often results in a gradual degradation of forest resources over time, rather than clear-cutting, leading to real deforestation. It is therefore difficult to estimate the contribution of charcoal to deforestation. The rate of deforestation in the country is estimated to be 469,000 ha per year (URT, 2017).

Considering high dependence on fuelwood in Tanzania, the environmental costs due to inefficient charcoal production and use are enormous (URT, 2019). In light of this serious situation, the Transforming Tanzania's Charcoal Sector project (TTCS) supported 30 villages in developing community-based forest management (CBFM) in their Village Land Forest Reserves that integrates sustainable charcoal and timber production. In year four of Phase two of this project, eight villages began to engage in sustainable timber production, thereby-adding another revenue stream in terms of producer livelihoods and community revenues. This present study aims to explore the potentials of utilizing wood waste especially the timber off-cuts and other wastes in the forests as a source of raw material for charcoal production. It is envisaged that charcoal production using off-cuts from timber harvesting in natural forests can provide another potential opportunity for improving utilization rate of raw material from timber production and therefore enhancing efficiencies of forests use, reduce the amount of wood wastes and providing additional income source which can stimulate local economic development (Ngaga et al., 2004).

2. Methodology

2.1 Location of the Study

This study will be carried out in the villages where MCDI is supporting sustainable timber harvesting under CBFM regime in Kilwa district. Currently MCDI is supporting a total of 67 villages scattered in 9 districts namely: Kilwa, Liwale, Monduli, Nachingwea, Namtumbo, Ruangwa, Rufiji, Tunduru and Karatu. In Kilwa district, MCDI is supporting 11 villages with VLFRs that have high potentials in term of timber off-cuts through on-going sustainable timber harvesting and mobile saw milling. The villages are: Nanjirinjiri A, Nanjirinjiri B, Likawage, Liwiti, Ngea, Mchakama, Nainokwe, Kikole, Kisangi, Namatewa and Kipindimbi (MCDI, 2020). The available timber off-cuts are found centralized at some selected single points where sawmills were located, but other wood debris, mainly from rotten boles and branches are scattered in the VLFRs.

2.2 Study Design

This study documents best existing charcoal production techniques that can be recommended for charcoal production using wood wastes. The assignment will be approached in two phases. The first phase involves desk review of literature to see if it is economically viable to produce charcoal using wood wastes, and if so, using which feasible charcoal production techniques while observing the existing legal issues.

The second phase will involve field trials of the potential improved charcoal production technologies from wood wastes. In Tanzania improved charcoal production technologies have been introduced in various parts but involved cutting of standing trees for the charcoal production. At present, Improved Basic Earth Mound Kiln technology is implemented by TFCG/TTCS under Transforming Tanzania's Charcoal Sector (TTCS) in Kilosa district. However, the use of this technology for the production of charcoal from the wood wastes has not been tested. Currently, there is some charcoal burning using traditional Earth Mound Kilns in the MCDI villages using timber off cuts in Kilwa district (Figure 1). Therefore, there is a need to introduce the improved technologies in these villages. Field trials that integrate sustainable timber harvesting and charcoal production from the wood wastes will be done. The field trials will assess the technical, economic (profitability) and regulatory aspects of timber off-cut based charcoal production modalities under different field conditions.

Figure 1. *A pile of wood off-cuts from* Dalbergia melanoxylon *arranged to be covered with earth to form an earth mound charcoal kiln (Source: URT, 2019).*

This working paper concerns the first phase of this study involving literature review. A literature review is a comprehensive summary of previous research on a topic. The literature review surveys scholarly articles, books, and other sources relevant to a particular area of research. The review should enumerate, describe, summarize, objectively evaluate and clarify these previous researches. Detailed literature review focusing on various studies, research reports, land and forestry legislations and regulations, peer-reviewed publications to identify the existing charcoal production technologies, economic viability of charcoal production using wood wastes and the legal framework supporting charcoal production from wood wastes was done. Online sources of information were a major approach using search engines such as Google scholar, higher learning institution libraries/repositories. The TFCG/MJUMITA and the client i.e. CoForEST project were also consulted for various documents about the project activities that have been implemented in the villages. District, Village Offices and private company offices in the study sites were also consulted to obtain relevant documents for the study.

As previously pointed out this first phase will inform the second phase of the study on areas that need concentration.

3. Preliminary findings

This chapter gives results from a desk review of the literature to see if it is economic viable to produce charcoal using wood wastes, and if so using which feasible charcoal production techniques while observing the existing legal issues.

3.1 Economic viability of charcoal production using timber off-cuts (centralized) and other wood waste / branches (scattered in the forest)

As stated previously, MCDI is supporting on-going sustainable timber harvesting and mobile saw milling in 11 villages under CBFM regime in Kilwa district. The villages are: Nanjirinjiri A, Nanjirinjiri B, Likawage, Liwiti, Ngea, Mchakama, Nainokwe, Kikole, Kisangi, Namatewa and Kipindimbi. The available raw material from timber/wood wastes are:

- Timber off-cuts centralized at some selected single points where sawmills were located, and
- Wood debris, mainly from rotten boles and branches scattered in the VLFRs (Figure 2).

Figure 2. Considerable amounts of wood are left as branches and tops in the VLFRs after removing logs for saw-milling.

The term wood waste means timber off-cuts, tree stem boles and branches remains as a result of poor wood quality or low average percentage timber recovery both in the forests and wood processing sawmills (Zoya, 2013 & Akhator *et al.,* 2017). In the context of this study therefore wood waste constitute wood left as logging waste (branches, tops and stem boles scattered in the forest) and sawmill waste (timber off-cuts, slabs, saw dust, shavings) left at the sawmill centre.

Merchantable timber volume for the miombo woodland timber species in Tanzania is estimated to be 40% of standing tree volume to account for branches and non-millable parts of the tree (Temu 1979). In Brazil, for each 1 ton of logged wood for sawing and veering, 2.14 tons of logging wastes can be generated (Numazawa et al., 2017), that is to say only 32% of the total tree volume is millable. These wastes seem underutilized and are typically stored within the managed and centralized areas, although Tanzanian legislation encourages its efficient utilization (URT, 2015; RFP, 2017).

Despite high availability, logging wastes are highly heterogeneous since they are derived from many species with variable wood properties. A study of Amazonian logging wastes generated from 20 timber species show significant variations for basic density, energy density, ash content and total extractives which in turn influenced the quality of charcoal. (Lima et al. 2020). Studies indicated that the timber species in the miombo woodlands are also preferred charcoal making species (Malimbwi, et.al. 2004; Malimbwi et.al 2005) but investigations that address the potential of wood waste for the charcoal production and how they are affected by the wood quality are scarce.

In order to determine the economic viability of charcoal production we first need to determine the volume of standing timber harvested in each of the village forest. Then the amount of wood left as logging waste (branches, tops and stem boles scattered in the forest) and timber off-cuts and slabs at the sawmill centre (sawmill waste) will be computed from the harvested total standing volume. The costs involved in the production of charcoal using the different technologies also need to be known.

3.1.1 The volume of standing timber trees

The amounts of total standing tree volume for the 11 villages for the period July 2018 to December 2020 (2.5 years) are shown in Table 1. It is observed that most of the standing wood (89%) harvested come from five villages of Nanjirinji A (Mbumbila A), Likawage, Nanjirinji A (Mbumbila B), Liwiti and Ngea. This indicates that the rest of the villages harvested only 11% of the total standing timber.

Table 1. *Amount of total standing trees volume harvested from MCDI CBFM villages*

S/N	Village	2018/19 (m^3)	2019/20 (m^3)	2020/21 (m^3)	Total Standing Tree Volume (m^3)
1	Nanjirinji A (Mbumbila A)		717.90	232.98	950.88
2	Likawage	67.11	582.85	50.26	700.22
3	Nanjirinji A (Mbumbila B)	333.59		20.00	353.59
4	Liwiti	185.45	30.00		215.45
5	Ngea	159.16			159.16
6	Mckakama	36.82	50.27		87.09
7	Kisangi	42.92	12.35	3.20	58.47
8	Namatewa	41.26			41.26
9	Kikole A	40.00			40.00
10	Kilindimbi		40.00		40.00
11	Nainokwe		25.00		25.00
	Total	**906.31**	**1458.37**	**306.44**	**2671.12**

Source: MCDI Database for the period July 2018 to December 2020 (2.5 years).

3.1.2 Estimated amount of logging and sawmill wastes

Table 2 shows the estimated amount of branches, tops and non-mill-able parts of the tree left scattered in the forest and the volume of timber off-cuts and slabs at the sawmill centre for the 2.5 years. For the estimation of the amount of branches, tops and non-mill-able parts of the tree left scattered in the forest, all standing tree volume was reduced by 60% since only 40% of the total standing timber volume is mill-able (Temu, 1979). With a sawmill recovery of 70%, the mill-able timber will be reduced by 30% to constitute the volume of timber off-cuts and slabs at the sawmill centre. Figure 3 shows one of the adopted portable sawmill for the MCDI project.

Table 2. *Estimated amount of logging and sawmill waste from MCDI CBFM villages in Kilwa*

S/N	Village	Standing Tree Volume (m^3)	Logging waste (m^3)	Sawmill waste (m^3)
1	Nanjirinji A (Mbumbila A)	950.88	570.53	114.11
2	Likawage	700.22	420.13	84.03
3	Nanjirinji A (Mbumbila B)	353.59	212.15	42.43
4	Liwiti	215.45	129.27	25.85
5	Ngea	159.16	95.50	19.10
6	Mckakama	87.09	52.25	10.45
7	Kisangi	58.47	35.08	7.02
8	Namatewa	41.26	24.76	4.95
9	Kikole A	40.00	24.00	4.80
10	Kilindimbi	40.00	24.00	4.80
11	Nainokwe	25.00	15.00	3.00
	Total	**2671.12**	**1602.67**	**320.53**

Figure 3. *Current MCDI Centralized and Mobile timber production approach with High efficient portable sawmill*

3.1.3 Estimated amount of charcoal from logging wastes

Evidence from the field as shown in Figure 1 and 2 indicates that the nature of the logging wastes (branches, tops and stem boles) are similar to those of harvested tree boles for charcoal making. The difference is only on the sizes, that logging wastes will constitute more small-sized wood. However, studies show that, the size of logs does not influence the wood to charcoal conversion efficiency. Factors contributing to wood-charcoal conversion efficiency are moisture content of wood involved in kiln preparation, specific weight of the wood and proper control during carbonization process due to some complete combustion of wood (Ishengoma and Nagoda 1991; Hofstad 1995).

As it has been shown under Section 3 and also guided under the current Guide to Sustainable Harvesting and Trade of Forest products from natural Forests of 2015 (URT 2015), Improved Earth Mound Kiln with better kiln management could be a better option for the scattered logging waste left in the forest due to its high wood-to-charcoal conversion efficiency, ease of construction and improved quality of charcoal produced. With this type of kiln, kiln efficiency of 15-25% can be attained (van Beukering et al., 2007; URT, 2019). Considering an average kiln efficiency of 20% and a conversion factor of 0.85 for fresh wood volume to wood biomass (Malimbwi and Zahabu 2008), the weight of charcoal (tons) that can be obtained from the branches, tops and stem boles scattered in the forest (fresh wood x 0.85 x 0.20) is determined. Assuming a bag of charcoal of 30 kg (Sawe, 2012), the expected number of charcoal bags from the logging waste is also calculated (Table 3).

Table 3. *Estimated amount of charcoal from logging waste from MCDI CBFM villages in Kilwa*

S/N	**Village**	**Logging waste (m^3)**	**Kgs of charcoal**	**Number of charcoal bags of 30 kg over 2.5 years**	**Number of 30 kg charcoal bags per year**
1	Nanjirinji A (Mbumbila A)	570.53	96,989.76	3,233	1,293
2	Likawage	420.13	71,422.44	2,381	952
3	Nanjirinji A (Mbumbila B)	212.15	36,065.67	1,202	481
4	Liwiti	129.27	21,975.90	733	293
5	Ngea	95.50	16,234.32	541	216
6	Mckakama	52.25	8,883.18	296	118
7	Kisangi	35.08	5,963.94	199	80
8	Namatewa	24.76	4,208.52	140	56
9	Kikole A	24.00	4,080.00	136	54
10	Kilindimbi	24.00	4,080.00	136	54
11	Nainokwe	15.00	2,550.00	85	34
	Total	**1602.67**	**272,453.73**	**9,082**	**3,633**

3.1.4 Estimated amount of charcoal from sawmill wastes

Table 2 shows that, for all of the MCDI villages, the estimated amount of sawmill waste constitute only 12% of the total timber production waste. This is equivalent to an average of 128.2 m^3 of sawmill waste annually but 7 out of the 11 villages have <25 m^3 annually. The sawmill wastes includes: timber off-cuts, slabs, sawdust, shorts, trimming and defective pieces caused by processing. While the woody sawmill wastes (Slabs, edgings and off-cuts) can be made into charcoal, sawdust and shavings can be used for power and heat production, and or made into briquettes. According to FAO 1990, the woody sawmill waste, constitute 50% of the total sawmill waste.

As it has also been shown under Section 3 and also guided under the current Guide to Sustainable Harvesting and Trade of Forest products from natural Forests of 2015 (URT 2015), half-orange brick kiln could be a better option for the woody sawmill waste concentrated at the sawmill sites. With this type of kiln, kiln efficiency of up 35% can be attained (Malimbwi and Zahabu, 2008; URT, 2019). Therefore, with kiln efficiency of 35%, a conversion factor of 0.85 for wood volume to wood biomass (Malimbwi and Zahabu 2008), and only considering 50% of all the sawmill waste, the weight of charcoal (tons) that can be obtained from the sawmill waste is determined. Assuming also a bag of charcoal of 30 kg (Sawe, 2012), the expected number of charcoal bags from the sawmill waste is also calculated (Table 4).

Table 4. *Estimated amount of charcoal from sawmill waste from MCDI CBFM villages in Kilwa*

S/N	Village	Logging waste (m^3)	Kgs of charcoal	Number of Charcoal bags of 30 kg over 2.5 years	Number of Charcoal bags per year
1	Nanjirinji A (Mbumbila A)	114.11	16,973.21	566	226
2	Likawage	84.03	12,498.93	417	167
3	Nanjirinji A (Mbumbila B)	42.43	6,311.49	210	84
4	Liwiti	25.85	3,845.78	128	51
5	Ngea	19.10	2,841.01	95	38
6	Mckakama	10.45	1,554.56	52	21
7	Kisangi	7.02	1,043.69	35	14
8	Namatewa	4.95	736.49	25	10
9	Kikole A	4.80	714.00	24	10
10	Kilindimbi	4.80	714.00	24	10
11	Nainokwe	3.00	446.25	15	6
	Total	320.53	47,679.40	1,589	636

3.1.5 Economic implications

Previous studies indicate that, using traditional earth mound kiln, the process of charcoal making involves wood cutting, kiln preparation, carbonization and finally unloading charcoal from the kiln (CHAPOSA 2002, Malimbwi *et al.* 2005). With an average kiln of 35 bags, it takes 13, 10, and 14 days for wood cutting, kiln preparation and carbonization respectively while unloading the charcoal kiln takes only about 4 days. However, the use of improved basic earth mound kilns improves wood-to-charcoal conversion efficiency, quality of charcoal produced, reduce kiln's wood wastage, and decrease production cost from US$3 to $1.7 per 30 kg charcoal bag (Sawe, 2012).

Current price of a bag of charcoal of 30 kg at kiln site in Kilwa is TShs 7,000 (MCDI staff personal communication, 16 Feb 2020), the revenues to be expected from the sale of this charcoal from logging waste for each of MCDI villages are shown in Table 5. The table also shows the estimated costs based on $1.7 per 30 kg charcoal bag and profit. The profit ranges from TShs 105,060 to TShs 3,995,978 but most of the costs for producing the charcoal will be paid for the human labour available at the village since household labour is usually used for the charcoal making (CHAPOSA 2002, Malimbwi *et al.* 2005).

Table 6 shows the revenues to be expected from the sale of charcoal from sawmill waste for each of MCDI villages using half orange brick kiln. Using this kiln the process of charcoal making involves cutting pieces of waste material into specific sizes, loading the wastes, carbonization; continuously smear with mud on the outer surface to cover cracks and unloading charcoal from the kiln. These activities will have some associated labour costs of almost half of that incurred with the use of improved basic earth mound kilns (Malimbwi and Zahabu 2008). However, apart from these operational costs, the initial costs of building the kiln should also be included. Currently, the cost for construction of half orange brick kiln (of 10 m3 sawmill waste material that can produce 30 bags of charcoal) is TShs 2,400,000/- (Mr Sango of TaTEDO personal communication 18 Dec 2020).

Table 5. *Estimated revenue, costs and profit for charcoal from logging waste for the MCDI villages in Kilwa*

S/N	Village	Number of Charcoal bags per year	Estimated Revenue (TShs)	Estimated Cost (TShs)	Estimated Profit (TShs)
1	Nanjirinji A (Mbumbila A)	1,293	9,052,378	5,056,399	3,995,978
2	Likawage	952	6,666,094	3,723,490	2,942,605
3	Nanjirinji A (Mbumbila B)	481	3,366,129	1,880,224	1,485,906
4	Liwiti	293	2,051,084	1,145,677	905,407
5	Ngea	216	1,515,203	846,349	668,854
6	Mckakama	118	829,097	463,110	365,987
7	Kisangi	80	556,634	310,920	245,714
8	Namatewa	56	392,795	219,404	173,391
9	Kikole A	54	380,800	212,704	168,096
10	Kilindimbi	54	380,800	212,704	168,096
11	Nainokwe	34	238,000	132,940	105,060
	Total	3,632.7	25,429,015	14,203,921	11,225,094

Experience shows that after construction the half orange brick kiln can be used for more than 10 years (Malimbwi and Zahabu 2008). Therefore the construction costs can be spread for the 10 years to be TShs 58,139.5. Considering this annual cost and the labour cost of producing a charcoal bag of 30 kg of US$ 0.85 (half of US$ 1.7) about, the expected revenues, costs and profit for charcoal from sawmill waste were estimated as presented in Table 6. The profit ranges from TShs (-209,982) to TShs 901,731 meaning that seven villages which currently have small amount of sawmill waste (<25 m^3) cannot break even by producing charcoal using the half orange brick kiln.

Table 6. *Estimated revenue, costs and profit for charcoal from sawmill waste for the MCDI villages in Kilwa*

S/N	Village	Number of Charcoal bags per year	Estimated Revenue (TShs)	Estimated Cost (TShs)	Estimated Profit (TShs)
1	Nanjirinji A (Mbumbila A)	226	1,584,166	682,435	901,731
2	Likawage	167	1,166,567	565,805	600,761
3	Nanjirinji A (Mbumbila B)	84	589,073	404,520	184,553
4	Liwiti	51	358,940	340,247	18,693
5	Ngea	38	265,161	314,056	-48,895
6	Mckakama	21	145,092	280,522	-135,430
7	Kisangi	14	97,411	267,206	-169,794
8	Namatewa	10	68,739	259,198	-190,459
9	Kikole A	10	66,640	258,612	-191,972
10	Kilindimbi	10	66,640	258,612	-191,972
11	Nainokwe	6	41,650	251,632	-209,982
	Total	636	4,450,078	3,882,843	567,234

3.2 Feasible charcoal production techniques using timber off-cuts and other wood waste from timber harvesting,

Charcoal is a prime source of energy which is made from organic matter in the absence of air at temperatures above 300°C. There are various methods for charcoal production. Some of these methods are crude and have low yield and quality of the charcoal produced while others are highly automated (Madadi, 2000). Charcoal is produced by slow heating wood (carbonization) in airtight ovens or retorts, in chambers with various gases, or in kilns supplied with limited and controlled amounts of air. In the kiln, heat converts wood to charcoal in the drying and the coaling stages (Ayhan et al., 2016). As generally accepted, carbonization refers to processes in which char is the principal product of interest (wood distillation, the liquid; and destructive distillation, both char and liquid) (Goldstein, 1981). At the usual carbonization temperature of about 675 K, char represents the largest component in wood decomposition products. Typical charcoal contains approximately 80% carbon, 1–3% ash, and 12–15% volatile components (Wenzl, 1970). There are three most common charcoal production methods today: earth kilns, brick and metal kilns.

3.2.1 Earth Charcoal Kilns

The oldest and still the most widely used method for charcoal production is the earth kiln (Malimbwi et al., 2004). Two varieties exist, the earth pit kiln and the earth mound kiln. An earth pit kiln is constructed by first digging a small pit in the ground. Then the wood is placed in the pit and lit from the bottom, after which the pit is first covered with green leaves or metal sheets and then with earth to prevent complete burning of the wood. The earth mound kiln is built by covering arranged pile of wood on the ground with earth.

In most parts of Tanzania, charcoal is produced in earth mound kilns made by covering a pile of logs with earth, igniting the kiln and allowing carbonization under limited air supply (Monela *et al*. 1993, CHAPOSA 2002, Malimbwi *et al.* 2005, URT 2019). The mound kiln is preferred over the pit where the soil is rocky, hard or shallow, or the water table is close to the surface (Malimbwi et al, 2004). Also the mound requires less labour than the pit kiln. Mounds can also be built over a long period, by stacking gathered wood in position and allowing it to dry before covering and burning. Typical earth mound kiln dimensions differ depending on the amount of wood available around the kiln site (Malimbwi *et al.,* 2004). With this type of kiln, the process of charcoal making involves wood cutting, kiln construction, carbonization and finally unloading charcoal from the kiln.

3.2.2 Brick Charcoal Kilns

The brick kilns are represented by the Argentine half orange Kiln (Figure 4) and the metal kilns. The half orange brick kiln was previously introduced in eastern Tanzania for use in the VLFRs (Malimbwi and Zahabu 2008) but its adoption was low due to:

- high initial investment cost,
- the need to process the billets into specific sizes which is time consuming,
- the need to transport the billets to kiln site since the kiln is not moveable, and
- the need to continuously smear with mud on the outer surface to cover cracks; this may be a problem especially in most of the charcoal producing areas where water is not readily available.

However, the use of this type of kiln may be suitable for timber off-cuts centralized at some selected single points where sawmills were located.

Figure 4. *Half Orange Kiln at Mazizi, Morogoro, Tanzania (Source Malimbwi and Zahabu, 2008)*

3.2.3 Improved Earth Mound Charcoal Kilns

As stated previously, Improved Earth Mound Kiln (Figure 5) technology is the only currently improved charcoal production technology that is implemented by TFCG/TTCS under Transforming Tanzania's Charcoal Sector (TTCS) in Kilosa district. The use of the Improved Earth Mound Kiln with better kiln management could be a better option. The IEMK is based on the traditional earth mound kiln modified by limiting air supply thereby controlling inlet air and limiting the exhaust air to a single chimney. These kilns are said to have improved wood-to-charcoal conversion efficiency. They also increase charcoal output per kiln and quality of charcoal produced, reduce kiln's wood wastage, and decrease production cost (Sawe, 2012; van Beukering et al., 2007).

Figure 5. *Improved Earth Mound Kiln at Ruvu Fuellwood Pilot Project, Coast Region, Tanzania.*

3.2.4 Charcoal Kilns Efficiencies

Table 7 shows the charcoal kiln efficiencies from the different types of kilns from the literature. Apart from the CHAPOSA (2002) study on traditional earth mound kilns, other studies do not show evidence of empirical studies on how the wood to charcoal conversion efficiency were measured to determine the kiln efficiencies (Madadi, 2000, Malimbwi *et al.,* 2004). CHAPOSA (2002) used data from twenty-one kilns from four sites and reveal the mean kiln efficiency of 19% ranging from 11-30%. The reported kiln efficiencies when using the Half Orange Brick Kiln and the Improved Earth Mound Kiln technologies is uncertain. The literature reports a range from 25-35% with no evidence of a study on how the kiln efficiencies were determined.

Table 7. *Charcoal kiln efficiencies from different kiln types in Tanzania*

Kiln type	Kiln efficiency	Author
Earth Mound Kiln	15%	URT, 2019
	19% (ranging from 11-30%)	Malimbwi and Zahabu 2008
Improved Basic earth mound kiln	25%,	URT, 2019
	15–25%	van Beukering et al., 2007
Half orange brick kilns, metal kilns and retorts	Beyond 25%,	URT, 2019
	27-35%	(Malimbwi and Zahabu, 2008).

Experience from CHAPOSA (2002) shows an average of 19% traditional earth kiln efficiency, 18 trees of 32 cm diameter at breast height (dbh) are used to produce 26 bags each weighing 56 kg of charcoal. That is, 1 m^3 of wood yields 2.7 bags of about 56 kg of charcoal (CHAPOSA 2002). According to Hofstad (1995) factors contributing to kiln efficiency variation are moisture content of wood involved in kiln preparation and its specific weight. Therefore tree species involved in kiln preparation contribute greatly to kiln efficiency variation. Lack of proper control during carbonization process is also reported to reduce efficiency due to some complete combustion of wood (Ishengoma and Nagoda 1991). It was noted from CHAPOSA (2002) that experienced specialized charcoal burners attain much more wood-charcoal production efficiency compared to seasonal burners.

3.3 Policies, strategies and legal frameworks governing charcoal production using wood waste from timber harvesting

The Ministry of Natural Resources and Tourism prepared for the first time in 2007 a harvesting guide, exporting and trading forest products. The main purpose of the guidelines is to provide guidance to be followed in sustainable harvesting and trade of forest products and strategies to strengthen the management of natural forest resources. This guide is based on National Forest Policy and Forest Act Chapter 323 of 2002, as well as Government Notices Nos. 69 and 70 of 2006.

These guidelines required that District harvesting committee be established and charged with the roles to prepare and maintain a register of all charcoal dealers in the district under the custodian of the District Forest Office. The local government in turn, shall, in areas of jurisdiction, set special areas for preparation and selling of charcoal. The rules emphasize that any charcoal prepared, must comply with any fee, levy or charge by the village government, the Committee or any other relevant authority.

Currently, there is ‘A Guide to Sustainable Harvesting and Trade of Forest products from natural Forests of 2015’ (URT, 2015). In addition to the instructions given in the 2007 Guideline, the new guide stress the need for the preparation and implementation of forest management plan which is a management and harvesting vision for various uses of the forests. This plan among other things specifies the amount of trees allowed to be harvested annually in each area and the amount of trees to be planted. In addition, it is required that every forest should have a harvesting plan to guide sustainable harvesting. It is emphasized that harvesting of forest products will be done by adherence to the Rules, Regulations and Guidelines. This guidelines guides stakeholders and the general public: on the process of harvesting, processing and trade of forest products; provisions for the establishment of forest products processing industries; conditions for trade of forest products domestically and abroad; and various documents legally acceptable when harvesting, exporting and trading forest products including charcoal.

Chapter 2 (2.1) of these guidelines provides the procedures for harvesting wood for charcoal making. It is required that harvesting trees for energy such as charcoal making; drying tobacco; drying of fish; burning bricks; lime burning; and baking bread will be done in the following order:

1. Identify and allocate forest areas for charcoal production, tobacco drying, fish drying, brick burning, lime burning and baking of bread every year;
2. Everyone involved in charcoal production, tobacco drying, fish drying, brick burning, lime burning and baking of bread will be required to obtain a license;
3. Applications for registration and licensing will be submitted to the Forestry Officer or the District Forestry Manager and will be discussed and decided by the District Harvesting Management Committee;
4. Each Forest Officer and District Forest Manager will be required to have a list of charcoal harvesters and traders, tobacco drying, fish drying, brick burning, lime burning and baking of bread;
5. The village government will keep a list of people who will be involved in charcoal making, tobacco drying, fish drying, brick burning, lime burning and baking. The register will also contain a record of the number of charcoal bags and signatures for each harvester;
6. Every logger for the charcoal and wood trade, tobacco drying, fish drying, brick-burning, lime-burning, bakery or similar business must pay royalties as set out in the Forest Regulations, Tender and Auction or Agreement specifically in accordance with the Forest Act and its Regulations as well as the Public Procurement and Management Act;
   a. Similarly, the harvester will be required to contribute to the tree planting clause by paying five percent (5%) of the royalty and the money will be deposited in the Tanzania Forest Fund (TaFF);
   b. Logging for firewood, charcoal production, tobacco drying, fish drying, brick burning, lime burning and baking of bread shall be done by selecting trees suitable for the activity only as stipulated in the Forest Act chapter 323;
   c. Charcoal production will be done using efficient technologies for example built-in ovens (half-orange or Casamanse Kiln);
   d. The village government will ensure that environmental protection is taken into account in the harvesting area; and
   e. Permission to harvest and use of wood from natural forests for energy to operate industrial plants will not be issued.

A person involved in charcoal production therefore needs to be registered by the village government and get a licence from the Forestry Officer or the District Forestry Manager. Apart from the payment for the license, other required charges include royalty and tree planting fees which is 5% of the royalty. According to the Government Notice No. 255 of 2017 (URT, 2017), the royalty is TShs 12,500/- per 50 kg charcoal bag.

However, in practice charcoal business is done through charcoal dealers. To start the business as a charcoal dealer, one needs to pay a fee for registration of charcoal dealer and get a license which costs TShs 256,000/- per year (2020 rate) (URT, 2017). The charcoal dealer then goes direct to the producers; buy the charcoal and transporting it after obtaining a transit pass from the District Forest Officer. At this stage the dealer will be required to pay: the royalty, district and village fees charged on per bag basis. It is at this stage where royalty may be charged twice if the dealer is not made aware that royalty is already charged to the timber dealers. However, this is an opportunity for the villages to sell their charcoal from wood waste at a higher price. By making a case clear that the royalty of the trees is already paid by the timber dealers, the villagers may set price of their charcoal at a normal kiln site price plus royalty (i.e TShs 7,000/- + 12,500/- = 19,500/-). However, good price negotiation and stakeholders consultation skills are needed in order to make this happen.

3.4 Minimum annual timber harvesting quota as threshold for village to qualify for charcoal production from timber off-cuts/wood waste.

3.4.1 Harvesting quota for timber

In principle, when setting timber harvesting plan, the most important variables to consider are tree size distribution and the felling cycle/quota. The size distribution shows whether or not the timber species meet the minimum Dbh for harvesting with adequate regeneration. For most natural forest timber species in Tanzania the minimum Dbh allowed for harvesting is 45 cm and 25 cm for *Dalbergia melanoxylon* and *Combretum imberbe*. Whereas duration of a forest management plan in Tanzania is always 5 years, the felling cycle for natural forests is however conveniently set at 20 years. According to MNRT (2015), a tree will have increased by 6 cm in 20 years with annual diameter increment of 3 mm. For the species with minimum harvestable Dbh of 45 cm, this means that at least half of trees of smaller diameter class of 35-44.9 cm will have grown to merchantable size of ≥45 cm Dbh during the 20 years' period. This will constitute the harvestable volume for the next felling cycle.

Based on the results from the forest inventory data collected from the entire forest (or a selected forest management unit), a harvesting plan for timber is prepared. All qualifying trees in terms of species and sizes constitute the harvestable crop for the entire felling cycle of 20 years. According to the Land Act No 4 of 1999 (URT, 1999) and the Water Resources Management Act of 2009 (URT, 2009), harvesting should **NOT** take place in the following areas:

- Within 60m of the banks of a permanently flowing river or permanent water source;
- Within 20m of a spring or the banks of any regularly flowing stream or 30m of the banks of any regularly flowing Small River;
- Within a buffer distance (from the banks) equal to the width of any gully formed by ephemeral wet season stream, e.g. not within 2m of the banks of a gully which is 2m wide;
- Steep slopes (to reduce the impact of harvesting on soil erosion);
- Areas that are considered as sacred and have religious significance to members of the community;
- Around reservoirs of water (permanent and temporary) that may be important to local fauna; and
- Areas close to a temporary watercourse, where close is defined as being within a distance from the banks equal to the width of the gully.

Based on these conditions, the harvestable crop is reduced by 10-15% as a precaution against disturbing the sensitive areas in the forest. This is followed by the computation of annual harvesting levels (i.e. allowable cut). The annual allowable cut is 1/20 of the harvestable crop and is spread in the whole forest (or a selected block).

3.4.2 Harvesting quota for charcoal production

As pointed out previously, TFCG implemented a Swiss Agency for Development and Cooperation funded project "Transforming Tanzania's Charcoal Sector" (TTCS), which aimed to make charcoal production legal, sustainable, pro-poor and commercially viable.

Sustainable charcoal production was one component of the TTCS project. The approach promotes good management of the charcoal production process in Morogoro region, eastern Tanzania. It started with 10 villages in Kilosa district. Village land-use planning (VLUP) that creates a village land forest reserve (VLFR) is the first step, before a locally-elected village natural resources committee is instituted to support development of the reserve's management plan. Forest management units are then designated in the reserve, containing sustainable charcoal production areas, which take about 10 per cent of the reserve. The Forest Management Units (FMU) are divided into 50 m x 50 m harvesting coupes based on a 24-year rotation. In each FMU, biomass assessment is done to develop harvesting plans. Harvesting is done through a rotation system i.e. once an area is harvested, it will be harvested again after 23 years. Charcoal producers are then trained on sustainable production practices, and the committee receives training on financial management and enforcement of the practices.

3.4.3 Harvesting quota for charcoal production from timber off-cuts/wood waste

Currently there is no minimum annual timber harvesting quota established as threshold for village to qualify for charcoal production from timber off-cuts/wood waste. However, depending on the chosen production techniques, charcoal can be produced from all the MCDI CBFM villages as they have accumulated enough wood wastes from logging residues and mobile saw milling industrial waste. The current MCDI annual report for 2019-2020 financial year (MCDI, 2020) indicates that it supported sustainable timber harvesting in 22 villages across 4 districts (Kilwa, Rufiji,Tunduru, and Namtumbo). The organization supervised all harvesting operations in all the CBFM villages providing refresher training on safe and efficient harvesting practices to 323 VNRC and logging supervisors to ensure compliance with group scheme FSC standards. Based on this MCDI report, for 2019/2020 FY alone 9 villages namely Likawage, Ngapa, Nainokwe, Nanjirinji A, Mchakama, Kisangi, Sautimoja, Liwiti and Kipindimbi in Kilwa and Tunduru Districts were supported to harvest and sell 868.29 m^3 of standing tree volume worth TZS 276,882,990/- for sawn timber production.

Also, as pointed out in Section 3.1, the potential of all MCDI villages to produce charcoal for the period 2018 to 2023 is enormous. This suggests that the utilization of wood waste is, by itself, enough and it should not be supplemented by felling of lesser preferred timber species. A recent study in Songea region revealed that most of the timber tree species in the miombo woodlands are also preferred charcoal species (Songea District Council, 2020). While harvesting trees for timber requires a minimum tree size of 45 cm dbh, charcoal harvesting utilizes even small diameter trees and hence jeopardizing timber production.

4 Conclusions and Recommendations.

4.1 Conclusions

In order to determine the economic viability of charcoal production, the volume of standing timber harvested in each of the village forest was determined. Then the amount of wood left as logging waste and timber off-cuts and slabs at the sawmill centre was computed from the harvested total standing tree volume. The costs involved in the production of charcoal using the different technologies were determined and the profit computed. The profit ranges from TShs 105,060 to TShs 3,995,978 when the charcoal is made from logging waste using improved earth mound kilns. When the charcoal is made from sawmill waste using half orange brick kiln, the profit ranges from TShs (-209,982) to TShs 901,731 meaning that seven villages which currently have small amount of sawmill waste (<25 m^3) cannot break even by producing charcoal using the half orange brick kiln. However, field study is required to authenticate all the data and assumptions made in these computations.

There are three most common charcoal production methods i.e earth kilns, brick and metal kilns. In most parts of Tanzania, charcoal is produced in earth mound kilns made by covering a pile of logs with earth. On average these kilns give a kiln efficiency of 19%. The brick kilns can have kiln efficiency ranging from 25-35%. but its adoption is low due to: high initial investment cost, the need to process the billets into specific sizes which is time consuming; the need to transport the billets to kiln site since the kiln is not moveable, and the need to continuously smear with mud on the outer surface to cover cracks; this may be a problem especially in most of the charcoal producing areas where water is not readily available. However, the use of this type of kiln may be suitable for timber off-cuts centralized at some selected single points where sawmills were located. On the other hand Improved Earth Mound Kiln with better kiln management could be a better option for the scattered wood waste left in the forest due to its high wood-to-charcoal conversion efficiency, convenience and improved quality of charcoal produced.

There exist policies, strategies and legal frameworks that support charcoal production from standing wood which also apply to production of charcoal from wood wastes. Currently, there is A Guide to Sustainable Harvesting and Trade of Forest products from natural Forests of 2015. In addition to the instructions given in the 2007 Guideline, this guide provides the procedures for harvesting wood for charcoal making. A person involved in charcoal production needs to be registered by the village government and get a licence from the Forestry Officer or the District Forestry Manager which costs TShs 256,000/- per year. Other required charges include a royalty of TShs 12,500/- per 50 kg charcoal bag and tree planting fees which is 5% of the royalty. However, in practice the charcoal business is done through charcoal dealers who goes directly to the producers; buy the charcoal and transporting it after obtaining a transit pass from the District Forest Officer. With this arrangement, the dealer will be required to pay: the royalty, district and village fees charged on per bag basis. It is at this stage where royalty may be charged twice if the dealer is not made aware that royalty is already charged to the timber dealers. However, this is an opportunity for the villages to sell their charcoal from wood waste at a normal kiln site price plus royalty (i.e TShs 7,000/- + 12,500/- = 19,500/-). However, good price negotiation and stakeholders consultation skills are needed in order to make this happen.

This study revealed that, 10 out of 11 villages break even when producing charcoal from the wood waste. This suggests that the utilization of wood waste is by itself enough and it should not be supplemented by felling additional trees. This is because most of the timber tree species in the miombo woodlands are also preferred charcoal species. While harvesting trees for timber requires a minimum tree size of 45 cm Dbh, charcoal harvesting utilizes even small diameter trees and hence jeopardizing timber production.

4.2 Recommendations for further study (Phase II):

In collaboration with MCDI, TaTEDO and TFCG, field visits to the MCDI villages in Kilwa district will be done to assess not only the amount and composition of wood wastes but also how appropriate the waste is for the production of charcoal. The on-going experience of producing charcoal from wood wastes in the MCDI project area will also be assessed. These assessments will form a basis for the identification of potential charcoal production technologies to be trialled for the timber off-cuts (centralized) and other wood waste/branches (scattered in the forest). The trials will involve training of charcoal producers on a particular technology and field demonstrations on its use.

Further, during the field visits legal issues identified during the literature review in relation to charcoal production using wood waste from timber harvesting will be further explored. This will go hand in hand with the further assessment of the minimum annual timber harvesting quota as threshold for village to qualify for charcoal production from timber off-cuts/wood waste.

References

Akhator, P., Obanor; A. Ugege, A. 2017. Nigerian Wood Waste: A Potential Resource for Economic Development. *Journal of Applied Sciences and Environmental Management* (JASEM) 21(2): 246–251. Available online at [www.ajol.info and www.bioline.org.br/ja]. https://dx.doi.org/10.4314/jasem.v21i2.4.

Ayhan Demirbas, Waqar Ahmad, Rami Alamoudi & Manzoor Sheikh (2016). Sustainable charcoal production from biomass, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 38:13, 1882-1889, DOI: 10.1080/15567036.2014.1002955.

Butz, R.J. (2013) Changing land management: A case study of charcoal production among a group of pastoral women in northern Tanzania, Energy for Sustainable Development 17 (2013) 138–145, http://dx.doi.org/10.1016/j.esd.2012.11.001.

Falcão, M. P. 2008 "Charcoal production and use in Mozambique, Malawi, Tanzania, and Zambia: historical overview, present situation and outlook".

FAO (2017) *The charcoal transition: greening the charcoal value chain to mitigate climate change and improve local livelihoods*, by J. van Dam. Rome, Food and Agriculture Organization of the United Nations, 184pp. Available online at (www.fao.org/publications)

FAO 1976. Wood Chips Production, Handling and Transport. Rome, Italy.

FAO 1990. FAO 1990 Energy conservation in the mechanical forest industries, FAO Forestry Paper No. 93 Rome, Italy.

FBD (2007) Community Based Forest Management Guidelines for the establishment of Village and Forest Reserves and Community Forest Reserves, 56pp.

Hofstad, O. 1995. Wood and Deforestation by charcoal supply to Dar es Salaam. Journal of Environmental Economics and Management 33: 17–37. In: R. Janssen, D. Rutz (Eds.), Bioenergy for Sustainable Development in Africa, Springer, London (2012), pp. 75-80

Ishengoma, R. C. & Nagoda, L. 1991. Solid wood physically and mechanical properties, defects, grading and utilization as fuel. A compendium; NORAD. Ås NLH, Norway. 229 p.

Kaale B.K., Ndilanha A.E., Songela F. and Abdi H. (2000). Fuelwood and Charcoal Uses with Possible Alternative Energy Sources in Ikwiriri Township and Mbunju Mvuleni Village – Rufiji District. TaTEDO Technical Report No. 4 for Rufiji Environment Management Project (REMP).

Lima, M.D.R., Simetti, R., Assis, M.R. de, Trugilho, P.F., Carneiro, A. de C.O., Bufalino, L., Hein, P.R.G., Protásio, T. de P., 2020. Charcoal of logging wastes from sustainable forest management for industrial and domestic uses in the Brazilian Amazonia. Biomass and Bioenergy 142, 105804. https://doi.org/10.1016/j.biombioe.2020.105804

Madadi, L.M. 2000. Species preferences, tree sizes and kilns efficiency for charcoal making in Coast region: A case study for Mbwewe miombo woodland. Unpublished Special Project Report for Award of BSc. Degree in Forestry at Sokoine University of Agriculture, Morogoro, Tanzania, 24 pp. + II Annexes.

Malimbwi, R.E., E. Zahabu, L.M. Madadi, G.C. Monela, S. Misana and Jambiya, G.C. 2004. Tree Species Preferences, Volume Estimation and Charcoal Kiln Efficiencies in Eastern Tanzania Miombo Woodlands. In: *Proceedings of the 18th Annual General Meeting and Scientific Conference of Tanzania Association of Foresters on "Energy Crisis and Forest Destruction".* (Edited by Mushi, J.A. *et al)* 28 –30 October 2004, Morogoro Tanzania, pp 35-39.

Malimbwi, R.E., Zahabu, E., Misana S., Monela, G. C., Jambiya, G. C. & Mchome, B. 2005. Charcoal supplying po-tential of the miombo woodlands: The case of Kitulangalo area, Tanzania. Journal of Tropical Forest Science 17(2): 197–210

Malimbwi, R.E., Zahabu, E. and Mchome, B. 2007. Situation analysis of charcoal sector in Dar es Salaam: charcoal supply and consumption. Consultancy Report for WWF Tanzania Programme Office, Dar Es Salaam.

Malimbwi R.E., and Zahabu, E.M. 2008. Woodlands and the charcoal trade: the case of Dar es Salaam City**.** Working Papers of the Finnish Forest Res Ins, 98: 93-114

MCDI 2020. FORVAC Monthly Progress Report-Nachingwea District. 6pp.

Ministry of Natural Resources and Tourism (MNRT), 2015. Feasibility Study for a Management Model of Participatory Forest Management. Kilombero and Lower Rufiji Wetland Ecosystem Management Project. Ministry of Natural Resources and Tourism, Dar es Salaam. 127 p.

Miya M, Ball SMJ & Nelson FD (2012) Drivers of Deforestation and Forest Degradation in Kilwa District. Mpingo Conservation & Development Initiative (MCDI).

Monela, G. C., OKtingáti, A. & Kiwele, P. M. 1993. Socio-economic aspects of charcoal consumption and environmental consequences along Dar es Salaam – Morogoro highway, Tanzania. Journal of Forest Ecology and Management 58: 249–258

Ngaga, Y.M., **L.M Madadi,** C.L Mongo and J.J. Kigula. (2004). Energy Technology and Alternative Energy Sources. In: *Proceedings of the 18th Annual General Meeting of Tanzania Association of Foresters on "Energy Crisis and Forest Destruction".* (Edited by Mushi, J.A. *et al)* 28 –30 October 2004, Morogoro Tanzania, pp 12-18.

Numazawa, C.T.D., Numazawa, S., Pacca, S., John, V.M., 2017. Logging residues and CO 2 of Brazilian Amazon timber: Two case studies of forest harvesting. Resources, Conservation and Recycling 122, 280–285. https://doi.org/10.1016/j.resconrec.2017.02.016

Sawe, 2012. Charcoal and firewood production and use in Africa**.** Web references [http://www.fao.org/sustainable-forest-management/toolbox/modules/wood-energy/basic-knowledge/en/?type=111]

Schure, J., Ingram, V., Sakho-Jimbira, M. S., Levang, P., & Wiersum, K. F. (2013). Formalisation of charcoal value chains and livelihood outcomes in Central- and West Africa. Energy for Sustainable Development, 17(2), 95-105. https://doi.org/10.1016/j.esd.2012.07.002

SEI (2016) Annual Report 2016. Available online at [https://mediamanager.sei.org/documents/Publications/SEI-Annual-Report-2016.pdf] Site visited 25th November 2020.

Songea District Council, 2020. Management Plan for Lihiga Village Land Forest Reserve, in Ndogosi Village. 48 p.

Temu, A.B. (1979). Estimation of millable timber volume in miombo woodlands. University of Dar es Salaam, Division of Forestry Record No. 7. 11pp.

UNDP, 2015 Assessment of Development Results: United Republic Of Tanzania. Edited by Catharine Way, e-ISBN: 978-92-1-057271-2. 164pp.

United Republic of Tanzania (URT), 1998. *National Forest Policy*. Forestry and Beekeeping Division, Ministry of Natural Resources and Tourism, Dar es Salaam. 59 p.

United Republic of Tanzania (URT), 1999. *Village Land Act* (and Regulations) No. 5 of 1999. Ministry of Lands and Human Settlements. Government Printer. Dar es Salaam, Tanzania.

United Republic of Tanzania (URT), 2002. *Forest Act* No. 14 of 2002. Forestry and Beekeeping Division, Ministry of Natural Resources and Tourism, Dar es Salaam. 127 p.

United Republic of Tanzania (URT), 2004. *Environmental Management Act* of 2004. Vice Presidents Office – Environment, Dar es Salaam 158 p.

United Republic of Tanzania (URT), 2004. *Forest Act* Notice of 2004. Forestry and Beekeeping Division, Ministry of Natural Resources and Tourism, Dar es Salaam. 119 p.

United Republic of Tanzania (URT), 2009. *Water Resources Management Act* 2009. Ministry of Water. Government Printer. Dar es Salaam, Tanzania.

United Republic of Tanzania (URT), 2015. A Guide to Sustainable Harvesting and Trade of Forest products from natural Forests. https://www.tfs.go.tz/index.php/en/resources/view/mwongozo-wa-uvunaji-endelevu-na-biashara-ya-mazao-ya-misitu-yanayovunwa-kat

United Republic of Tanzania (URT), 2017. Fourteenth Schedule of Forest (Amendments) Regulations 2017 Tanzania Forest Services Agency, Ministry of Natural Resources and Tourism, Dar es Salaam. 20 p.

URT (2019) *Assessing Potential and Identifying Optimal Strategies for National Charcoal sub-Sector Development in Tanzania*. National Task Force on Charcoal Sub-Sector Assessment Draft Final Report submitted to Forestry and Beekeeping Division (FBD).

URT. (2017). Forest Reference Emission Levels (FREL Tanzania), 56pp.

van Beukering, P., Kahyarara, G., Massey, E., di Prima, S., Hess, S. & Geofrey, V. 2007. Optimization of the charcoal chain in Tanzania. \prem Working Paper [Cited 27 March 2007].

VPO (Vice President’s Office) (2013). National Strategy for Reduced Emissions from Deforestation and Forest Degradation (REDD+)

Wenzl, H. F. J. 1970. The Chemical Technology of Wood. New York, USA: Academic Press.

Zoya, T. (2013) Utilization of Wood Waste: Logging and Industrial Waste. ARID Agriculture University, 12pp.