

EVALUATING DRY WOODLANDS DEGRADATION AND ON-FARM TREE MANAGEMENT IN KENYAN DRYLANDS

DISSERTATION

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Abstract

Tropical dry forests and woodlands are comprised of trees that are specially adapted to the harsh climatic and edaphic conditions, providing important ecosystem services for communities in an environment where other types of tropical tree species would not survive. Due to cyclic droughts which results in crop failure and death of livestock, the inhabitants turn to charcoal production through selective logging of preferred hardwood species for their livelihood support. This places the already fragile dryland ecosystem under risk of degradation, further impacting negatively on the lives of the inhabitants.

The main objective of the doctoral study was to evaluate the nature of degradation caused by selective logging for charcoal production and how this could be addressed to ensure the woodlands recover without impacting negatively on the producers' livelihoods. To achieve this objective, the author formulated four main specific objectives namely: 1) To assess the impact of selective logging for charcoal production on the dry woodlands in Mutomo District; 2) To evaluate the characteristics of the charcoal producers that enforces their continued participation in the trade; 3) To assess the potential for adoption of agroforestry to supply wood for charcoal production, and; 4) To evaluate the potential for recovery of the degraded woodlands through sustainable harvesting of wood for charcoal production. The findings based on the four objectives were compiled into to four scientific papers as a part of a cumulative dissertation. Three of these papers have already been published in peer reviewed journals while the final one is under review.

The study used primary data collected in Mutomo District, Kenya through a forest inventory and household survey both conducted between December 2012 and June 2013. The study confirmed that the main use of selectively harvested trees is charcoal production. Consequently, this leads to degradation of the woodlands through reduction in tree species richness, diversity and density. Furthermore, the basal area of the preferred species is significantly less than the other species. However, the results also show that the woodlands have a high potential to recover if put under a suitable management regime since they have a high number of saplings. The study recommends a harvesting rate of 80% of the Mean Annual Increment (MAI), which would ensure the woodlands recover after 64 years. This is about twice the duration it would take if no harvesting is allowed but it would be easier to implement as it allows the producers to continue earning some money for their livelihood.

The study also demonstrates that charcoal production is an important livelihood source for many poor residents of Mutomo District who have no alternative sources of income. As such, addressing the problem of this degradation would require an innovative approach that does not compromise on the livelihoods of these poor people. An intervention that involves total ban on charcoal production would therefore not be acceptable or even feasible unless people are assured of alternative sources of income. The study recommends an intervention with overarching objectives geared towards: 1) diversification of the livelihood sources of the producers to gradually reduce their dependence on charcoal; 2) introduction of preferred charcoal trees in agroforestry systems especially through Farmer Managed Natural Regeneration (FMNR) to reduce pressure on the natural woodlands; 3) controlled harvesting of hardwoods for charcoal production from the natural woodlands at a rate below the MAI; 4) promotion of efficient carbonisation technologies and practices to increase charcoal recovery; 5) promotion of efficient combustion technology and cooking practices to reduce demand side pressure, and; 6) encourage fuel switching to other fuels like LPG and electricity.

Key words: Tropical dry woodlands and forests; Charcoal production; Forest degradation; Farmer Managed Natural Regeneration (FMNR); Sustainable biomass; Forest Mean Annual Increment.

Dedication

This PhD thesis is dedicated to my family who stood by me and gave me moral support during my studies in Germany and Kenya.

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List of abbreviations

ASAL	Arid and Semi-Arid Lands
CNRD	Center for Natural Resources and Development
DBH	Diameter at Breast Height
FAO	Food and Agriculture Organisation of the United Nations
FMNR	Farmer Managed Natural Regeneration
GoK	Government of Kenya
HDI	Human Development Index
ICRAF	The World Agroforestry Center
IUFRO	Union of Forestry Research Organizations
KES	Kenya Shillings
KNBS	Kenya national Bureau of Statistics
M.A.S.L	Meters Above Sea Level
PCA	Principal Component Analysis
PHR	Poverty Headcount Ratio
SSA	Sub-Saharan Africa

CHAPTER 1. INTRODUCTION

1.1. Background

Tropical dry forests and woodlands are vegetation formations which comprise of scrubs, bushlands, thickets, wooded grasslands, and dense woodlands (Chidumayo & Gumbo, 2010). They occur in Arid and Semi-arid lands (ASAL's) characterized by about 300 to 1200 mm of annual rainfall and a dry period of five to ten months (FAO, 2000). The dry woodlands are comprised of trees that are specially adapted to the harsh climatic and edaphic conditions (Chidumayo & Gumbo, 2010; Zida *et al.*, 2007). As such, they are able to provide important ecosystem services to the agro-pastoral and pastoral communities in an environment where other types of tropical tree species would not survive (Maass *et al.*, 2005). Among the ecosystem services they provide are woodfuel, timber and non-timber products, climate regulation, soil fertility maintenance, flood control as well as carbon sequestration and storage (Kiruki *et al.*, 2016; Becknell *et al.*, 2012; Grace *et al.*, 2006; Maass *et al.*, 2005).

According to Murphy & Lugo (1986), tropical dry forests and woodlands constitute 42% of the open and closed forests within the sub-tropical landmass, while Chidumayo & Gumbo (2010) reported that they cover approximately 17.3 million km². Chidumayo & Gumbo (2010) further reported that in Sub-Saharan Africa (SSA), the dry forests and woodlands are found in 31 countries and are the dominant vegetation in 63% of these. In addition, Pricope *et al.* (2013) state that about 1.1 billion people live in the African drylands with a majority of them living below or close to the poverty line. The wide spatial coverage of the drylands and the critical role they play in livelihood support to the inhabitants means that any threat to their existence would have catastrophic effects in SSA.

Despite the undisputed importance of the dry forests and woodlands as enumerated above, they have been indiscriminately subjected to unsustainable land-use practices leading to either deforestation or degradation (Butz, 2013; Chidumayo & Gumbo, 2013; Chidumayo & Gumbo, 2010; Lambin *et al.*, 2003). Deforestation occurs when all the vegetation is cleared for agriculture or other land uses (Chidumayo, 2013; Grainger, 1999), while degradation is defined as the temporary or permanent reduction in the density, structure, species composition or productivity of a forest or woodland or a reduction in its capacity to produce

wood biomass or regenerate (Kiruki *et al.*, 2016; Butz, 2013; Chidumayo, 2013; Chidumayo & Gumbo, 2013; Grainger, 1999).

Chidumayo & Gumbo (2010) reported that dry forests and woodlands in western and eastern Africa have been the most affected by agricultural expansion with over 50% of dry forests having already been converted to agricultural land. Degradation through extraction of wood and non-wood forest products like charcoal and building materials further exacerbates the condition of the remaining woodlands (Kiruki *et al.*, 2016; Butz, 2013; Chidumayo & Gumbo, 2010), with Lambin *et al.* (2003) reporting that the annual rate of degradation of the forests and woodlands in Africa is almost 50% that of deforestation. In the Eastern Horn of Africa region, Pricope *et al.* (2013) demonstrated that between 2001 and 2009, up to 16% of woodlands had been degraded to grasslands or bare land through: (a) unsustainable wood harvesting to meet rapidly increasing population woodfuel demand and; (b) reduced precipitation that has affected natural regeneration. Some of the most affected areas are: northwestern Ethiopia; Eastern Kenya (near the border with Somalia and around Dadaab refugee Camp) and; southern tip of Somalia along the Indian Ocean Coast. The degradation is one of the main causes of vulnerability of pastoral and agro-pastoral economies in SSA (Butz, 2013).

Over 80% of Kenya's land area is arid or semi-arid and is covered by grasslands and sparse woody vegetation consisting of dry bush and open wooded grassland (GOK, 2010). These wooded lands in the ASAL's are generally classified as either woodlands or bushlands according to the FRA 2000 classification (Wass, 2000) and are collectively referred to as dry woodlands. In total, the country has about 37 million hectares of dry woodlands (Wass, 2000).

The Kenyan drylands play an important role for the national economy, as they account for about 80% of the country's ecotourism interests, and are home to about 75% of the country's wildlife and 46% of the livestock population (Barrow & Mogaka 2007). Furthermore, they are a major supplier of domestic energy in the form of woodfuels, especially charcoal for which 91% of the wood is harvested from the natural dry woodlands (KFS & KNBS, 2009).

34% of the Kenyan population live in the ASAL's where they practice subsistence farming, agro-pastoralism or nomadism (Pricope *et al.*, 2013; Worden *et al.*, 2009; Barrow & Mogaka, 2007). Cyclic droughts which result in crop failure and death of livestock leave these already vulnerable inhabitants without any source of livelihood (Barrow & Mogaka, 2007). Charcoal

production has become one of the most important coping mechanisms, especially in areas in close proximity to urban centers like Nairobi and Mombasa (Kiruki *et al.*, 2016; Ahrends *et al.*, 2010; Muyanga, 2005). With time, driven by free availability of woodstock, minimal capital requirements and insatiable demand for charcoal from the rapidly growing urban centers, some people who initially engaged into charcoal production as a coping mechanism adopt it as a full-time economic activity (Schure *et al.*, 2014; Wunder, *et al.* 2014; Butz, 2013; Kutsch *et al.*, 2011).

According to Bailis (2009), charcoal production in Kenya has for a long time been associated with agricultural expansion especially in the Rift Valley region. In this case, charcoal is a bi-product of agriculture and there is no chance of the woodland recovery. However, production of charcoal through selective logging is quite common in the drylands in the east of the country, extending all the way to the coastal region (Kiruki *et al.*, 2016; Mugo & Poulstrup, 2003). These regions are key suppliers of charcoal to Nairobi, Mombasa and other surrounding towns. As a consequence of the selective logging, woodland degradation is a common occurrence with the residual woodlands comprised mainly of juvenile trees of the preferred species and softwoods that are not favored for charcoal production (Kiruki *et al.*, 2016). Indeed, Mugo & Poulstrup (2003) reported that tree felling is so indiscriminate, the charcoal producers even fell trees traditionally preserved for animal fodder thus increasing their vulnerability in time of drought.

To address problems associated with unsustainable charcoal production in SSA, researchers have made several wood resource management recommendations to supplement the markets, policy and legal framework reforms already underway in many countries. Key aspects among these recommendations are:

1. Supporting on-farm feedstock/tree production through agro-forestry systems and woodlots (Iiyama, 2014; Bailis, 2009; Arnold and Persson, 2003);
2. Use of improved carbonization and combustion technologies to reduce wood and charcoal demand, respectively (Iiyama, 2014; Kutsch *et al.*, 2011; Bailis, 2009);
3. Sustainable management of wood resources by ensuring extraction does not surpass re-growth and the harvested sites are allowed to regenerate (Chidumayo & Gumbo, 2013 ; Kutsch *et al.*, 2011; Otuoma *et al.*, 2011; Girard, 2002).

This doctoral thesis presents the findings of a study conducted in Mutomo District in Kenya between 2012 and 2015 that shows how the woodlands in the area have been degraded

through selective logging for charcoal production. The thesis is cumulative, with key findings which are presented as chapters five to seven already published in internationally recognised peer reviewed journals.

The woodland degradation following selective logging is manifested through reduction in targeted tree species density and basal area as well as general reduction in tree diversity and evenness. Despite this, charcoal plays a key role in livelihoods support in many dry lands, Mutomo included, where the majority of the people depend on rain-fed agriculture (Kiruki *et al.*, 2016; Iiyama *et al.*, 2014; Zulu & Richardson, 2012; Muyanga, 2005). Addressing the degradation therefore needs a holistic approach that promotes woodlands recovery without compromising on the livelihoods of the poor rural producers.

Based on this understanding, this thesis analyses the nature of the charcoal producers in the study area and their level of dependence (in terms of income) on charcoal. This is important so as to shed light on the impact any measure undertaken to address the degradation would have in terms of the number of people to be affected and their adaptive capacity (ability to switch to alternative livelihood sources) in case charcoal production is stopped.

In addition, the thesis evaluates the capacity of the inhabitants to adopt trees on-farm (based on their socio-economic characteristics) and their preferred mode of tree adoption and management practices. This information sheds light on the viability of promoting agroforestry trees for charcoal production to reduce pressure on the natural woodlands. Moreover, diversification into agroforestry systems gives the farmers an alternative source of income which would reduce the high dependency on charcoal.

1.2. Structure of dissertation and synopsis of the publications

This cumulative dissertation presents the results of the study conducted in Mutomo District in nine chapters. Chapter one is the introduction of the study, chapter two the state of the art, chapter three the study objectives and chapter four the methods and data analysis techniques used. Chapters five, six and seven address the study research specific objectives and their manuscripts have either been published or submitted for publication to peer reviewed journals. Chapter five addresses degradation of the dry woodlands due to charcoal production. This work has been published in the Journal of Arid lands. Chapter six characterises the charcoal producers based on their level of dependency on charcoal income.

This work has been published in the Energy for Sustainable Development journal. Chapter seven evaluates how farmers adopt and manage trees for different utilities, including for charcoal production, in their agroforestry systems. This work has been published in the Agroforestry Systems Journal. The final chapter presents a summary of the main findings of the study and the conclusions.

CHAPTER 2. STATE OF THE ART

2.1. Charcoal production and dry woodlands degradation

The debate on the impact of woodfuel extraction (firewood and charcoal) on dry woodlands is highly divisive (Butz, 2013; Chidumayo & Gumbo, 2013). Some authors argue that charcoal production leads to degradation of woodlands thus compromising their capacity to provide ecosystem services to sustain livelihoods (Iiyama *et al.*, 2014; Ahrends *et al.*, 2010). Others, however, dispute this assertion stating that unless the land is put under cultivation, the woodlands have the capacity to regenerate to their near original state (Chidumayo & Gumbo, 2013; Zulu & Richardson, 2013; Arnold *et al.*, 2006).

There is, however, a general consensus that woodlands in close proximity to urban centres, which happen to be the largest consumers of charcoal in SSA, are mostly subjected to sustained large-scale charcoal production which leaves them little time to regenerate and thus susceptible to degradation (Butz, 2013; Chidumayo & Gumbo, 2013; Ahrends *et al.*, 2010). With urbanization in SSA — mainly propelled by rural urban-migration and high population growth rates — projected to double by 2030, demand for charcoal and consequently pressure on existing wood resources is expected to continue rising (Iiyama *et al.* 2014; Zulu & Richardson, 2012; Maes & Verbist, 2012).

Harvesting for charcoal production is done either through clear felling of an entire block of woodland or selective logging of preferred species and sizes (Butz, 2013; Chidumayo & Gumbo, 2013; Arnold *et al.*, 2006). Both cases lead to woodland degradation when the woodland is not converted to agricultural land. Forest and woodland degradation is defined as temporal or permanent reduction in the density, structure, species composition or productivity of vegetation cover (Chidumayo & Gumbo, 2013; Chidumayo & Gumbo, 2010; Lambin *et al.*, 2003). Nevertheless, studies have shown that with proper management where the affected woodlands (especially those dominated by coppicing species) are given enough time to re-grow, they have the ability to recover (Butz, 2013; Otuoma *et al.*, 2011; Luoga *et al.*, 2004). However, if the harvesting is not properly managed, this has the potential to materially alter the composition and physiognomy of the woodlands and might lead to undesirable ecological consequences (Ahrends *et al.*, 2010; Okello, 2001).

In spite of this, the effect of charcoal production on the woodland structure and dynamics in terms of tree species richness, diversity, density and regeneration has received little attention and thus is not well understood (Butz, 2013; Ahrends *et al.*, 2010). This problem is occasioned by methodological and data collection constraints (De la Barreda-Bautista *et al.*, 2011; Archibald & Scholes, 2007; Mwampamba, 2007; Arnold & Persson, 2003) as monitoring of the woodlands through remote sensing has proven difficult due to annual changes in leaf display and the presence of a substantial grass layer (De la Barreda-Bautista *et al.*, 2011; Archibald and Scholes, 2007). As such, many countries in SSA do not have (accurate) data on the extent of the dry forests and woodlands as well as the rate of biomass extraction and use (Iiyama *et al.*, 2014; Pricope *et al.*, 2013; Chidumayo & Gumbo, 2013; Chidumayo & Gumbo, 2010; Arnold & Persson, 2003; Girard, 2002). Lack of credible woodfuel data was actually blamed for underestimation of the forests and woodlands productivity and grossly overestimated woodfuel consumption levels that led to declaration of an impending woodfuel crises in Africa in the 1980s that never came to pass (Mwampamba, 2007; Arnold & Persson, 2003; Girard, 2002).

2.2. Charcoal production and poverty alleviation

It is undisputed that charcoal is the most important domestic fuel in urban centers of many SSA countries (Butz, 2013; Chidumayo & Gumbo, 2013; Arnold & Persson, 2003; Girard, 2002) and will remain so in the foreseeable future (Iiyama *et al.*, 2014; Zulu & Richardson, 2012; Arnold *et al.*, 2006). In addition, it provides millions of jobs directly to producers, transporters and traders, who in turn support millions of dependents (Iiyama *et al.*, 2014; Schure *et al.*, 2014; Mwampamba *et al.*, 2013). However, with producers receiving very low returns, some researchers argue charcoal production is more of a poverty trap for the poor producers (Zulu & Richardson, 2012; Angelsen & Wunder, 2003), while others report that it can give the poor people a pathway out of poverty as resulting revenues could contribute to household savings, investment, wealth accumulation and asset building (Schure *et al.*, 2014; Khundi *et al.*, 2011).

Even though the charcoal-poverty discourse is quite divisive, there is general consensus that the poor small-scale producers spend most of their income on sustenance leaving them little or no savings for alternative supplementary investment (Schure *et al.*, 2014; Arnold *et al.*, 2006). However, the large-scale producers normally operate production as a business

enterprise and have higher returns, which after expenses leave surplus for saving (Schure *et al.*, 2014; Kambewa *et al.*, 2007). The savings may be invested in other sectors like agriculture or retail business which leads to diversification of their revenue portfolio, thus reducing their vulnerability (Schure *et al.*, 2014; Khundi *et al.*, 2011).

As such, the scale of charcoal production and level of dependence on resulting income determines whether a producer will be locked in perpetual charcoal dependence or is able to use charcoal revenues to improve the well-being of his family. It is therefore important to recognize the heterogeneous nature of the producers when addressing charcoal sustainability challenges as any measures taken will affect these groups differently. For example, the poor and high charcoal-income dependent households will be hardest hit by a production ban while the well-up households with diversified farm and off-farm income portfolio will be much less affected.

2.3. Tree adoption and management in drylands' agroforestry systems

Trees in dryland agroforestry systems play an important role in supporting rural livelihoods by providing essential ecosystem goods and services like food, fuel, fodder, medicine, building materials, soil erosion and flood control as well as watershed and biodiversity protection (De Leeuw *et al.*, 2014; FAO, 2013). In particular, trees play a key role in resilience building during crop failure due to droughts. For example, fodder trees are the main source of browse for animals (Mortimore & Turner, 2005; Mortimore & Adams, 2001) while charcoal production is a major source of subsistence income (de Leeuw *et al.* 2014; Jama & Zeila, 2005).

The high dependency on trees for timber, woodfuel and non-timber products in natural woodlands leads to their degradation mostly through harvesting at rates exceeding the natural re-growth rates (Iiyama *et al.*, 2014; Chidumayo & Gumbo, 2010; Jama & Zeila; 2005). To reduce the pressure on the natural woodlands, it is advisable that farmers adopt agroforestry systems for specific products highly demanded within their community but deemed scarce in the natural woodlands (Vallejo *et al.*, 2014; FAO, 2013; Fifanou *et al.*, 2011). Indeed, adoption of charcoal production trees species in agroforestry systems has been regularly put forward as a suitable solution to forests and woodlands degradation due to charcoal production (de Leeuw *et al.* 2014; Iiyama *et al.*, 2014; Chidumayo & Gumbo, 2010; Jama & Zeila, 2005).

There is general lack of knowledge on the agroforestry systems in drylands especially on the choice of species, mode of management, and intensity of adoption (De Leeuw *et al.*, 2014; Chidumayo & Gumbo, 2010). This could be due to; 1) the structural complexity of the system and multiplicity of derived products and services (Abebe *et al.*, 2013; Fentahun & Hager, 2010; Sood & Mitchell, 2009) and; 2) the heterogeneity of the systems, even under similar biophysical conditions, influenced by the socio-economic conditions and needs of individual households (Dawson *et al.*, 2014; Sabastian *et al.*, 2014).

CHAPTER 3. OBJECTIVES

Many dry woodlands in SSA, have been degraded through indiscriminate felling of trees for charcoal production (Kiruki *et al.*, 2016; Iiyama *et al.*, 2014). In the case of Mutomo, this is mostly done through selective logging of preferred hardwood¹ tree species known to produce dense charcoal believed to burn for a longer time (Kiruki *et al.*, 2016; Mutimba & Barasa, 2005; Muyanga, 2005). However, charcoal production is a livelihood activity that provides the poor rural people with income generating opportunity in an area where few such opportunities exist and thus cannot be simply wished away. A holistic approach to address the problem of dry woodlands degradation through sustainable management without compromising on the livelihoods of the poor charcoal producers is therefore needed.

The overall objective of this doctoral thesis is to evaluate the nature of degradation caused by selective logging for charcoal production and how this could be addressed to ensure woodlands recovery without negatively impacting on the poor producers' livelihoods. The specific objectives of the study are;

1. To assess the impact of selective logging for charcoal production on the dry woodlands in Mutomo District.
2. To evaluate the characteristics of the charcoal producers that enforces their continued participation in the trade.
3. To assess potential for adoption of agroforestry to supply wood for charcoal production.

¹ This categorization is based on the local people interpretation according to the density of charcoal produced and not on the scientific classification of angiosperms (hardwoods) and gymnosperms (softwoods)

CHAPTER 4. METHODS

4.1. Study area

This study was conducted in Mutomo District of Kitui County in the former Eastern Province of Kenya. The district has an area of 20,402 km², of which 6,290 km² is located within Tsavo East National Park (see Figure 4-1). Its altitudes range from 400 m a.s.l. in the floodplains in the south to 900 m a.s.l. on the Yatta plateau in the west (GOK, 2009). The district is categorized as arid and semi-arid with limited agricultural potential due to high temperatures ranging between 20-34°C and low rainfall (500-1050 mm per annum), which 70% of the times is below expected levels (Muyanga, 2005).

The natural vegetation in Mutomo District belongs to the Southern Acacia-Commiphora bushland and thicket ecoregion, which is part of the tropical and subtropical grasslands, savannas, and shrublands biome according to the WWF classification of terrestrial biomes and ecoregions (<http://worldwildlife.org/biomes>). The ecoregion covers about 36.4% of the country, mostly in its Eastern side, and is characterised by dense bushland of 3-5 meters in height with occasional emergent trees of about 10 meters in height. The dominant tree species are *Acacia spp.* and *Commiphora spp.* (Millington *et al.*, 1994). Tsavo East National Park, which occupies the lower side of the district was established in 1948. The park is protected with an electric fence since 2003 to reduce human-wildlife conflicts.

The district has a population of about 180,000 people living in 32,896 households (KNBS, 2010). About 53% of the men and 89% of the women are illiterate (GOK, 2009), while 66% of the population live below the poverty line (GOK, 2009; Muyanga, 2005). In addition, the district lacks proper infrastructure like paved roads, clean water supply and electricity (GOK, 2009). For example, it is common for people to walk over 5 km to access basic facilities like schools, water dams and health centres.

The average land holding is five hectares even though most of the land is categorized as government trust land with only 3% of the households holding title deeds (GOK, 2009). Subsistence rain-fed agriculture is the main source of livelihood with the majority of the people growing maize, while others grow dryland crops such as pigeon peas, cow peas, green grams, sorghum and millet (GOK, 2009; Kitonga, 2009). Other economic activities include charcoal production, bee keeping, livestock rearing, poultry farming and sand and ballast

quarry mining (GOK, 2009). However, the unreliability of rainfall with the district experiencing droughts every second year makes the inhabitants highly vulnerable to drought-related risks (GOK, 2009; Muyanga, 2005).

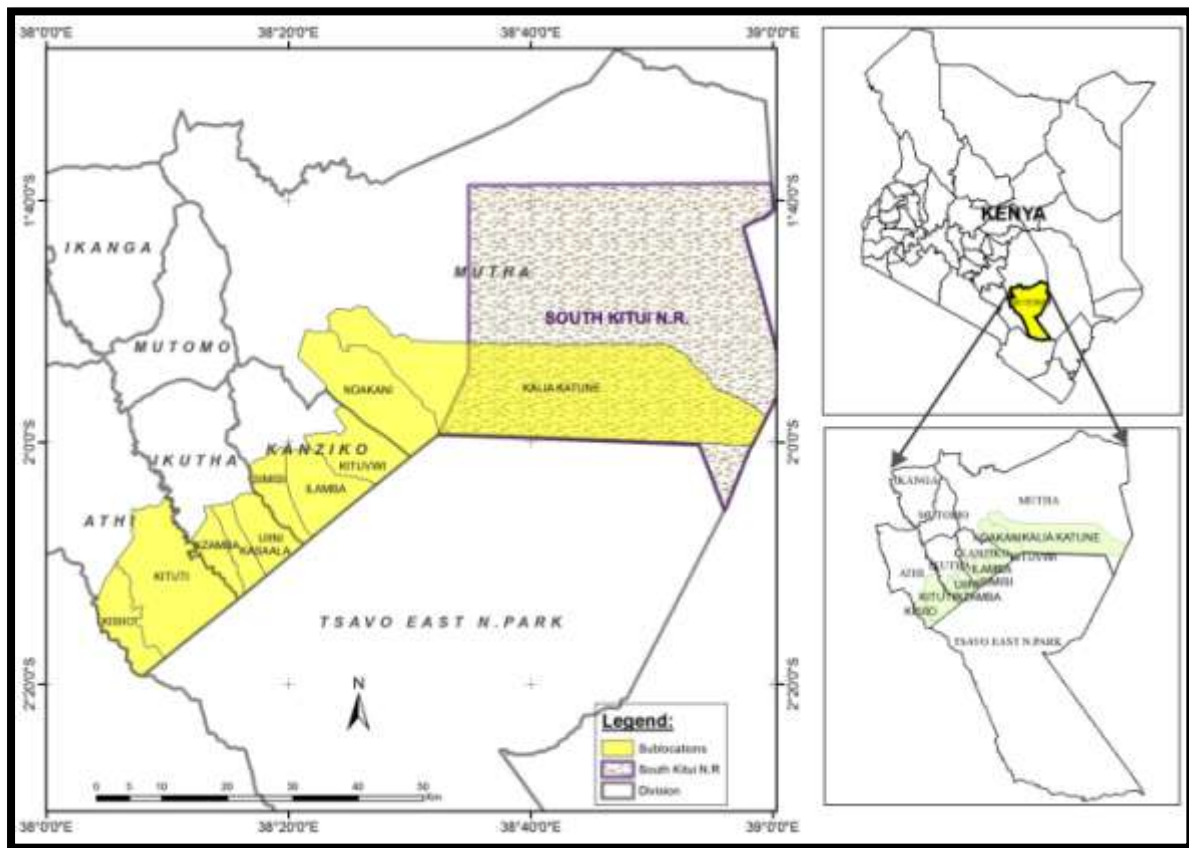


Figure 4-1: Map of Mutomo District showing the divisions

Source: own elaboration

Due to remoteness, lack of basic infrastructure, illiteracy and harsh climatic conditions, the residents have access to very few non-farming income generating opportunities except for the provision of basic services like education and health. Most of the people have to contend with casual employment (menial jobs like tilling land and fetching water) or consumer goods retail businesses. Charcoal production has also emerged as an important coping mechanism since 1998 with about 66% of the population involved in production (Kiruki *et al.*, 2016).

Charcoal production started in 1998 mostly as a coping strategy to drought (Kiruki *et al.*, 2016). However, the District Forest Officer reported that it has currently developed into a widespread economic activity, mostly driven by urban growth in Nairobi and other neighboring urban centres like Kitui and Machakos. Many people are currently engaged in charcoal production as a fulltime employment. As a consequence, charcoal production in

Kitui County as a whole, is reported to have increased from 400,000 bags (each weighing around 35 kg) in 2001 (Practical Action, 2010) to over a million bags in 2013 (GOK, 2013). Of this total, the local forest officer estimated that over 60% of the county's charcoal production comes from Mutomo District (equivalent to 600,000 bags).

The *Acacia* species, among other hardwoods, are specifically targeted for charcoal production while the *Commiphora* species and other softwoods are mostly left standing. This selective felling has in some areas resulted in a residual forest dominated by softwood tree species (Kiruki *et al.*, 2016).

All the charcoal is produced using traditional earth mound kilns whose efficiencies are estimated to range from 8 to 20% depending on factors such as the producer's kiln building and operation skills and the moisture content of wood (Chidumayo & Gumbo, 2013). This type of kiln is preferred mostly because it is cheap to establish as it involves covering the wood with soil and grass freely available on harvesting sites (Kambewa *et al.*, 2007; Luoga *et al.*, 2000). The charcoal is then packed in ≈ 35 kg bags and sold to brokers, transporters or resellers as observed elsewhere in Kenya (Mutimba and Murefu, 2005).

The district and the country as a whole did not have a charcoal regulatory framework until 2009 when the government gazetted the Charcoal Rules (2009). The lack of regulation has been blamed for: a) promoting and/or maintaining inequality in revenue sharing across the supply chain, from producers to urban retailers; b) encouraging corruption along transportation routes, and; c) perpetuating indiscriminate cutting of wood (Njenga *et al.*, 2013; Mutimba & Murefu, 2005).

The charcoal Rules (2009) were made to regulate production, transportation and sale of charcoal. Through this legislation, all charcoal producers are supposed to be organized in groups and licensed after demonstrating that they would only produce charcoal from sustainably grown trees (GOK, 2013). Other conditions they should meet to qualify for licensing are: a) description of where the charcoal will be produced, the type and volume of trees to be used and the carbonization technology; b) development of a reforestation/conservation plan that outlines how the cut trees/ shrubs will be replaced and managed and; c) clearance from the local environment committee that is mandated to assess the environment situation in the area to avoid land degradation (Luvanda *et al.*, 2016; Kitui County Government, 2014; wa Gathui *et al.*, 2011). To date, the Charcoal Rules (2009) remain largely unenforced in many parts of the country and some of the stakeholders do not

even know of their existence (Luvanda *et al.*, 2016; Iiyama *et al.*, 2014b; wa Gathui *et al.*, 2011). This is occasioned by corruption, inconsistencies in the regulations and delays in issuing of licenses (Iiyama *et al.*, 2014b; Maitai, 2014).

The Kenyan constitution (2010) devolved the forestry and energy docket, which are concerned with charcoal production to the county level. As per the requirement of the constitution, the County Government of Kitui (where Mutomo District is located) legislated the Kitui County Charcoal Management Act (2014), which is aligned with the Charcoal Rules (2009) to regulate charcoal production in the County (County Government, 2014). However, just as is the case with the Charcoal Rules (2009), the County Charcoal Management Act (2014) remains largely unenforced and charcoal production in the county is still unregulated.

4.2. Research approach and data collection

The study was done in two phases: 1) A forest inventory of the woodlands in the southern part of Mutomo District and Northern part of Tsavo East National Park, conducted between December 2012 and January 2013 and; 2) a household survey done by administering a structured questionnaire in five sub-locations in June 2013.

The first phase was primarily to collect ecological data that was used to: a) evaluate the status of dry woodlands and the nature of degradation. In the second phase, household socioeconomic characteristics and tree planting and management data was collected to be used to: a) evaluate the scale and patterns of charcoal production; b) assess the socioeconomic drivers to charcoal production and the level of dependence on charcoal, and; c) assess the tree planting and management practices in agroforestry systems.

The forest inventory was done in 64 sample plots, each measuring 20m by 20 m, of which 45 were in the unprotected woodlands and 19 were control plots in the Tsavo East National Park. The square plots were chosen as they were easy to set up using a tape measure and they have been found to be more cost effective than circular and rectangular ones (Anthonie & Alparslan, 2007). When conducting the forest inventory, the International Union of Forestry Research Organizations (IUFRO) recommendation as described in Anthonie & Alparslan (2007) were used. The IUFRO describes how to take measurements for trees growing on slopes, for trees with irregular bole shapes at breast height, for leaning and forked trees and for trees with excessive butt swell (See figure 4-2). All trees with a diameter at breast height

(DBH) ≥ 5 cm were measured and identified by species with the help of the local forest officers. Saplings (those below 5cm DBH) and stumps were also identified, measured and recorded. Finally, the number of charcoal kilns within a radius of 50 meters from the centre of the plot was recorded.

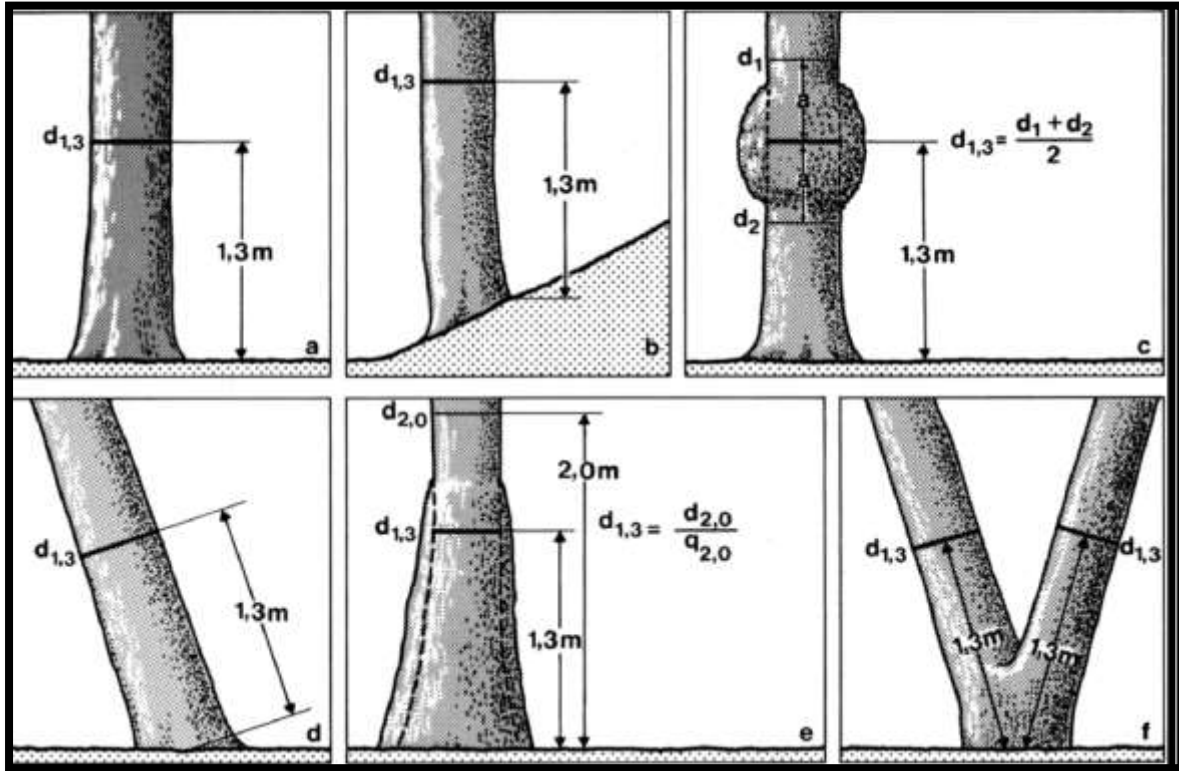


Figure 4-2: Locating the tree breast height

Source: Anthonie & Alparslan, 2007

The second phase was done in June 2013 through a household survey by administering a structured questionnaire in five sub-locations (the smallest administrative unit) of the district namely; Kalia Katune, Kituvwi, Ilamba, Kasaala and Kituti (see Figure 4-1). The questionnaire was divided into three main parts intended to collect information on: 1) household socio-economic characteristics; 2) household tree adoption and management in agroforestry systems; and 3) charcoal production and sale (see a sample questionnaire in appendix 1).

The study opted for a household survey because it affords wider geographical coverage through selection of a representative sample, which reduces the cost and allows for in-depth analysis of a subject matter compared to a census (United Nations, 2005). Respondent

households were selected from a list of all the households supplied by the local administration through systematic random sampling. This was done by first selecting the first household randomly from the first 20 in the list and then selecting each 20th household thereafter. A total of 189 households representing 5% of the total households in the 5 sub-locations were interviewed with the household head or the spouse acting as the respondent.

More on the specific methods applied in different sections of the study is further explained in the respective chapters (from chapter five to seven) of the thesis.

CHAPTER 5. CHARCOAL PRODUCTION THROUGH SELECTIVE LOGGING LEADS TO DEGRADATION OF DRY WOODLANDS: A CASE STUDY FROM MUTOMO DISTRICT, KENYA

Geoffrey M.Ndegwa, Udo Nehren, Friederike Grüninger, Miyuki Iiyama, Dieter Anhuf.

Journal of Arid Land. August 2016, Volume 8, Issue 4, pp 618–631

Abstract

Provision of woodfuel is an important ecosystem service of dry forests and woodlands. However, charcoal production through selective logging of preferred hardwood species has the potential to alter the physiognomic composition of the residual or re-growth woodlands and may lead to their deterioration and degradation. This study, conducted through forest inventory in Mutomo District in Kenya, assessed the impact of charcoal production on unprotected dry woodlands in terms of tree density, targeted species basal area, species richness, evenness and Shannon diversity. The parameters of the disturbed woodlands were evaluated for significant differences with those of the neighbouring protected Tsavo East National Park, which served as a reference for an ecologically undisturbed ecosystem. By evaluating the consequence of tree harvesting for charcoal production, this study confirmed the overall significant differences between the protected and unprotected woodlands in all the tested parameters. To confirm if the differences in the land-covers of the woodlands had any influence on their degradation, all mentioned parameters were compared between the four differentiated classes and their respective control plots in the protected areas. At the “land-cover level”, the statistically significant difference in the basal area of tree species preferred for charcoal production between the protected and unprotected open trees confirms that the class with a high density of large mature trees is the prime target of charcoal producers. In addition, there seems to be a general trend of lower values of tree species richness, evenness and Shannon diversity for the unprotected woodlands subjected to charcoal production. On the other hand, the disturbed woodlands display the potential to recover through their comparably high saplings density. The findings make an important contribution to the discourse on the impact of charcoal production in dry woodlands, a topic that is highly controversial among researchers.

Keywords: charcoal burning; forest degradation; selective harvesting; *Acacia-Commiphora* bushland; coppicing.

To read the entire publication, kindly visit the journal web page at: [10.1007/s40333-016-0124-6](https://doi.org/10.1007/s40333-016-0124-6)

CHAPTER 6. CHARCOAL CONTRIBUTION TO WEALTH ACCUMULATION AT DIFFERENT SCALES OF PRODUCTION AMONG THE RURAL POPULATION OF MUTOMO DISTRICT IN KENYA

Geoffrey M.Ndegwa, Dieter Anhuf, Adrian Ghilardi Udo Nehren, Miyuki Iiyama.

Energy for Sustainable Development. August 2016, Volume 33, Pages 167–175.

Abstract

Charcoal is among the most important domestic fuels in many countries of Sub-Saharan Africa (SSA). Its production has been conventionally considered as an agricultural off-season activity to supplement household income and cope with harvest failures. This study used primary data at the household level from an important charcoal supplying dry land region in Kenya to evaluate if income from charcoal contributes to wealth accumulation. The findings show that small-scale producers were more dependent on income from charcoal and casual labour, the two sectors whose income was uncorrelated to wealth index. This group was the poorest among the producer groups and vis-à-vis non-producers in terms of both total income and wealth level. In contrast, large-scale producers derived about half of their income from charcoal production but had more diversified livelihood sources especially in business and agriculture. Despite the fact that charcoal income was not directly correlated with the wealth index, large-scale producers derived absolutely large income from charcoal activities, which made them well-off among all the categories of households. The findings challenge the dichotomous policy debates on either promoting or banning charcoal production but necessitate better targeted policy interventions, which explicitly consider differences in charcoal producers to properly target social goals.

Keywords: Charcoal production; Poverty; Rural livelihoods; Wealth.

To read the entire publication, kindly visit the journal webpage at:

<https://doi.org/10.1016/j.esd.2016.05.002>

CHAPTER 7. TREE ESTABLISHMENT AND MANAGEMENT ON FARMS IN THE DRYLANDS: EVALUATION OF DIFFERENT SYSTEMS ADOPTED BY SMALL-SCALE FARMERS IN MUTOMO DISTRICT, KENYA.

Geoffrey Ndegwa, Miyuki Iiyama, Dieter Anhuf, Udo Nehren, Sabine Schlüter.

Agroforestry Systems (2016). DOI: [10.1007/s10457-016-9979-y](https://doi.org/10.1007/s10457-016-9979-y)

Abstract

Agroforestry systems in Sub-Saharan African drylands are complex and heterogeneous in nature even under similar biophysical conditions. This can be attributed to household needs and socio-economic status which influence the species and utility of the adopted trees. This has an impact on the trees establishment and management system through planting or Farmer Managed Natural Regeneration (FMNR). This study evaluates how trees for different utilities are managed and which socio-economic factors influence these decisions. The study used primary data collected in Mutomo District, Kenya through a household survey based on a structured questionnaire. A paired sample t-test was done to assess the preferred mode of adopting trees for different utilities while factor analysis was used to characterize the households as either planting trees or practicing FMNR. Multiple linear regression using household regression factor scores as independent variables and socio-economic indicators as dependent variables was done to ascertain which socio-economic factors affect tree adoption. The results show that trees planted were mostly exotic species valued for their nutrition and commercial value, while FMNR was used for subsistence products and environmental services. Household size, livestock levels and mobility had a positive correlation with tree planting, while income, access to markets and roads had an inverse correlation. Access to natural woodland, distance to the nearest motorable road and land size had a positive correlation with tree protection. It is hoped that this knowledge will act as a reference point when designing agroforestry projects in similar areas to ensure they are more aligned to specific site and household conditions.

Keywords: Agroforestry; Farmer Managed Natural Regeneration (FMNR); Tree adoption; Drylands; Socio-economic characteristics. To read the entire publication, kindly visit the journal webpage at: [10.1007/s10457-016-9979-y](https://doi.org/10.1007/s10457-016-9979-y)

CHAPTER 8. SUMMARY OF RESULTS AND CONCLUSIONS

The main objective of this study was to evaluate the nature of degradation caused by selective logging for charcoal production and how this could be addressed to ensure woodlands recovery without impacting negatively on the producers' livelihoods. To achieve this objective, the authors formulated four main specific objectives namely: 1) To assess the impact of selective logging for charcoal production on the dry woodlands in Mutomo District; 2) To evaluate the characteristics of the charcoal producers that enforces their continued participation in the trade, and ; 3) To assess potential for adoption of agroforestry to supply wood for charcoal production. The following section outlines the key findings of this study based on the four specific objectives:

8.1. The impact of selective logging for charcoal production on the dry woodlands in Mutomo District

Based on the findings of this research we conclude that the main use of the trees harvested in the study area is charcoal production as there is a direct linear relationship between the number of kilns and that of observed tree stumps. The producers practice selective logging targeting large diameter hardwood tree species while leaving the softwoods standing. Some of the targeted tree species are *Acacia lahai*, *Acacia nilotica*, *Acacia seyal*, *Acacia senegal*, *Berchemia discolora* and *Grewia bicolor*. Futhermore, the findings show that degradation is manifested through reduction in preferred tree species density and basal area. In addition, the affected woodlands have a significantly lower number of tree species and lower Shannon diversity and evenness indices. As such, it is clear that charcoal production through selective logging leads to degradation of the dry woodlands.

After comparing the status of different land-cover classes between the protected (in Tsavo East National Park) and unprotected woodlands (in human settlement area), the study found the most significant impact of charcoal production in the open trees land-cover class. This particular class has a high density of the preferred tree species in large sizes making it an obvious target for charcoal producers. We therefore conclude that the nature and level of the impact depends on the accessibility of the woodland and availability of the preferred tree species in large quantity and size.

The study findings also show that the unprotected woodlands generally have a higher density of saplings, an indication of high rate of regeneration in the opened-up spaces through selective harvesting. This is due to better light penetration and reduced competition for water and nutrients. However, the number of saplings is lower in the shrubs land-cover class, which has a thick layer of grass and shrubs undergrowth which quickly colonizes the opened-up spaces thus suppressing regeneration.

The study also found that there is active regeneration through seedlings and coppices from the harvested stumps. This is a good indicator that the woodlands can easily recover if wood extraction is sustainably managed.

8.2. Characteristics of the charcoal producers that enforce their continued participation in the trade

This study revealed that charcoal production in the study area is a regular economic activity undertaken by about half of the inhabitants. The findings also show that there are three distinctive categories of charcoal-producing households differentiated by their production levels and relative/absolute dependency on charcoal within their diversified livelihood strategies. These categories are: a) small-scale producers who comprise of 53.7% of all the producers and derived 64% of their income from charcoal; b) medium-scale who comprise of 33.7% of the producers and derived 54% of their income from charcoal, and; c) large-scale who comprised of 12.6% of all the producers and derived 58% of their income from charcoal.

The *small-scale* producers are more heavily dependent on charcoal with unreliable casual labor coming in second. The *medium-scale* producers have charcoal as the highest income source but their income portfolio is more diversified with casual labor, business and farming playing an important role. Their income is about 2.5 times that of the *small-scale* producers implying they are well-off. The *large-scale* producers derive most of their income from charcoal but business contributes almost a quarter of their income with agriculture also making sizeable contributions. Their income is about five times that of the *small-scale* producers signifying their well-up status.

Poverty, low literacy levels, large households and lack of livelihood diversification strategies are some of the factors that push people to charcoal production. However, the status of the charcoal producing households (in terms of income and wealth) improves with diversification

into other farm and non-farm activities. With little income that is mostly spent on sustenance, the *small-scale* producers are not able to save and invest in alternative income generating activities like the *large-scale* producers. This reinforces their high dependence on charcoal unlike the *large-scale* producers who can depend on alternative sources in case income from charcoal is not available. In particular, the ability of the *large-scale* producers to invest in business and agriculture seems to give them a platform to create more wealth from the charcoal proceeds.

The *small-scale* producers are therefore the most vulnerable group and would be the most affected in case of drastic elimination of the charcoal income source. As such, to address charcoal production related degradation caused by this group, one would require targeted interventions that entail gradual empowerment to diversify into other sources of income while reducing the level of dependency on charcoal.

8.3. Potential for adoption of agroforestry to supply wood for charcoal production

The findings of this study show that many households in Mutomo District have already adopted trees in their agroforestry systems either by planting or through FMNR. The findings also show that the utility of a species together with the socio-economic factors of a household influence the mode of tree establishment and management. For example, wealthy households with enough labor, good transport infrastructure and market access are more likely to invest in tree planting for products destined for the market. However, households with a large size of land, poor transport infrastructure and poor market access are more likely to be engaged in FMNR for subsistence products or environmental services.

In addition, households that adopt commercial-based agroforestry of exotic tree species are more likely to be engaged in tree planting. This augers well for them as they also get to procure improved seedlings which can guarantee better yields as compared to the indigenous varieties. On the other hand, households engaging in FMNR mostly adopt indigenous species valued locally for their products or environmental services.

The majority of the people in the study area are poor and depend on charcoal or casual labour for their livelihood. The transport infrastructure is also poor making access to the market quite difficult. They do not have access to water for irrigation and have to travel far to collect

water for domestic use. As such, the place seems most suited for adoption of trees for personal consumption products and environmental services through FMNR.

Indeed, for the few people who have adopted charcoal trees on their farmlands, FMNR is the preferred mode of tree management. Charcoal trees being mostly indigenous hardwood species, coppice easily when felled and their seeds are easily dispersed from the existing trees. As such, even though they are rarely planted in the area, proper management through FMNR could be an important intervention to relieve pressure from the natural woodlands for source of charcoal feedstock. The ease of tree establishment and management, the inhabitants' traditional knowledge of the species and low labor requirement make FMNR a very favorable method for the poor people in such harsh environment.

8.4. Conclusions and recommendations

This study demonstrates the extent to which selective harvesting of hardwoods for charcoal production has resulted in woodlands degradation in Mutomo District thus making invaluable contribution on the ecological impact of charcoal production, a controversial issue that has largely divided opinion. However, the findings also show that charcoal production is an important livelihood source for many poor residents of Mutomo District who have no alternative sources of income. Any intervention aimed at addressing charcoal production related degradation would therefore have to safeguard the livelihoods of the poor producers. Interventions that involves total banning of charcoal production as has happened in the past in many SSA countries would neither be acceptable by the poor producers nor applicable.

Based on the findings, the study recommends a holistic intervention that entails: 1) diversification of the livelihood sources of the producers to gradually reduce their dependence on charcoal; 2) introduction of preferred charcoal trees in agroforestry systems especially through FMNR to reduce pressure on the natural woodlands; 3) controlled harvesting of hardwoods for charcoal production from the natural woodlands at a rate below the MAI; 4) promotion of efficient carbonisation technologies and practices to increase charcoal recovery; 5) promotion of efficient combustion technology and cooking practices to reduce demand side pressure; 6) encourage fuel switching to other fuels like LPG and electricity to reduce demand side pressure.

The study findings are expected to assist the government/government institutions and key stakeholders (NGO's, CBO's and other development partners) in the process of: 1) laws and policy development; 2) program development and implementation, for sustainable livelihoods, woodlands management and energy supply.

The study identified key gaps that need to be filled to better understand the dynamics of charcoal production and woodlands degradation so as to be able to address this problem.

These gaps include:

1. Lack of accurate data on charcoal production and consumption patterns. This makes estimation of amount of unsustainably produced charcoal and the impact this has on deforestation and forest degradation as well as on carbon emissions impossible.
2. Lack of accurate data on the dry woodlands productivity which makes development of sustainable management plans difficult.
3. Lack of long-term empirical data on the dry woodlands regeneration patterns after selective logging for charcoal production.
4. Lack of in-depth knowledge of key tree species preferred for charcoal production and how they can be domesticated in agroforestry systems to alleviate pressure on natural woodlands.

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Appendix 1: Sample questionnaire

This questionnaire will be used to collect information for a study on "Degradation of dry forests due to selective logging for charcoal production in the dry forests". All the information collected using this questionnaire will be used specifically only for the purpose of this research and the findings will assist in understanding problems related to dry forests degradation due to unsustainable charcoal production and design of sustainable solutions. Your cooperation is highly appreciated.

Part I: Socio-economic characteristics

Section A: Household location					
Questionnaire no.		Enumerator		Date	
Village		Sub-location		Location	
Division		District		County	
GPS coordinates	Latitude (N/S): _ _ _ _ o _ _ _ _ . _ _ _ _ '		Longitude (E/W): _ _ _ _ o _ _ _ _ . _ _ _ _ '		
Section B: Household identification					
Name of respondent:			Gender	<input type="checkbox"/> female	<input type="checkbox"/> Male
Relationship to household head	_____	Head of household name (if different)	_____	Gender	<input type="checkbox"/> Female <input type="checkbox"/> Male
Household size	_____ Adults; _____ Children (below 18 yrs)		Household gender (No.)	_____ Female	_____ Male
Enumerator Note: If a respondent is not willing to participate in the interview, please note the reason and get a replacement household from the supervisor					
Section C: Education					
C. Please fill in the following information on the education status of the household					
Household member	Highest level of education.	Profession (where applicable)	Living within homes 1= Yes; 0=No		
Household head					
Spouse					
Member (specify).....					
Member (specify).....					
Member (specify).....					
Member (specify).....					
Member (specify).....					
Member (specify).....					
Member (specify).....					
Member (specify).....					
Member (specify).....					
Code for education level: 0= never attended; 1=dropped out of primary school; 2= In primary school; 3=completed primary school; 4= In High school; 5=Dropped out of High school; 6=Completed high school; 7=In tertiary college/university; 8=completed tertiary college/university					

college/university; 999= Other (Specify)_____

Section D: land holding and land use

D.1. Did you migrate to the current location? I__I 1= YES 0=No

If the answer is YES, when? (Year) _____

D.2. i) How many land parcels do you have? I__I 1=1; 2=2; 3=3; 4=4; 5= more than 4 (Specify _____)

Note: The numbers will be used as codes for the rest of the interview with 1 being where the interview is taking place)

ii) How big is your land parcel(s) in hectares? Parcel1 I__I; Parcel 2 I__I; Parcel 3 I__I; Parcel 4I__I

(To covert acres to hectares use 1ha= 2.5 Acres)

iii) How far are your other land parcels from your homestead (in the land parcel where interview is taking place)? Parcel 2 I__I; Parcel 3 I__I; Parcel 4I__I 1= less than 1km; 3=1-5km; 4=5-10km;

5=More than 10 km.

iv) Do you own the land parcel (s)? Parcel1I__I; Parcel 2 I__I; Parcel 3 I__I; Parcel 4I__I 1=YES 0=No

If the answer above is YES, go to D3. If no, go to D4

D.3. i) How did you acquire the land parcel? Parcel1 I__I; Parcel 2 I__I; Parcel 3 I__I; Parcel 4I__I

1= Bought ; 2= Inherited ; 3=Given by government; 4=Borrowed; 5= Given by relative

99=Other (specify)_____

ii) Do you have a title deed for the parcel(s)? Parcel1 I__I; Parcel 2 I__I; Parcel 3 I__I; Parcel 4I__I

1= YES ; 0=No

D.4.i) If you do not own the land, under what terms are you living in/using it? Parcel1 I__I; Parcel 2 I__I;

Parcel 3 I__I; Parcel 4I__I 1= Leased; 2=Squatting; 3=Rented ; 4=Communal ownership ;

99= Other (specify)_____

D.5. Do you cultivate the land parcel(s)? Parcel1I__I; Parcel 2I__I; Parcel 3 I__I; Parcel 4I__I 1= YES; 0=NO

If the answer above is YES, go to D6

D.6.i) Which crops do you cultivate? Parcel 1 I____I; Parcel 2 I____I; Parcel 3 I____I; Parcel 4 I____I (multiple answers accepted) **1=maize; 2=Beans; 3=Green grams; 4=Millet; 5=Sorghum; 6= Pigeon peas (Nzoo); 7= Cowpeas (Nzooko); 8= Cassava; 999=Others** (specify)_____

ii) What factors have influenced your decision to plant these crops in these particular parcels?
Parcel 1 I____I; Parcel 2 I____I; Parcel 3 I____I; Parcel 4 I____I (multiple answers accepted) 1=distance from homestead; 2= security; 3=land tenure; 4= topography; 5=soil conditions; 6= water availability; 7= Market availability; 8= cultural values; 999=Other (specify)_____

D.7. Among the crops you grow in **D.6.i** above, which do you grow as cash crops? I____I (use the same code as **D.6.i** above)

D.8. i) Do you have a natural woodland (that from the best of your knowledge was not planted but has naturally established and regenerated itself) in any of your land parcels?
Parcel 1 I____I; Parcel 2 I____I; Parcel 3 I____I; Parcel 4 I____I **1=YES; 0=NO**

ii) If the answer above is **YES**, what proportion? Parcel 1 I____I; Parcel 2 I____I; Parcel 3 I____I; Parcel 4 I____I
1= Less than 10% ; 2=10-25%; 3= 25-50%; 4=50-75%; 5=more than 75%

D.9. i) If your answer in **D.8.i** is **No**, did you in any of the land parcels have any natural forest in the last 10 years? Parcel 1 I____I; Parcel 2 I____I; Parcel 3 I____I; Parcel 4 I____I **1=YES; 0=NO**

ii) If your answer is **YES**, why did you clear the forest? Parcel 1 I____I; Parcel 2 I____I; Parcel 3 I____I; Parcel 4 I____I
1=for agriculture; 2=for charcoal production; 3= For construction; 4=For mining; 999=Other (specify) _____

D.10. i) Do you practice shifting cultivation? I____I **1= YES ; 0=NO**

ii) If **YES**, what do you do with the land afterwards? I____I **1=left to regenerate naturally;**
2=enrichment planting with indigenous trees; 3=plant exotic trees; 999= other (specify)_____

D.11. i) Do you irrigate any of your land parcels? I____I **1= YES ; 0=NO**
If **YES**, go to **D.12**,

ii) If your answer is **NO**, Why? I____I 1= lack of water; 2=Lack of technology; 3=Not necessary; 4=Lack of skills; 5= not affordable; 99= other (specify) _____

D.12 i) What type of irrigation do you use? Parcel 1 I____I; Parcel 2 I____I; Parcel 3 I____I; Parcel 4 I____I
1= Flood irrigation; 2=Drip irrigation; 3= Watering with watering can; 4=Overhead irrigation;
99= Other (specify)_____

ii) What is the source of your irrigation water? Parcel 1 I____I; Parcel 2 I____I; Parcel 3 I____I; Parcel 4 I____I
1 = tanks/infrastructure with harvested water; 2 = dams or water ponds; 3 = boreholes;
4 = water pumps; 5 = River/Stream/lake; 999=Others (Specify)_____

iii) How far is the water source from your land? Parcel 1 I____I; Parcel 2 I____I; Parcel 3 I____I; Parcel 4 I____I
0= Inside the land; 1= less than 1km; 3=1-5km; 4=5-10km; 5=More than 10 km.

Section E: Livestock

E.1. Which of the following livestock do you have ?

Livestock	Number	Breed 1=Indigenous; 2= Improved	Purpose: 1=personal use (food, transport, ploughing etc); 2= commercial (animal, products and services); 3=pet; 4=cultural value; 999=Other (specify)_____	Land parcel where the animals live(use codes in section D)
Cattle				
Goats				
Sheep				
Donkey				
poultry				
camel				
pigs				
Other (specify)_____				

E.2. If you have cattle, sheep or Goats, what rearing practice have you adopted? I__I **1=Zero grazing;**
2= free range grazing; 3=ranching; 999=other (specify)_____

E.3. If you practice zero grazing, where do you get the feed/fodder from? I__I **1=Buy; 2= Own farm;**
government/trust land; 4= friends/relatives land; 999=other (specify)_____

E.4. If you practice free range grazing:

i) Where do you normally take them for grazing? I__I 1=in my land parcel; 2= in friends/relatives land; 3=in government/trust land; 4=on the roadside; 999= other (specify)_____

ii) in which ecological niches do you mostly graze? I__I **1= in the forest; 2= open grassland;**
3= on the hills; 4= near river bank; 5= old farmland; 999= other (specify)_____

iv) Do you protect crops/trees from being destroyed by the animals? I__I **1=YES; 0=NO**

v) If the answer in iv above is YES, how? I__I 1=live fence; 2= stacking thorn bushes; 3= barbed wire; 999= other (specify)_____

Section F: Sources of income

F.1. Please indicate the sources of income for the household in the table below

No.	Source	HH member(s) involved	How regularly (Days per month)	Amount (per month)	Amount (per Annum)
1	Formal employment				
2	Casual labour				
3	Selling farm produce (crop and animal products except timber and wood fuel)				
4	timber				
6	Charcoal				

7	Brick making				
8	honey				
9	Sand harvesting				
10	Remittances				
11	Rent (house, farm, equipment)				
12	Business (not dealing with own farm products)				
13	Other (specify)_____				
	Codes	1=father; 2=mother; 3=son; 4=daughter; 999=other _____	1=less than one week; 2= 1 week; 3=2 weeks; 4=3 weeks; 5= full month		

SECTION G: Socio-economic status

G.1 Housing. Please indicate the status of your house.

Ownership	No. of rooms	Roof material	Wall material	Floor material
1=owned; 2=rented; 3=inherited; 999= Other_____		1=Tiles; 2=iron sheets; 3=thatch; 4=polythene paper; 999=other_____	1=stones/concrete; 2= bricks; 3=mud; 4=timber; 5=iron sheets; 999=other_____	1=concrete; 2=earth; 3=tiles; 999=other_____

G.2.i) What is the source of your domestic water? I ___ I 1=River/lake /swamp; 2= piped;

3=borehole; 4=dam/water pan; 5=roof-top water harvesting

ii) How far is the water source? I ___ I 0=within the homestead; 1= within 1km; 2=1-5km;

3=5-10km; 4=over 10km

G.3.How far is your household from the nearest primary school? I ___ I 1=within 1 km; 2= 1-5km;

3= 5-10km; 4= over 5km

G.4.i) What are your sources of energy for lighting and cooking? (Use an X to mark)

	Firewood	Charcoal	LPG	electricity	solar	Crop residue	Cow dung	Candle	Other (specify)
Cooking									
lighting									

ii) If your energy source for cooking is charcoal, where do you source it from? I ___ I

1=own farm; 2=Trust land; 3=government forest; 4=freely from neighbors/relatives/friends;

5=Bought; 999=other (Specify)_____

iii) if the charcoal is produced within your household, who is responsible for the production?

I __, __, __I (multiple answers accepted)

1= father; 2=mother; 3=daughter(s) [age(s) __, __, __]; 4=Son(s)[age(s) __, __, __];

5=Hired labour; 999=Other (specify)_____

iv) If your energy source for cooking is firewood, where do you source it from? I __I

1=own farm; 2=Trust land; 3=government forest; 4=freely from neighbors/relatives/friends;

5=Bought; 999=other (Specify)_____

v) Who is responsible for firewood collection? I __, __, __I (multiple answers accepted)

1= father; 2=mother; 3=daughter(s) [age(s) __, __, __]; 4=Son(s)[age(s) __, __, __];

5=hired labour; 999=Other (specify)_____

vi) How far from your homestead is your most common source of firewood? I __I **0= within the**

homestead; 1=less than 1km; 2=1-5km; 3= 5-10km; 4= over 10km

vii) How regularly do you collect the firewood? _____ **times per week**

viii) How long does it take to collect one firewood head load? (from departure to return to the

homestead) _____ **hours**

ix) How can you rate accessibility of firewood? I __I **1= Readily accessible; 2=accessible; 3=scarce;**

4= Very scarce

(Note: **readily accessible** when it can be collected within 1km form the homestead; **accessible** when it can be collected up to 5km from the homestead; **scarce** when it can be collected over 5km for the homestead; **very scarce** when it can only be collected over 10km.)

G.5.i) How far is the nearest health center from your household? I __I **1=within 1 km; 2= 1-5km;**

3=over 5km

ii) How regularly do you visit the health center? I __I **0=never; 1=Once per week; 2=once per month;**

3= once every 3 months; 4=once every 6 months; 5=once per year

G.6.i) How far is the motorable road from your household? I __I **1=less than 1km; 2= 1-5km;**

3=over 5km

G.6.ii) When you don't have access to motorable transport (car, motorcycle) what forms of transport do

you use to transport goods ? I __I 1=Human; 2=bicycle; 3= donkey cart; 99=other

(specify)_____

G.6.iii) How would you rate the quality of road infrastructure within your village? I __I **1=very good;**

2=good; 3= fair; 4= poor; 5=very poor

G.7.i) How far is the market where you can buy farm inputs or sell farm produce from your household?

I __I 1=less than 1km; 2=1-5 km; 3= 5-10km; 4= over 10 km

G.8. Which of the following assets do you own?

Asset	Car	Motorcycle	Bicycle	Cart	Television	Mobile	Radio
Number							
Age (years)							

Part II: Tree adoption and management

Section G: Tree planting

H.1.i) In the last 36 months (or 3 years) did you plant any trees? [___] **0 = No, 1 = Yes**

ii) If your answer is **YES**, go to **H.2**

iii) If your answer is **NO**, go to **H.3**

H.2. write down all the main tree species that you have planted in the last 3 years

No	Species	Why did you plant this tree	Where on your farm did you plant this tree	How many have you planted?	How many are still surviving?	Where did you get the planting material (seeds/seedlings) from?
1						
2						
3						
4						
5						
6						
7						
8						
9						
		Code : Purpose 1 =Fruit 2= Timber 3 =Charcoal 4 =Firewood 5 =Medicine 6 =Income 7 =Fodder 8 =Bee forage 9 =Shade 10 =Windbreak 11= Erosion control 12 =Soil fertility 13 =Riverbank stab 14 =Live-fence, 15=Farm tools making wood 99=Other, Specify.....	Code: Niche 1.Scattered in crop farm; 2.External boundary/ live fence; 3.Hedges within farm/soil conservation bunds; 4.Woodlot or river line section; 5. Home compound; 6.Fallow land; 99. Other (specify).....			Code: Source 1.Neighbour 2.Bought from the market 3. NGO (Specify)..... 4.Ministry/Bureau of Agriculture 5.Ministry of Forestry, 6. Own farm 7. Forestry and wildlife enterprises 999. Other, specify.....

H.3.i) Why have you not planted trees? I __, __, __, __, __ I (multiple answers accepted in order of strength)

1=lack of seedlings; 2= lack of water; 3=no enough land; 4= lack of skills; 5= no need to plant;
7=culturally unacceptable; 96= other (specify)_____

ii) If the reasons mentioned above could be addressed, would you be willing to plant trees? I____I
1=YES; 0= NO

ii) If your answer is **YES**, which species and for what purpose? (Use codes in H.2)

No.	Species	Land parcel (use codes in Section D)	Percentage of land*	Purpose
1				
2				
3				
4				
5				

*approximate percentage of land parcel respondent would be willing to plant the trees

H.4.i) Do you have any skills on tree propagation and management? I____I 1=YES; 0= NO

ii) If your answer is **YES**, how did you acquire them? I____I 1=formal training in school/college;
2=training from government/non-governmental organization; 3=learnt from relative/friend;
4=reading from literature; 5= Mass media; 99=other (specify)_____

H.5.i). Do you intercrop your crops with trees? |____|(0 = No, 1 = Yes)

ii) If **YES**, please explain which and why?

.....
.....
.....

H.6 In the last 36 months, have you or a member of your household protected any naturally growing tree in any of your land parcel? |____|(0 = No, 1 = Yes)

If your answer is **YES**, please fill in the following table

No	Species	In which land parcel (use codes in Section D)	Why did you protect this tree	How many have you protected?	Where on your farm is this tree	What is the purpose of this tree
1						
2						
3						
4						
5						
6						
7						
8						
9						

			Code for protecting: 1=Tree is beneficial for timber, fuel, fruit, shade, soil fertility 2=Lack of seeds/Seedlings of the species 3=Tree has cultural value, 4=Tree is endangered		Code: Niche 1.Scattered in crop farm; 2.External boundary/ live fence; 3.Hedges within farm/soil conservation bunds; 4.Woodlot or river line section; 5. Home compound; 6.Fallow land; 99. Other (specify).....	Code : Purpose 1 =Fruit 2= Timber 3 =Charcoal 4 =Firewood 5 =Medicine 6 =Income 7 =Fodder 8 =Bee forage 9 =Shade 10 =Windbreak 11= Erosion control 12 =Soil fertility 13 =Riverbank 14 =Live-fence, 15=Farm tools making 999=Other, Specify.....
--	--	--	--	--	---	--

H.7. Please indicate the five tree species which you consider most important, their use and abundance in your locality (in farmlands and natural woodlands) **in order of their importance**

Rank	Local name	Common name	Abundance. 1=Very abundant; 2=abundant; 3=rare; 4=very rare; 5=extinct	Use*
1				
2				
3				
4				
5				

*Code for use: 1=Food/Fodder; 2=Timber; 3=Shade; 4=Mulching; 5=Soil Fertility; 6=Fire wood; 7=Charcoal; 8=Medicine; 9=Pest Control; 10=Erosion Control; 99=Other (specify)_____

(Note: **Very abundant** when it comprises of the highest number of trees the in the locality; **abundant** when it can be found in most farms in the locality; **rare** when it can be found only in a few selected farms in the locality; **very rare** when in can hardly be found in the locality; **extinct** when it cannot be found anywhere in the locality but used to be there.)

Part III: Charcoal production

I.1.i) In the last 12 months have you or a member of the household produced charcoal? (0 = No, 1 = Yes)

If yes in F.1 above, please complete the following table

When?	Tree source (Code ^a)	Tree species used (list all)	Charcoal produced (state in sacks)	Technology (code ^b)	Who did the tree harvesting? (state no. of male and female)	Who did kiln set up and operation? (state no. of male and female)	Charcoal used personally (state in sacks)	Charcoal sold (state in sacks)	Sold who (Code ^c)
Within the last 3 months					M <input type="checkbox"/> F <input type="checkbox"/>	M <input type="checkbox"/> F <input type="checkbox"/>			
3-6 months ago					M <input type="checkbox"/> F <input type="checkbox"/>	M <input type="checkbox"/> F <input type="checkbox"/>			
6-9 months ago					M <input type="checkbox"/> F <input type="checkbox"/>	M <input type="checkbox"/> F <input type="checkbox"/>			
9-12 months ago					M <input type="checkbox"/> F <input type="checkbox"/>	M <input type="checkbox"/> F <input type="checkbox"/>			

^aSource of trees: 1=own land parcel; 2=given by neighbors/friend/relative; 3=bought(in cash, exchange for labour or goods); 4=freely from government forest/roadside; 96=other

^bTechnology of charcoal production: 1=traditional earth mound kiln; 2=brick kiln;3= drum kiln; 4=Casamance kiln; 96=other

^cCharcoal sold to: 1=transporter; 2=broker; 3=neighbour; 4= visitor/passers-by; 96=other

ii). If you bought the trees, how much does a tree suitable for charcoal production cost? _____KES

iii) How many sacks of charcoal would such a tree produce? _____sacks

iv) If you source the trees from your own farm, who makes the decision on which trees to be used and when?

I _____ I 1=Male; 2=female; 3=Collective decision; 999=Other (specify) _____

v) Who makes decision on how the income will be spent? I _____ I 1=Male; 2=female; 3=Collective decision; 999=Other (specify) _____

I.2.i) On average, how many sacks of charcoal do you make per kiln per run? (State) _____sacks

ii) How long does one kiln take from preparation to offloading the charcoal? _____Days

I.2: In order of preference, which are the 5 most preferred tree species for charcoal production and their availability in your locality?

Rank	Tree species	Availability 1=abundant; 2=readily available; 3=rare; 4= very rare; 5=extinct	Reason. 1=customer demand; 2=easy to work with; 3= quality charcoal; 999=other
1			
2			
3			

4				
5				

(Note: **Very abundant** when it comprises of the highest number of trees the in the locality; **abundant** when it can be found in most farms in the locality; **rare** when it can be found only in a few selected farms in the locality; **very rare** when in can hardly be found in the locality; **extinct** when it cannot be found anywhere in the locality but used to be there.)

I.3: in order of use, which are the 5 most used tree species for charcoal production?

Rank	Tree species	Reason. 1=Customer demand; 2=easy to work with; 3=Good quality charcoal; 4=readily available; 999=other_____
1		
2		
3		
4		
5		

I.5: If you or a member of your household have been involved in charcoal production:

i) How did you get the skills?) 1=from family/friends; 2=Demonstration from NGO's/government organization; 3=Reading; 4=trial and error; 999=other

ii) Why did you get involved in charcoal production?) 1=It is a family business; 2= it is the only available source of income; 3= chose it as a profession; 4= did it for wages; 999= other

iii) How regularly do you produce charcoal?

1=the whole year; 2= when there is drought; 3= between crop harvesting and the next planting season; 4=when I am need of money eg. for hospital, school fees etc; 999= other

I.6: i) Are you aware of the charcoal rules that govern charcoal production in the country? 0 = No, 1 = Yes

ii) If your answer is **YES**, how did you get to know about the rules? **1=Government institution** (KFS, MOE, MOA, etc); 2= NGO; 3= family/friend; 4= church/public baraza; 5=mass media/poster; **999=other** Name:.....

I.7: If your answer in I.6 is **YES**, which requirements of the rules have you met to legally and sustainably produce charcoal?

i) Planted trees for suitable for charcoal production? 0 = No, 1 = Yes

If **YES**, which species? 1.....2.....

3.....3.....

How many of each species? 1=I____I; 2=I____I; 3=I____I; 4=I____I

ii)Organized into a group for the purpose of applying for a charcoal producer license? 0 = No, 1 = Yes

If **YES**, how many members are in your group? (State)

iii) Conducted environmental Impact assessment through the local environmental committee?

0 = No, 1 = Yes

iv) Prepared a reforestation/forest conservation plan for your woodland? 0 = No, 1 = Yes

v) Procured efficient charcoal production technologies (kilns)? 0 = No, 1 = Yes

vi) Attended training on efficient charcoal production skills?) 0 = No, 1 = Yes

vii) Formed a Charcoal Producer Association? *0 = No, 1 = Yes*

viii) Applied for a charcoal producer license? *0 = No, 1 = Yes*

I.8: If any answer in I.7. above is **NO**, please explain why?

I.9: Please rank 5 main challenges towards attaining full compliance with the charcoal rules.

1=too expensive to implement; 2=lack of technical know-how; 3=lack of technical support from government; 4=long and bureaucratic registration/verification process; 5=corruption; 6=climatic factors (rainfall, drought); 999=other (specify).....

Rank1..... Rank2..... Rank3..... Rank4..... Rank5.....

Versicherung (gem. §4 Abs. 3 Satz 1 Nr. 5 PromO):

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