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Value chain of charcoal production and its implications on forest degradation in Bié Province, Angola

Master thesis

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Declaration

I hereby declare truly that this thesis is my own work and quoted only according to the references listed within. However, contributions of others are involved, especially under the guidance of doc. Ing. Bohdan Lojka, Ph.D.

Prague, April 2015.

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While our honour belongs to past, our focus will always be the future. For us the BIGGEST task, always come after the honour and the BEST honour always comes by gratitude.

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Abstracts (English)

Charcoal as a commodity carries numerous misconception in the public domain or perception. Firstly, charcoal is mostly domestic energy source used by the poor. Secondly, charcoal production constitutes the main cause of deforestation. The forest degradation that follows harvesting wood for charcoal production is probably more prevalent than total deforestation. The objective of the study was to evaluate the impact of charcoal production on natural forests of Bié province and also describe the whole value chain of charcoal production. We hypothesized that charcoal production in Bié province is one of the major causes of forest degradation, especially decreasing the occurrence of *Brachystegia* species in natural forests. For the data collection, three villages where charcoal production is a common practice in Bié province were selected. The primary data were gathered through qualitative (semi-structured questionnaire survey) and quantitative (market observation) methods and the data came from 330 respondents interviewed during June - September 2014. A Logistic (Logit) regression model in SPSS was used to study the factor influencing the decision to use charcoal by households Furthermore, four main types of charcoal were collected and analyse their caloric value. The dominant species used for charcoal production in Bié was *Brachystegia spiciformis,* due to its availability in natural forests. By using the amount of charcoal supplied into Chissindo market the forest degradation rate arising out of charcoal production was at range of 21 to 27 thousand hectares per year. The participants of the charcoal production value chain were identified as: producers, transporters, traders and consumers. The charcoal production was found to be relatively profitable business for most of the stakeholders involved. Charcoal can be an excellent domestic fuel if it could be produced in a sustainable manner. The demand of charcoal is more likely to remain stronger if policies are not aimed to reduce consumption of charcoal.

Keywords: *Brachystegia spiciformis,* deforestation, forest products, miombo forest, wood-fuel production, domestic energy.

Abstracts Czech

Dřeveného úhlí nese četné mylnou ve veřejné vnímání. Za prvé, dřevěné uhlí je považovan za domácí energetické zdroj energie pro chudé. Za druhé, výroba dřevěného uhlí představuje hlavní příčinu odlesňování. Degradace lesů, kterou následuje těžba dřeva pro výrobu dřevěného uhlí je zřejmě častější než celková odlesňování. Cílem toho studium bylo zhodnotit vliv produkce dřevéného uhlí na přirozených lesů v provincii Bié a také popsat celý hodnotový řetězec výroby dřevěného uhlí. Předpokládali jsme, že výroba dřevěného uhlí v Bié je jednou z hlavních příčin degradace lesů, zejména snižuje výskyt druhů Brachystegia v přírodních lesích. Pro sběr dat byly vybrány tři vesnice, kde výroba dřevěného uhlí je běžná praxe. Prvotní údaje byly získány na základě kvalitativní (semi-strukturovaného dotazníkového šetření) a kvantitativní (průzkum na trhu) metody. Údaje přišel z 330 respondentů oslovených v červenci až září 2014. Logistic (Logit) regresní model v SPSS byla použita ke studiu faktoru ovlivňující rozhodnuty o použití dřevěného uhlí v domácností. Dále byly Jístění čtyři hlavní hlavní rostlin druhy preferované k vyrobě dřeveného uhlí a take bzlz analyzované jejich spalné teplo hodnotu. Dominantní druhy používané pro výrobu dřevěného uhlí v Bié byla *Brachystegia spiciformis*, kvůli její dostupnosti v přirozených lesích. Pomocí množství dřeveného uhlí dodávané do trhu Chissindo, znehodnocování lesů sazby plynoucího z výroby dřevěného uhlí byla v rozmezí od 21 až 27.000 ha ročně. Účastníci ve výrobní hodnotového řetězce byly identifikovány jako: výrobců, přepravců, obchodníků a spotřebitelů. Produkce dřeveného uhlí že je poměrně výnosný byznys pro většinu zúčastněných stran. Dřeveného uhlí může být vynikající domácí palivo, jestli by to mohlo být vyráběno udržitelným způsobem. Poptávka po dřeveného uhlí je více pravděpodobné, že zůstane silnější, když zásady nejsou zaměřeny na snížení spotřeby uhlí.

Kličova slava: *Brachystegia spiciformis,* odlesňování, lesní produkty, les miombo, výroba dřevěných paliv, energie domácíc zdrojů.

Abstracts Portuguese)

O carvão vegetal como uma mercadoria carrega númerosos equívocos em domínio público ou percepção. Em primeiro lugar, o carvão vegetal é considerado fonte de energia domestica utilizada pelos pobres. Em segundo lugar, a produção de carvão constitui a principal causa de desmatamento. A degradação florestal que surge da produção de carvão é provavelmente mais prevalente do que o desmatamento total. O objetivo do estudo foi avaliar o impacto da produção de carvão vegetal sobre as florestas naturais da província do Bié e também descrever toda a cadeia de valor da produção de carvão vegetal. Nossa hipótese é que a produção de carvão na província do Bié é uma das principais causas de degradação das florestas, especialmente a diminuição da ocorrência de espécies Brachystegia em florestas naturais. Para a coleta de dados, foram selecionados três aldeias onde a produção de carvão vegetal é uma prática comum. Os dados primários foram coletados por intermédio métodos qualitativos (semi-estruturado inquérito e intrevistas) e quantitativos (observação no mercado - PRA). Os dados vieram de 330 respondentes entrevistados durante junho-setembro de 2014. O modelo de regressão (Logit) em SPSS foi utilizado para estudar os fatores influenciando a decisão de usar carvão vegetal por parte das famílias. Além disso, foram coletadas quatro tipos principais de carvão vegetal e analisado o seu valor calórico. A espécie dominante utilizadas para a produção de carvão vegetal no Bié foi *Brachystegia spiciformis*, devido a sua abundancia em florestas naturais. Usando a quantidade de carvão fornecido no mercado Chissindo a taxa de degradação da floresta decorrente da produção de carvão vegetal foi à aproximadamente de 21-27.000 hectares por ano. Os participantes da cadeia de valor de produção de carvão vegetal foram identificados como: produtores, transportadores, comerciantes e consumidores. A produção de carvão vegetal é um negócio relativamente rentável para a maioria das partes envolvidas. O carvão vegetal pode ser um excelente combustível doméstico se ele poderia ser produzido de forma sustentável. A demanda de carvão vegetal é mais provável que se mantenha forte se as políticas não são destinadas a reduzir o consumo de carvão vegetal.

Palavras-chave: *Brachystegia spiciformis*, desmatamento, produtos florestais, floresta do miombo, produção de madeira, energia doméstica.

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1. INTRODUCTION

Since 1970s, FAO and Word Bank reported all wood based fuels into one umbrella term - as fuelwood and woodfuel. Woodfuel when is referring to charcoal and (Mwampamba et al., 2013) fuelwood as unprocessed woodfuel referring to firewood only (FAO, 2004). To harmonize terminologies in the bioenergy sector (e.g. Unified Terminology UBET) try to not separate the charcoal from other solid woodfuels. Charcoal presents physical, chemical and social characteristics which defer from other woodfuels especially when the final product is used as domestic energy for residential cooking and heating. Charcoal is a fuelwood by-product obtained by the process of carbonisation (Chidumayo, 2013). According to International Energy Agency (2006), charcoal is a solid biofuel or wood carbonized by partial combustion. The production of this commodity is conducted usually by thousand of scattered rural farmer.

The charcoal situation in the world has been hampered by the lack of reliable information, because very small fraction of charcoal production is recorded and assessed. Therefore, the actual magnitude of use, impacts on forests and rural livelihoods has been a subject of considerable debates. The wood energy situation in developing countries is a matter of reserved questions. In Asia, the consumption of wood energy is declining while in Africa it remains higher (Steierer, 2011). Charcoal consumption tends to grow faster than firewood consumption and its use is becoming much larger in Africa and South America (Chidumayo, 2013). For Sub-Saharan Africa countries, charcoal is not only the major source of household energy, it is also an important source of household incomes. It has several advantages compared to firewood, especially among the urban underprivileged farmers. Charcoal has higher energy content, its less to bulky, easier to transport and burns more cleanly (Zulu and Richardson, 2013).

Charcoal and firewood consumption could lead to forest degradation or even worse to deforestation; the widespread used of woodfuel energy in Angola is greatly understimated and the impact of charcoal production on Angolan forest is unknow. The neglited regulation of charcoal trade caused by charcoal alone need to be estrutured. It is thought that firewood and charcoal production is one of the major driving forces for deforestation in Angola.

The attempt to study charcoal production in Angola is a new issue. This study was desined to describe and evaluete the all charcoal value chain in Bié Province - Angola. Before 1995, production of charcoal in Angola was not a financially feasible activity among Angolan farmers, becouse in that time farmers were focused only on agriculture activitie to generate income. Today the dependance on this comodity is evident in each single village of Angola The impact of this activity is so visible and imposible to hide, suspected to be the main cause of forest degradation.

Studies on charcoal production are demanded and complicated, due to the fact of environmental issues which seems to be the main problem. The data on charcoal production are usually generated from surveys which focus either on consumption or production rarely both (Mwampamba at el., 2013). The estimation of the quantities of charcoal produced in certain region is always misleading. The differences between recorded and reported data are enormous. Therefore, many studies on these issues have failed (Serenje et al., 1994, Labarta et al., 2007) just for the fact that they focused more on environmental impact (Arnold et al., 2006) and forget the economic issues and the sustainability of environmental facts resulting in higher questionability of it.

Only less than 20% of people have access to electricity in Angola and the rest 80% **(**Miranda Undated) of rural population rely on charcoal and firewood (IEA, 2006) either for domestic uses as energy supply or as a source of income. It is wondered why less attention has been given to the market of charcoal trade in Angola. This problem has been less studied, less researched within the country especially in Bié province which is the target area of this study. This study intend to assess to what extent the selected villages use the forest for charcoal production in order to satisfy their livelihoods in terms of increase access based on entrepreneurship opportunities yet complying with sustainable development. The outcome of this study would be useful in helping the policy maker in formulating the strategies to find alternatives sources of energies to reduce or even replace the charcoal and firewood furthermore, to target the right group of concern, to equally focus on both forestry resources conservation and socio-economic development which eventually may maximize the outputs and benefits for the selected villages by commencing to support enterprises development to improve livelihoods.

2. LITERATURE REVIEW

2.1 Concepts of value chain and charcoal definition

The value chain describes the full range of activities that goes from production conception to the end use (WBCSD, 2011) or even beyond that. As the product passes through several stages of the value chain, the value of the product increases (ILO, 2014). Using a value chain approach to access economic development, environmental facts and poverty reduction, involves addressing major constraints and capitalizing on opportunities faced by input suppliers, producers, processors, traders and other points along a given value chain. In case of charcoal value chain it goes from wood production until the consumption. The idea of value chain is based on the process in which inputs are transformed into outputs. The outputs involve the acquisition and consumption of a certain resource.

Porter's value chain consisted of a set of activities performed to design produce, market, deliver and support its product (Institute of management accountants, 1996; Kannegiesser, 2008). Rather than including all aspects of value chain it is important to focus on its backward and forward linkages of activities. In the narrow meaning, these activities constitute the chain which link producer to consumer. In agriculture, value chain analysis is emerging as a useful tool for analysing commodities (Vede et al., 2006), such as tea, coffee and even wooden furniture in case of the forest sector (Kaplinky et al., 2002). For example, primary products such as non-timber forest products are linked to final consumer through so-called short value chain (Vede et al., 2006). However, conducting a value chain analysis requires an approach on what is going on among the actors or activities inside of the chain and also on what keep these actors together (M4P, 2008). This is because agriculture and forestry value chains depend on the utilisation of environmental resources and there prevail traditional norms as well. This gives different concept of value chain from an academic perspective.

According to M4P (2008), the value chain is categorised into three approaches: (i) the filiere approach, (ii) the Porter framework approach and (iii) the global approach. This might be because each commodity should fit into at least one of them. The Concept of Filiere (Thread) approach was firstly used to analyse agricultural system of developing countries under the French colonial. It served as a tool to study the ways in which agricultural production e.g. rubber, cotton, coffee and cocoa should be organised in the contest of developing countries. The filiere approach was used in a number of French-funded development projects in 1980s and 1990s (M4P, 2008). It has economic and financial strands which focus on income generation and commodity distribution in the chain. This approach works for commodities that have not been accounted to the GDP of countries, like for example charcoal, mushrooms, bush meat and honey. This is because, there are few indications of how the accounts of these totalities can be systematised. The quantitative tradition of filière analysis has mainly attempted to measure inputs and outputs, prices and value-added along a commodity chain. However, this filiere approach failed because it did not consider broad historical questions such as the extent to which product 'diversity' was increasing or decreasing (Raikes at el., Undated).

The second concept is the Porter's framework on Porter (1985) on competitive advantages. It assessed how a firm position itself in the market and the relationship between suppliers, buyers and competitors. Porter (1985) developed the idea of competitive advantage which follows into: how a firm can provide a certain good or service of equivalent value compared to competitor but at lower cost? Or how an enterprise produces a good which costumers are willing to pay ever at higher price?

The Porter concept in value chain has a strict business application therefore, cannot be used for commodities like charcoal due to environmental facts. Finally the global approach has been applied to the analysis of global movement of some products (Gereffi and Korzerniewicz, 1994).

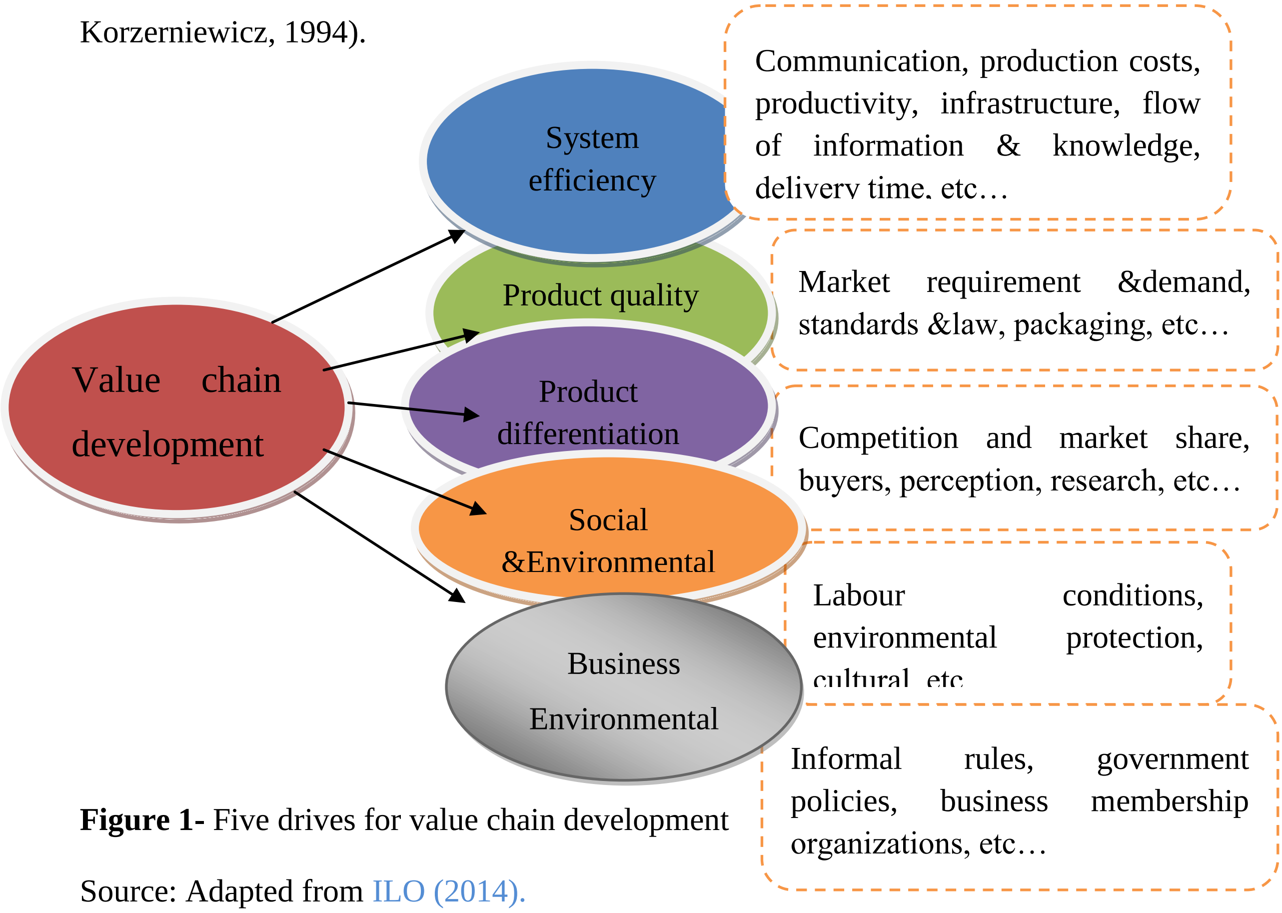

Figure 1- Five drives for value chain development

Source: Adapted from ILO (2014).

This approach examines the ways in which firms and countries are globally integrated and effects determining the global income distribution along the chain (Trienekens, 2011). In all process of value chain there are slightly a set of detailed factors that may influence the dynamics of the value chain, therefore, the ILO Value Chain Development approach emphasizes five drivers for value chain development (Figure 1).

Value chain presented can form the basis for formulation of projects and programs to provide support to a value chain or set of value chain in order to achieve a desired development outcome (M4P, 2008). The production of charcoal in the world differ from country to country however, there are common issues characterising the charcoal production, wood harvesting, charcoal transport and trade therefore, the system efficiency is suitable to analyse the charcoal value chain.

Charcoal is a fuel-wood produced by carbonisation of biomass (Chidumayo and Gumbo, 2013). It is extensively used for various purposes and can be an excellent domestic fuel. Charcoal can be made from virtually any organic material, like wood, straw, coconut shells, rice husks and bones (Bhattarai undated). Among wood, usually the hardwood species are preferred for charcoal making (e.g. Acacia, Mangroves, Oak, and Prosopis). There are various types of charcoal; the most important are those used for domestic energy purposes and those used in metallurgy. Charcoal for domestic energy purposes is obtained by pyrolysis process, while metallurgic charcoal is produced for blast furnace to produce pig iron (Brito and Barrichelo, 1981). The utilisation of this charcoal follows a certain chain that goes from production to consumption. Inside the chain a certain value is added which makes a commodity (charcoal) traded, it is called value chain.

2.2 Charcoal production in world

Charcoal production is a business activity today; it contributes to increase the house income and provides a safeguard against food-shortages and unemployment. It is a prime source of domestic energy of urban population in most African countries (Mwampamba, 2007; Sepp, 2008; IEA, 2009; Schure et al., 2013), as well as driving force for economic incomes in rural areas. It has been produced and used since the Stone Age. In developing countries it has been used as fuel for cooking and grilling while, in developed countries the charcoal is used mainly for recreational cooking as barbecue fuel (Reumerman and Frederiks, 2002; Stassen, 2002) and in industries in some cases.

The decision to consolidate wood energy data has been particularly devastating for charcoal which got lumped together with fuels such as firewood, dung and crop residues which are interchangeable with one another but not necessarily substitutes for charcoal (Mwampamba et al, 2013). The absence of data to evaluate local charcoal situation is huge. It is rare for the charcoal sector to generate data that capture production and consumption volumes. The data scarcity is due to the clandestine nature of production. Data are usually generated from surveys which are expensive to conduct and not always well executed. The attempts to estimate the real data have been made to guesstimate the production using the transported volumes as a proxy. Commercial charcoal production is largely unrecorded, there is very little control and virtually no one pays taxes (Salbitano, 2009). In Cameroon for instance, less than 1% of the estimated charcoal produced is the only amount captured by Special Forestry Sector (Schure et al., 2012). Large quantities of charcoal produced without official permits illustrate the predominantly informal and illegal character of the sector. The fact that much of wood fuel production and trade is informal it does not mean that the activity itself is unorganized. The problem of charcoal data remains intact, the sector itself does not have potential to control and to regulate the charcoal trade therefore charcoal databases cannot be created. The acquisition of charcoal data is a challenge however, on country level charcoal databases exist and are constructed from integrating information from various sources and from experts guesstimates (Mwampamba et al., 2013). At least two main datasets are reported under two organisations; Food and Agriculture Organisation of United Nations (FAOSTAT, 2012) and International Energy Agency (IEA, 2012) however, there is a big inconsistencies between IEA and FAO estimations of national charcoal production (Figure 2).

In most settings, knowledge of characteristics and role of the actors in the charcoal value chain (producers, transporters, traders, and retailers) that they play is limited and is largely based on anecdotal evidences. The reliability of this data for many developing countries is week, insuring that trusting in this data for statistics and policy decisions is dangerous figure 2. The higher differences in terms of incompatibility for both organisations are difficult to explain. For many countries, the FAO and IEA charcoal database do not coincide (Mwampamba et al., 2013). This makes difficult to discern the reliability of charcoal databases or deduce whether charcoal deficiency problem exists or not. It makes also difficult to define what charcoal is and the extent of the charcoal problem in order to apply the appropriate interventions.

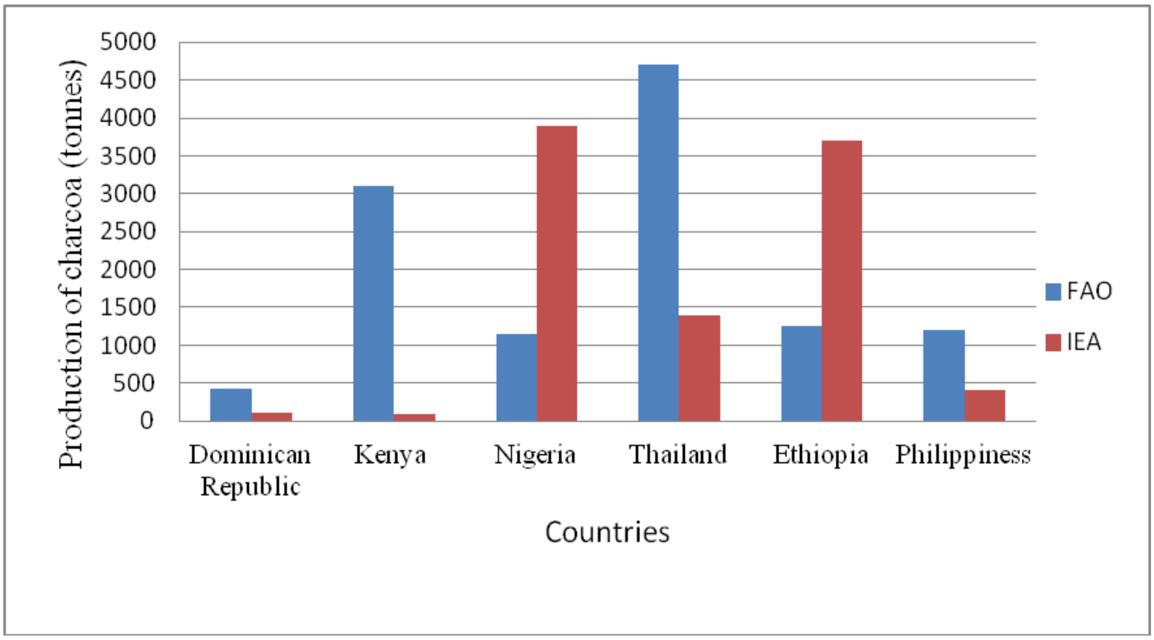

Figure 2-Incositences on charcoal nation production for 2010.

Source: Mwampamba et al. (2013).

Charcoal had been produced for many purposes than just energy reasons. In Egypt, it was produced for medicinal applications (Brito ans Barichelo, 1981) and during the Second World War the production for this purpose was developed industrially. It was used to remove organic compounds such as chlorine, gasoline, pesticides, and other toxic chemicals from water and air (1).

According to Steierer (2011), the production in Latin America is strongly influenced by the data reported by Brazil since the country produces about 30 - 47% of the charcoal in all Latin America (Colombo et al., 2006). Moreover, the share of Brazil in entire world is still the highest followed by number of African countries Figure 3.

Demand for charcoal continues to increase in Latin America and Africa, while it drops in Asia, and remains stable in the industrialized world (Table 1) where its recreational use is concentrated over the summer months. The techniques and technology for charcoal production have been improved; therefore the amount of charcoal produced increase as well. The producers of charcoal are moving from the traditional way of production to the more conventional one.

[1] http://forestry.about.com/od/alternativeforest/p/The-History-And-Business-Of-Making-Lump-Charcoal.htm

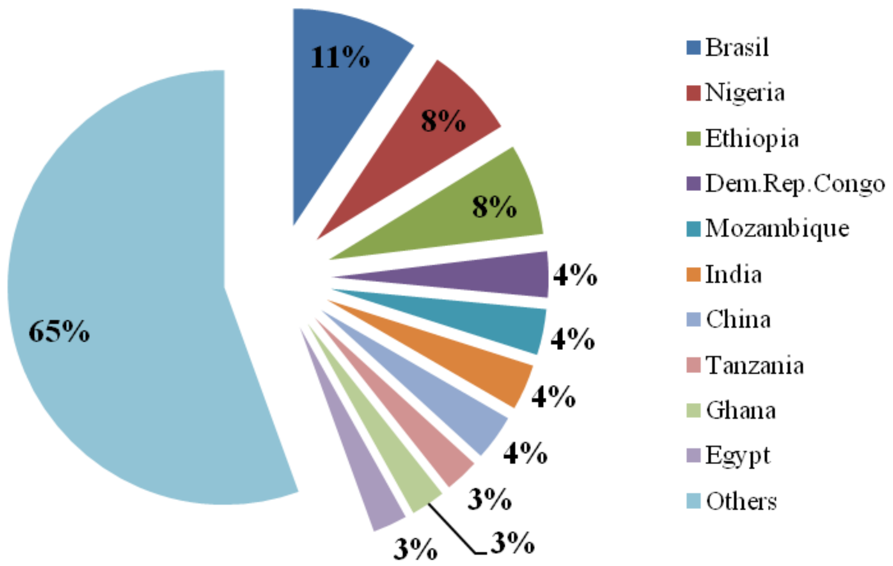

Figure 3-Top ten wood charcoal producing

Source: Steirer, (2011).

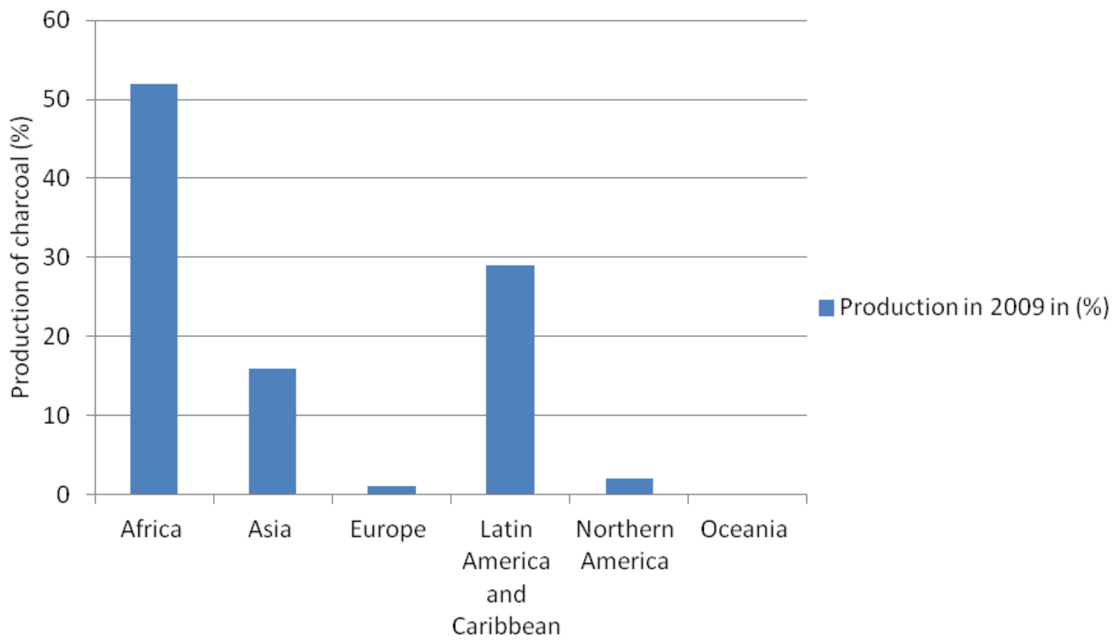

Figure 4-Production of charcoal by region

Source: Steierer (2011).

2.3 Comparative analysis of production and consumption of charcoal in DC

The global production of wood charcoal is estimated to be 47 million metric tons and increased by 9% since 2004 (Steierer, 2011). Africa produces the major part of the global production (63%). The region of Latin America and the Caribbean shows lows production compared to African countries.

In Myanmar about 42% of urban households use charcoal for cooking (Government of Myanmar, 2009) even 93% of urban household has access to electricity moreover, the effort to find alternatives sources are stronger. Therefore, charcoal as domestic energy is expected to replace firewood in rural areas. In Laos, the demand on charcoal increased in urban areas from 10% to 35% between 1995 and 2005 (Mwampamba et al., 2013). From the primary energy consumption in Lao 12 % represent charcoal.

In Cambodia, about 50% of urban population use charcoal for cooking (Geres Cambodia, 2014). The population and urbanization growth rates increases the demand for charcoal (Arnold et al., 2006 and World Bank, 2001) therefore, the population rate in those areas is directly proportional to charcoal production and consumption rate. These arguments are supported by recent findings by KIPPRA (2010) which showed that about 70% of the people in Kenya use charcoal which is similar to Uganda where 70% of timber and charcoal products are taken to Kampala city where majority use charcoal as domestic energy (Kakuru, 2010).

In year 2000, the charcoal consumption for three African countries was estimated to be 314,000 tons for Dar es Salaam (Tanzania), 140,000 tons for Maputo (Mozambique) and 245,000 tons for Lusaka (Zambia) (USAID, 2012). The consumption of charcoal in Africa is projected to double and firewood to increase by 24% between 2000 and 2030 (Alnold et al., 2006) due to population growth.

Charcoal is a highly commercialized commodity which can be easily transported over long distances. The production of this commodity in some of these countries like India and Nigeria for example, has been influenced by international trade. Nigeria exports about 60,000 tons of charcoal to the United Kingdom (Steirer, 2011) every year. Studies

(Mutimba and Baraza, 2005; Republic of Kenya, 2002) indicate that in Kenya only a small proportion of households produce charcoal for own use (about 7%).

2.3.1 Paradigms on charcoal production and consumption in Angola

Charcoal as a commodity carries numerous misconception in the public domain or perception. These misconceptions go from production phase until the last stage which is consumption. The paradigms here are; first, charcoal is mostly domestic energy source used by the poor. Secondly, charcoal production is the main cause of deforestation and finally that it is economically irrelevant. These and other paradigms are shared all over developing countries where charcoal has been produced. Mwampamba et al., (2013) reviewed these paradigms under the name myths and proved that intervention by the government has been influenced by these paradigms. In Angola, these paradigms are strongly highlighted and sometime the business itself indicates the status of the person the in society.

2.3.1.1 Charcoal is a domestic energy source used by rural population

Charcoal as a domestic energy, has been referred to as "energy for poor" (Arnold et al. 2006). Governments and institutions always targeted the rural population as major consumers of charcoal (Schure et al., 2013). However, studies on energy consumption demonstrated that poor people cannot afford charcoal due to their low income. Studies that made a distinction between rural and urban consumption of fuelwood (firewood versus charcoal) have not always been clear (Mwampamba, 2007). Charcoal is often reported as the main source of cooking energy for the majority of urban population. About 80% of people in Angola use charcoal (Chiteculo, 2013; IDF, 2011a), which makes unacceptable the hypothesis of charcoal being energy for rural population only. It involuntarily implies that consumption of charcoal encompasses a wide range of socio-economic groups (Mwampamba et al., 2013). The problem is that charcoal production is associated with poor traditional or even primitive practices. The true is that charcoal has been produced in rural areas and consumed by urban population causing damages all over.

2.3.1.2 Charcoal production is the cause of deforestation

Deforestation is not a new issue in our planet. The Mediterranean was already deforested before the fifth century; Europe also had series cases of deforestation in the 16^{th} century (Trirgood, 1981) due to the need of heating houses mainly in winter time. Haiti for instance has dropped from 60 percent of forest cover to less than 5 percent (Williams, 2011), due to land scarcity for cultivation. In Angola, the logging activity is not reported to cause deforestation, only charcoal and firewood is reported followed by itinerate agriculture.

As African cities grow, the request in charcoal production increased as well. The increased demand for charcoal always means cutting more trees to get wood for charcoal making, which may increase the rate of deforestation. In Brazil, it is estimated that 15% of deforestation from the Amazon is attributed to charcoal production (Uhlig, 2011).

The attempts to find the effect of charcoal production on forest degradation had not been successful Hosier and Milukas, 1992; Hofstad, 1997) due to the lack of information, maps, and old satellite images (Cabral, 2010). Chidumayo et al., (2013) studied this case and reported that the deforestation rate caused by charcoal production in tropical countries is less than 7% of the total forest loss. The deforestation caused by charcoal production has not been well demonstrated in Angola as well as in most Southern and Western African Countries. The forest degradation that follows harvesting wood for charcoal production is probably more prevalent than total deforestation (Chidumayo and Gumbo, 2013). The perceptions to link charcoal production to deforestation have been rebuked by several studies since the early 90s (Chidumayo, 1993) and this linkage developed two paradigms; *first*, that it is the direct driver of deforestation and *second*, that deforestation actually occurs in the areas with charcoal production (Mwampamba et al 2013). Arguments against the first paradigm have showed that deforestation was always a result of agriculture expansion and logging (Motel et al., 2009) neither charcoal however, charcoal was merely a by-product of the deforestation process. On the other hand it is also ridicule to believe that charcoal production cannot drive the deforestation process. Any prediction of deforestation rate is a challenge (Motel et al., 2009) and deforestation due to charcoal production is just a question of semantics, because the distinctions between the processes of deforestation versus degradation are latent. For many years, researchers misled about the meaning of both terms therefore, their results were never clear (Oduari et al., 2011). Deforestation is the long term loss of forest cover and degradation is the temporal removal of the forest (Sasaki et al., 2011).

According to Chidumayo (1993), charcoal production tends to consist in clearing of all standing vegetation, which gives immediate visual impact that are easy to link with deforestation. This argument was contradicted by Swami et al., (2009)'s observation, which indicated that there was selection of species for charcoal production and people do not necessarily cut each tree for charcoal. They select the species which have higher calorific value even though depend on availability of the species in the area. However, rather than deforestation, forest degradation is probably the outcome of charcoal production (Mwampamba et al., 2013).

2.3.1.3 Charcoal sector as economically irrelevant

The paradigm of charcoal being economically irrelevant started in 1990, when the production of charcoal and trade were used by the poor to find employment and livelihood in Africa. The traditional concept was that charcoal producers were always looked down within the society; they were called bad names such as "go away, you charcoal producer- or "*carvoeiros* in case of Angola (Chiteculo, 2013)" and "a charcoal producer never wears a white shirt" and so on. The business itself indicated the low status in the community. However, with the process of urbanization in the Developing Countries, many worthy people joined the business and the number of traders increased simultaneously (Ministry of Pastoral Development & Environment of Somalia 2004). The business of producing charcoal today became a clandestine and contributes less to formal economy. It is unregulated businesses that include charcoal transportation to foreign countries which are lucrative businesses making millions of dollars in profits (World Bank, 2009).

Charcoal production is found to be especially important for household with low agricultural capacity and also limited stocks of human and physical capital (Khundi et al., 2011). Actually it is estimated that the number of people dependent on or participating in the charcoal value chain are best available for Sub Saharan Africa (Mwampamba et al., 2013); in Dar-es-Salaam, Tanzania about hundred thousand people are engaged in charcoal production. In Kenya, about 700, 000 people (Sepp, 2008), for Malawi it is estimated to be

100, 000 people who support their livelihoods through charcoal production. According to Kalumiana (2000) findings, Zambia had about 50,000 charcoal producers, 3,500 transporters and 10,000 distributors of charcoal in 2003. In Mozambique, it estimated that about 150, 000 families are employed on charcoal production generating an annual income average of 250-3000 US$ per family (Falcao, 2006) while in Tanzania they are earning about US$ 176 to 645 as year average income (Malimbwi and Zahabu undated). In Angola, the statistic did not indicate number, however, it is clearly seen that every single farmer at least once per year had produced charcoal. The number of people engaged in charcoal business is remarkable. For example in Kenya, the number of charcoal producers, i.e. 200 000 is higher if compared to number of people working in education sector (Sepp undated). However, the estimations of International Energy Agency IEA (2006) predicted that by 2030 the number of people depending on traditional use of biomass (charcoal) will increase. Therefore, to believe that charcoal is economically non-profitable business is nonsense as it is seen in the results of this thesis.

2.4 Charcoal production techniques in Angola

The production of charcoal is an old trend. The traditional methods of making charcoal have changed, the simple methodologies have been rationalised and the science has verified the basic processes of carbonisation and spelled out the quantitative and qualitative laws which govern the process([2]). The new methods do not reside in the principle of carbonisation itself but in the rational use of heat, materials handling, labour time and recovery of by-products from the smoke given during carbonisation.

Charcoal in tropical countries is produced from aboveground tree biomass, implying that whole part of trees must be felled and wood carbonization is made in traditional kiln (Chidumayo and Gumbo, 2013). The traditional earth kiln or mound (Table 2) is suitable for small scale charcoal production in Angola and yet adapted for large scale production ([3]). The efficiency of this kiln is about 12 % according to Kalumiana and Shakachite (2003) in Zambia, 11-15 % in Tanzania and 8 -12 % for Ethiopia Yigard (2003). However, charcoal is mostly produced using the earth-mound kiln, an ancient

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[2] http://www.fao.org/docrep/x5555e/x5555e02.htm

[3] http://www.fao.org/docrep/x5328e/x5328e07.htm#chapter 6 making charcoal in earth mounds

technology dating from the middle ages (Adam, 2009). Some African countries (Kenya, Tanzania) are using technologies that have proved to be efficient and appropriate.

The casamance kiln is developed from earth traditional kiln; it has a chimney (which can be made of oil drums) at the back (Appendix A) where the air is released. The principle of this kiln is the same as earth kiln, the difference is that here the wood is cut into pieces of 0.5 metres long (Oduori et al., 2012) or 1-1.5 metres (Kenya Forestry Research Institute (KFRI), 2006) then are paced upright and covered with dried grass or foliage and then soil. However, it gives better carbonisation control resulting in higher yields, yet can be constructed whenever the material is found and has little cost. A comparative test of casamance kiln and traditional mound kilns showed higher quality of charcoal in casamance kilns due to shorter carbonisation and enhanced hot flue circulation. The disadvantage is that it is time consuming and has low productivity. Another type is the half orange kiln made of brick and covered for protection from rain (Appendix A). The wood is packed inside this kiln through a doorway, which is the sealed halfway up (Oduor, 2012, KFRI, 2006, Bailis et al., 2013). These kilns have been constructed for medium and large scale production in Brazil. The kilns are constructed for commercial purposes, it produces 80 -120 bags depending on actual radius of the kiln. About 70 % of Brazil's charcoal is produced by these kilns.

A traditional earthen kilns yield a mass of charcoal equal to 10 – 20% of the mass dry wood input (Bailis, 2009) while, hot tail kilns can be 25-30 % efficient (Pennise et al., 2001). Another type of kiln is the drum kiln. It is made from original drum; the carbonisation process takes 6 to 12 hour (Oduor, 2012, Kenya Forest Research institute, 2006), which gives a recovery rate of 3 to 4 times if compared with traditional earth kiln. The drum is modified by welding a chimney holder made of a short piece of metal pipe to fit a chimney of 6 cm diameter and 1 m length on the bottom side. In this kind of kiln the wood must be cut into pieces of 80 cm length and 6-10 cm diameter average. The wood should have at least 20% of moisture content (KFRI, 2006). Each drum kiln has a capacity of 0.4 m^3 of wood and yield of 3 bags of charcoal. This type of kiln is used in Kenya, Malawi, Ethiopia, Thailand, etc. This technology is appropriate for domestic production and recommended only for domestic needs neither for commercial investments (Monica et al., 2013).

Hot-tail kilns are the most prevalent charcoal production technology in Brazil but today container kilns are being introduced by some producers (Bailis et al., 2013). However, there are other advanced technologies to produce charcoal that are mainly used in developed countries like France. In Serbia for instance, the BTRexp Company founded in 2008 developed a construction of furnace (Appendix A) that can produce high-quality charcoal using most advanced technology. The quality product and energetic efficiency of this furnace care far for human environment recommended by FAO advisers. On the basis of contract on license purchase, BTRexp Company has the right that allow them to build these furnaces in Serbia, Bornea, Croatia, Slovenia, Macedonia, Romania and Montenegro.

The efficiency of a charcoal kiln is measured as the mass of charcoal obtained from a kiln decided by the mass of wood initially put into the kiln (Hibajene and Kalumiana, 2003). In this sense, it is important to mention on what basis the masses are indicated in relation to the moisture content of the wood.

Table 1: Summary of charcoal production technologies

Type of technology	Applicability	Advantages	Disadvantages	Efficiency (%)
Traditional earth kiln	small scale production	Known and easily mounted	Not easy to control charcoal	15 -20
Casamance	Small scale production	Controlled air flow and process	Stack arrangement, need precision	26-30
Drum kiln	Domestic uses	Easy to construct	Charcoal easily contaminated	20-30
Portable metal kiln	Large and small scale production	Portability and good recovery	Costly	26-30
Half orange kiln	Small scale production	Use small material	Costly	50-60

Source: Kenya Forestry Services, USAID, UNDP, GEF Umbrela cost sharing agreement report 2008.

2.5 Production and commercialization of charcoal in Angola

The report and record on charcoal data in Angola has been done from 1969 to 1973 (IDF, 2011b). From 1974 to 2004 no records of charcoal data (Figure 6) that was available due to the political instability in the country. Therefore, there is an unknown gap on when the charcoal became a business activity.

The data on wood energy collected from Institute of Forest Development (IDF) since 2005 to 2011 indicated that energy consumption for domestic purposes in the household sector is led by a combination of charcoal in urban areas and firewood in rural areas.

The production of charcoal requires licenses which are ensured by IDF, this is same for other forest products like firewood and timber (Figure 5). The number of licenses for charcoal and firewood tend to increase and the charcoal production in Angola gained big space and increased drastically by illegal production of it. Majority of producer do not ask for licenses to start charcoal business.

The production of charcoal was always clandestine. There was never existed a charcoal industry or even a company responsible for the production of this commodity (IDF, 2011a). In the last days, the production of charcoal and firewood represent 60% of national energy balance followed by oil 41.7%. In Angola the charcoal production is estimated to be 253, 104 tonnes yearly in average (IDF, 2011) from which Bié Province has a share of 5, 325 tonnes per year. In 2004, FAO estimative indicated that the marketing of wood in Angola is about 5 million cubic meters per year. Regarding to charcoal, the market supply is estimated to be 7.2 million cubic meters per year. Luanda is the main charcoal consuming region and the consumption per capita in average is the 100kg / year. However, it is assumed that these figures do not represent reality.

Figure 5- Licenses ensured to explore forest resources

Sources: IDF 2011.

The controlled production in the country is only possible due to issuant of licences. However, in 2010 the reduction of licences for charcoal and firewood production (**Figure 5**) resulted on significant reduction of charcoal and firewood exploitation.

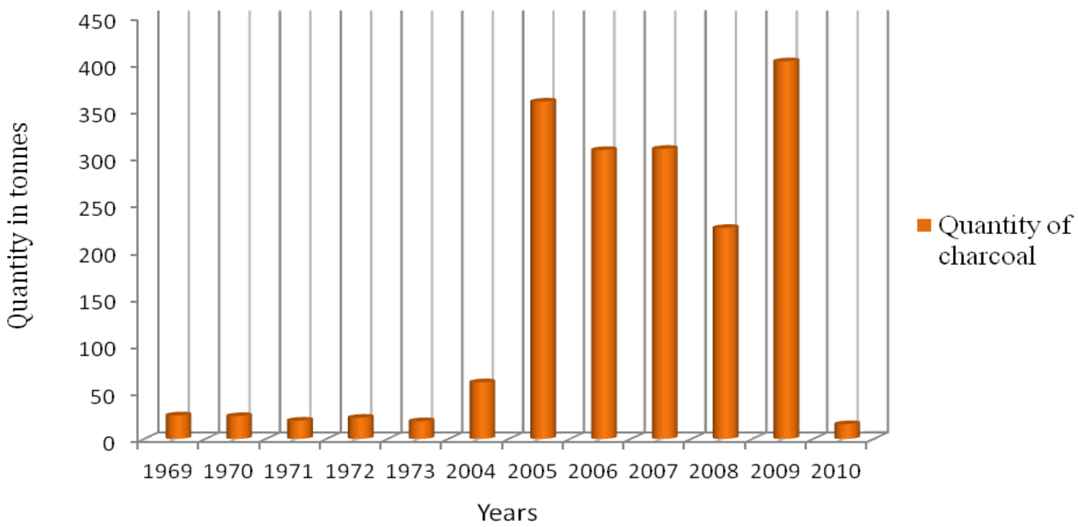

Figure 6- Average of charcoal production in Angola

Sources: IDF 2011.

2.5.1 Process of charcoal production in Angola

Due to the type of tools used in cutting trees process, (axes and slashes) the charcoal makers called "Carvoeiros" are not able to cut large trees with more than 30cm diameter. Trees with smaller diameters have been burned for charcoal due to easy transport and ordering process (Figure 7). The tools used during the production of charcoal are in most case the same used for farm activities (Axe, hoe...) rarely they use power saw.

The stages involved in charcoal production are (Figure 5): *(i) felling/cutting of trees*; *(ii) piling of the logs into clamp*; *(iii) covering the clamp with dug and soil lumps; (iv) Carbonisation of the wood into charcoal* and then (v) *harvesting of charcoal from the kiln and packaging it into bags*. The amount of charcoal produced from a kiln depends on several factors related to carbonisation efficiency (Hibajene and Kalumiana, 2003).

Biomass Technology Group suggested that, since charcoal production cannot be easily replaced by alternative energy sources affordable in Angola, it is important to develop policy measures that aim at charcoal production an utilisation of more sustainable ways, avoiding higher prices of the product.

The wood for charcoal production is now found far away from the villages therefore, these activities force people to spend several hours every day in order to collect wood for charcoal. This reduces the time that farmer should devote to other activities, such as farming and education (International Energy Agency, 2006).

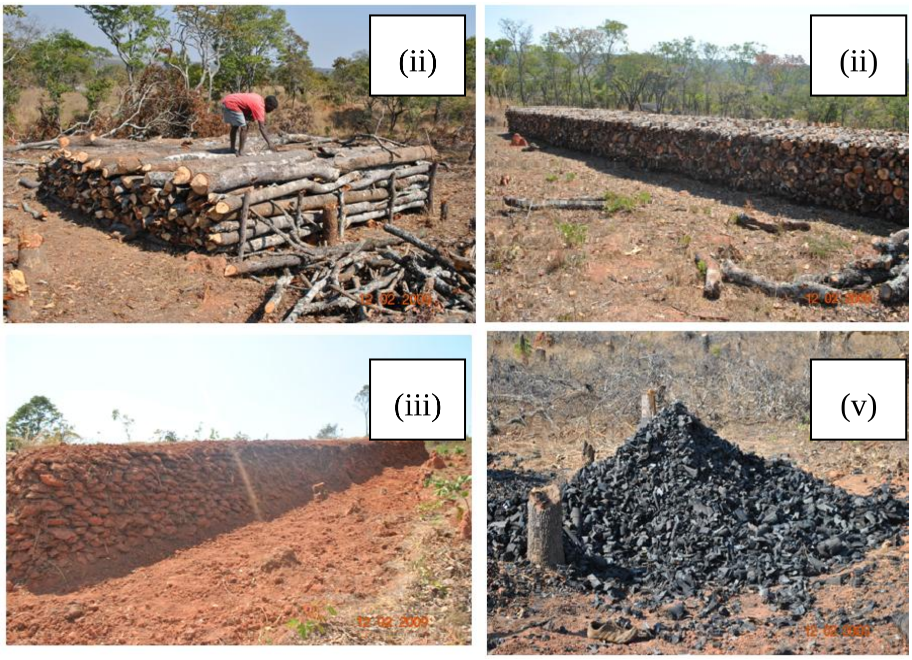

Figure 7- Process of charcoal production at traditional earth kiln in Bié province – Angola

2.5.2 Tree species used for charcoal production in Angola

Any kind of wood can be used to make charcoal (Ganesan and Nema, 2006) but, the quality of charcoal varies from species to species and it depends on the method of carbonization applied.

In Europe, the charcoal production has been recorded in pre-historic finds for six thousand years ago (Massengale, 2006). The most used species for charcoal burning in Europe were: beech (*Fagus sp*.), hornbean (*Carpinus sp*.), ash (*Fraxinus sp*.), maple (*Acer sp*.), birth (*Betula pendula*), pine (*Pinus sp*.), and spruce- *Picea sp* (Samojlik et al., 2013).

In African, the vegetation is not yet fully known and understood. The most important challenge for Central African charcoal species identification is the extreme diversity of woody species (Hubau et al., 2012) therefore, the charcoal production always follow the availability of the species within each country. For example if softwood is used to make charcoal, it will make soft charcoal which burn quickly. However, *Casuarina equisetifolia*, *Acacia mearnsii*, *Acacia polyacantha*, *Acacia xanthophloea*, and *Combretum* species are some of the species that produce higher charcoal quality (Mugo and Ong 2006, Mutimba and Baraza 2005). Charcoal production is considered as a big threat because it targets specific preferred species found in natural forests and woodlands (Mugo and Ong, 2006). Moreover, it always depends on availability of the species in the country.

In Angola, most of the charcoal produced comes from miombo forest where the predominant species are; *Brachystegia spiciformis* (Manda), *Brachystegia ssp* (Samba), *Isobernadia angolensis* (moné), and *Julbernardia paniculata* (Chiteculo, 2013). However, other indigenous species are been used too like; *Pterocarpus angolensis* (Girassonde), *Afxelia cuazensis* (Uvala), *Albizia adianthifolia* (Mukasa), *Erythrophleum africanum* (Mucoso) (Diniz, 1996). The preference of each species depend on its availability, in the central plateaus (Bié, Huambo) for instance the preferred species are *Brachystegia spiciformis* (Manda) and *Brachystegia ssp* (Samba) and it is the most common species used for charcoal production. While, in the northern part the preferred species are *Terminalia superba* (Limba), *Chlorophera exelsa* (Moreira) and *Ceiba pentandra* (Mafumeira). Moreover, in the Miombo woodlands, some tree species are known to produce poor quality charcoal and others are too hard to cut.

2.5.2.1 Brachystechia ssp.

Brachystegia spiciformis is the defining tree species of miombo woodland, the vegetation type that dominates the south-central African sub-region (Backeus et al., 2006). The genus *Brachystegia* comprises 28 species according to flora *Zambesiaca* however; the precise number depends on how the species are defined. Its distribution on miombo woodland depends on soil factors. *Brachystegia* for example is found mainly on the red and grey soil (Backeus et al., 2006). Miombo woodlands have been considered a disclaimer, dependant on fire, but most trees, including dominating miombo species of *Brachystegia* and *Julbernardia,* are fire-sensitive at young age.

The mean annual rainfall in the miombo region ranges from 650 to 1400 mm, majority of which falls in the summer season (October–March). Miombo woodland can be divided into dry miombo and wet miombo subtypes (White, 1983), where the dry part is characterized by floristically impoverished vegetation and lower canopy height (15 m) compared to wet miombo woodland (Frost, 1996). Most miombo species, including the dominant species, are deciduous and shed all of their leaves during the dry season, (July to September). Leaf flush, particularly in the wet subtype; it occurs before the onset of the wet season.

The explanation for this pre-greening behaviour is unknown, but its onset appears to be related to high temperatures in the late dry season and is presumably restricted to areas with adequate ground water reserves (Chidumayo, 1993).

2.6 Production and commercialisation of charcoal in Bié province

In entire province, the access to wood for charcoal production is not regulated in practice, much less managed in an unsustainable manner, where firewood and charcoal are represent the main outcome from forest. Moreover, the market prices of these products almost entirely reflect extraction costs (IDF, 2011). Middlemen and retailers play a catalyst role, mostly in larger market of Chissindo. Under such conditions, the only limit to wood fuel production is the occurrence of trees within an economically tolerable distance from the place of consumption. Charcoal produced from wood coming from natural forest generally requires only investments in physical labour, because the raw material comes for “free” to the charcoal producer. Plantations forests, if managed responsibly, have a particular important role to play in providing a renewable and environmentally friendly energy resource. However, they remain untouched for charcoal production except the eucalyptus plantation in Cunhinga municipality. The trend of charcoal production in Bié province tends to increase (Figure 8).

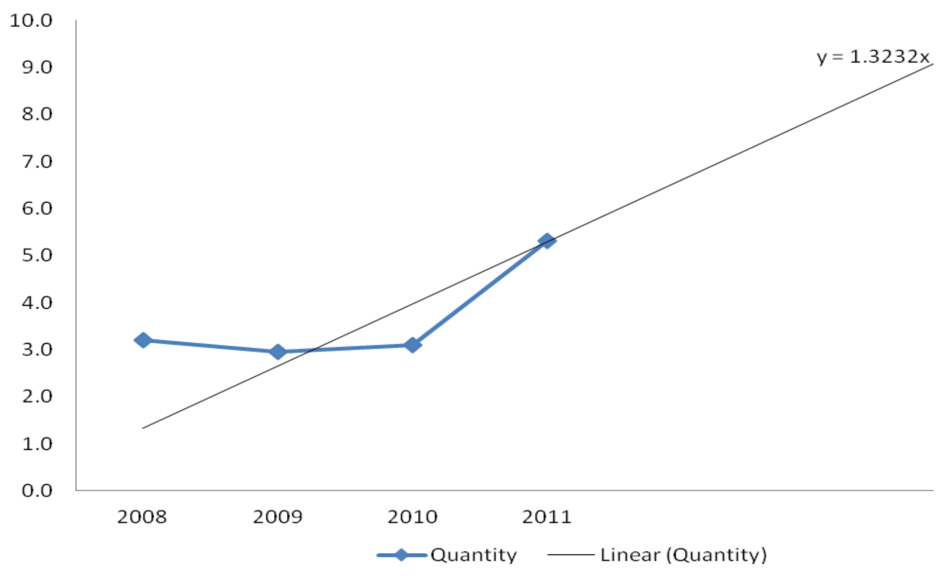

Figure 8-Avarage production of charcoal in Bié province

Source: (IDF 2011)

The distribution of forest products in the provincial market are not clear as a result, the control of charcoal for instance exists only on production and transport site. Two broad regimes for wood production and harvesting can be differentiated: (i) natural forest resources and (ii) plantations including small-scale woodlots. However trees outside forests notably agro-forestry systems and trees along roadsides are not used for charcoal production.

3. OBJECTIVES

The objective of the study was to evaluate the impact of charcoal production on natural forests of Bié province, Angola. The specific objectives of the study were:

i. to investigate tree species used for charcoal production and compare their calorific power;

ii. to analyse the value chain of charcoal from production to the consumption level;

iii. to suggest suitable and viable strategies aimed to reducing forest degradation caused by charcoal production with special regard to environmental and socio-economic impact of charcoal production on local ecosystems and livelihood.

Based on literature review, several hypotheses were stated:

- **H1**. The charcoal production in Bié province is one of the major causes of forest degradation, especially decreasing the occurrence of *Brachystegia* species in natural forests;
- **H2**. The preferences of consumers on a certain type of charcoal drive the higher charcoal production of it which increases forest degradation;

4. METHODOLOGY

4.1 Study site

For this study Bié province, was selected. Bié Province is located in the central part of the country between 10°34´´– 14°18´´South latitude and 15°42´´– 19°13´´ East longitudes. The surface area is estimated to be 70,314 km^2 with an approximate of population of 2 million people (MINAGRI, 2012) from which 80% is peasant.

The main socio-economic activities in this province are agriculture, fishery, and trade. Bié province has a long history at national level in terms of agricultural production. In the past, it was considered as national granary because of its higher production of cereals in the whole country. The province was self-sufficient in terms of agricultural products; it produced cereals for both domestic consumption and exportation. Currently, the production is mainly based on subsistence production. The main crops grown in the region are: maize, beans, wheat, sorghum, soybeans, sunflower, potato, cassava, and vegetables.

The provincial agricultural sector still experiences several deficiencies regarding improvement of production. The low yields of cereal production are caused mainly by the absence of specialized technical assistance and also the absence of infrastructure (Saiovo, 2014). Consequently most of agricultural labour force live in the rural areas where the reconstruction of the main infrastructures especially roads are still insignificant. The shortage of skilled technicians is one of the major challenges that the provincial agriculture sector faces.

The government efforts to improve the agricultural productivity in these areas are based on supporting the farmers with inputs and provide them technical assistance. However, the number and the quality of skilled expertise in agriculture sector still do not satisfy the actual demand.

In terms of forestry, the Province is at its way of development. The general characteristic of Bié forest is open forest or miombo forest; several types of vegetation are distributed in the area of Alto Kwanza. However, it is not known yet the exact extent of forest cover. The dense forests are found in the municipalities of Camacupa, Cuemba, Andulo and Chitembo where is located the biggest forest reserve (Umpulo reserve) of

Angola with 450,000 ha. There have been viewed signs of deforestation due to the production of charcoal and firewood by farmers living around the reserve.

The Province of Bié is administratively dived into nine municipalities with 23 villages. In this study three municipalities selected (Figure 9) from which one village in each municipality was sampled for study purposes i.e. Kuito as the centre region (covering the Nequilo village), Catabola (Canjungo village) and Cunhinga (Etunda village).

The reasons to choose these areas were as follows:

a) More than half of the population in Bié use charcoal as domestic energy even in public institutions like hospitals, prisons, and restaurants.

b) Charcoal production is an important source of income for people in rural areas.

c) There is a high deforestation rate of the natural forest in the Province (Figure 9).

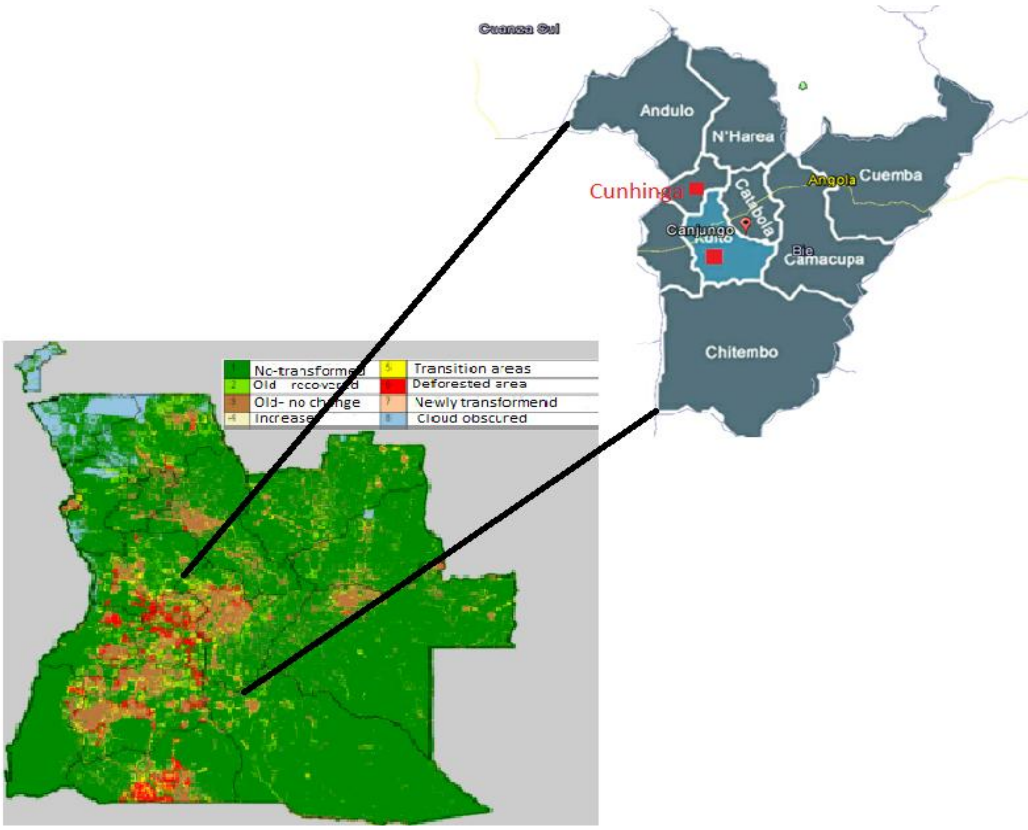

Figure 9-Study area with deforested places

The selected villages are considered the most productive centres of charcoal. Canjungo village has high extension of natural forest where at least 75% farmer has two t three hectares of forestland. While in Etunda village the natural forest is in advanced stage of degradation which probably rose from charcoal production. However, some farmers in Etunda have their own plantation, mainly of eucalypts. Nequilo villages has bigger extension of forestland but not bigger as Canjungo. There the degradation rate is not higher but, today more a more farmers are shifting from agriculture activities to charcoal production. The main reasons to access these villages for our study were mainly the proportional quantity of charcoal that comes from these villages and visible empty space in the forest for the most part along the road.

4.2 Data collection

For the purpose of data collection both *primary* and *secondary* were collected. The literature reviewed was categorised into two domains: socio-economic and environmental related to formalisation of charcoal. This helped to build-up the information on charcoal production and consumption in the world, Angola and Bié province. They were collected through study of online published and unpublished materials relevant for the subject under investigation.

The primary data were gathered through qualitative (semi-structured questionnaire survey) and quantitative (market observation) methods. For the present study the primary data came from 330 respondents interviewed during July - September 2014 in three purposively selected charcoal producing villages of Bié. However, a quantitative market observation (charcoal market-Chissindo) was done from June to September 2013 and July to September 2014.

The target group depended on the actors along the charcoal value chain surveyed. They were identified into four stakeholder groups: *producers (farmer), transporters, traders* and *consumers*. Each of those actors was surveyed separately with different questionnaire.

4.2.1 Producers

The target group here were local rural smallholders (mainly farmers) who produce charcoal in selected villages. The data on producers were collected through a self-developed questionnaire; containing items of different formats (see Appendix B). The respondents were selected trough snowball sampling method and the sample size depended mainly on willingness of local village producers to cooperate. However, the total number of producers (farmers) surveyed was 98; the respondents came from Nequilo villages (n = 26), Canjungo village (n=45) and Etunda village (n=27). For Nequilo and Etunda villages the surveys took one day for each while for Canjungo village took two days to be questioned. The survey beginning by accessing major components of household information like; livestock, business income, agriculture and agro-forestry activities, forest products used directly by householder (vines and medicinal plants), reliance on non-forest products (Table 3).

The survey assessed species used for charcoal in each producing area and recorded the names of the species. Self-assessment items measurements were done, recording the diameters of trees and the quantity of charcoal that fits into one bag. The number of active kilns (those where wood was ready for carbonisation process) and old kilns site were recorded too.

The structure of the questions for all producers was following; multiple choices, asking either for one option or all that apply, dichotomous answers like “Yes” and “No”. The questionnaire contained about 20 questions (Appendix B), designed to not take more than 20 minutes to be filled.

We also collected the four most used types charcoal made from the following species; *Brachystegia spiciformis, Brachystegia boehmii, Pterocarpus angolensis* and *Eucalyptus gradis.* These species were brought to Czech Republic in order to analyse the calorific value of the charcoal.

Table 2. Questionnaire themes and the types of information collected

Questionnaire theme	Type of information
Agricultural production	Priority crops grown, Average yields per year, training in agricultural production...
Household income and capital assets	Livestock ownership, domestic assets, farm products to be sold, etc...
Charcoal production*	Species used, quantity obtained from one kiln, price sold, mean of transport used, etc...
Household characteristics	Gender, educational level of household head, position of household head in community, farming experience in years

*charcoal production section was the main focus of the questionnaire covering 85% of the questions.

4.2.2 Transporters

In the same manner the semi-structured questionnaire was directed to *transporters* of charcoal from the same villages. The transporters were stopped on the road; questions on prices charged per one bag, quantities of bags carried and the distances from where charcoal has been transported were incurred. The sample size depended on the willingness of the transporters (drivers) to stop and cooperate therefore; the questionnaire had to be shorter and designed to take not more than 10 minutes **(see Appendix B**). Altogether 23 transporters participated in the survey, coming from Nequilo (n=9), Canjungo (n=8) and Etunda (n=5).

4.2.3 Traders

To estimate the amount of charcoal traded we followed qualitative methods of survey trough a Participatory Rural Appraisal (PRA), where charcoal traders were observed either on the roadside (highway collection centres) or in the Chissindo market of Kuito where charcoal has been sold. For the traders, the major data were access through interview.

The number of vehicles (trucks, bicycle and pick-ups) carrying bags of charcoal were counted and recorded from June to September 2013 and July to September 2014 **(see Appendix B)**. The vehicles that brought charcoal two times in one month were counted two times as well. The observation was done in even days, three times per week (Monday, Wednesday, Friday) and then change the order in the following week (Tuesday, Thursdays, Saturday).

4.2.4 Consumers

Data on charcoal consumption in the study areas (Bié province-Kuito) was obtained through a semi-structured questionnaire survey, as well. Two particular districts were selected districts (Bairros) in the city of Kuito: Camalaia and Piloto districts with 105 and 250 families, approximately. Houses with person living in there were not counted. The questionnaire here was administrated by the students of Universidade Jose Eduardo Dos Santos, Faculty of Agriculture (FCA- Faculdade de Ciências Agrárias) who live in those districts. The questionnaire began by collecting information on the main energy source for cooking, how often they use charcoal and went on to find out how much do they spend on different types of fuel. There was also collected information concerning the size of household, the amount of charcoal used per day, week or month, and the price paid per unit of charcoal. Questions on propriety ownership were not included into the questionnaire.

The questionnaire was a structured one with open-ended questions and dichotomous answers like “Yes” and No” and closed question (see appendix B). The questionnaire was designed to not take more than 15 minutes.

In order to have a representative sample size, there was adopted a mathematical model from Miller and Brewer (2003); (Israel, 2013) to determine the sample sizes for each of the district at 99% confidence level. The model is expressed below:

$n = \frac{N}{1+N*(e^2)}$ Where n is the sample size, ***N*** is the total population and ***e*** is the confidence interval significant level of 95%. However, the sample size for Piloto district was 133 from 250 instead of 153 and for Camalaia district was 65 respondents from 105 instead of 83.

4.3 Data analysis

4.3.1 Analysis of the effects of charcoal production on forest degradation

The forest degradation caused by charcoal production was calculated by using the model from Chidumayo (2013) to calculate the deforestation rate using the amount of charcoal accessed on production site, by converting the number of bags into tonnes:

forest degradation (ha) = Charcoal produced (t)* (1/0.19)/ biomass density (2)

Where 0.19 is the wood conversion rate for earth kilns efficiency and the biomas density for miombo forest was estimated at 76 t of wood/ha (FAO 2005; Chidumayo, 1991; Hibajene and Kalumiana 2003). There were a lot of uncertainties and it was necessary to perform a lot of parameters like; amount of charcoal that fit into one bag in kilograms, efficiency of the kiln and the wood volume per hectare of forest. For the purpose of this study the parameters were obtained through literatures that estimate such parameters except the amount of charcoal that fit into a sack, the diameters of the trees size cut for charcoal production (which was measured by researcher) and the amount of charcoal supplied in Chissindo market. For the calculation the total amount of charcoal was necessary to convert the number of bags to kg (multiplying by 35 kg) and subsequently to tonnes then multiply 12 (months of the year) and divided by 4 (months of the observation done in Chissindo market) and finally we applied to equation (2).

4.3.2 Qualitative data analysis

The main participants of the charcoal value chain identified were four: producers, transporters, traders and consumers. The identification of this actor was based on the activities they were doing and their role along the value chain.

The qualitative data were transcribed into tables and graphs connecting them and interrelating themes into the chain of charcoal. The rest of data were converted into percentages to express the characteristics of the actors (producers, transporters, traders and consumption) along the charcoal value chain, where the analysed was based on the perception of the researcher on collected information.

The laboratory results were also qualitatively analysed by comparing the calorific value of the charcoal from different tree species to its moisture content.

4.3.3 Quantitative data analysis

For the quantitative data and statistical analysis, Microsoft excel spread sheet, and IMB SPSS software were used, respectively. Due to the fact that data did not show normal distribution, it was suitable to use non-parametric statistic test such as Mann-Whitney test and ANOVA to determine differences in means of charcoal price. The one sample t-test was applied too. Spearman and Kendal correlation were applied to correlate the income from charcoal and the household size and eventually the number of people engaged in charcoal business in the household.

<u>Calculation of charcoal consumption per capita</u>

The average values were always calculated and the number of households that used charcoal for other purposes than cooking for the family was excluded from the calculation of the consumption per capita (restaurants, hospitals, prisons etc.). From 198 households interviewed only 194 were used in the analysis.

The annual consumption per capita was calculated using the mathematical model from Mwampamba (2007) to determine the consumption per capita when assessed on urban charcoal consumption in Tanzania:

$$Cc = \frac{NS}{H} \quad (1)$$

Where H is the household size, S is the number of bags consumed by the household per month. The N is total of months in the year.

A Logistic (logit) regression model in SPSS was used to study the factor influencing the decision to use charcoal by households. The dependent variable was whether a household use or not charcoal to cook their meal. The code's variables were 1 = yes and 0 = not. The independent variable were; household size, purchasing price of charcoal, how often a household use charcoal per week, the quantity of charcoal used per month per household and the use of other alternative sources to cook meal like for example Gas (GLP).

The Logit model was:

$$Logit: p = Pr[Y=1] = 1/1+e^{-X_i'\beta_i}$$

X_i= predicted variable

β_i= is a vector of regression coefficient

$1+e^{-X'\beta}$ = predicted probability of the decision

4.3.3.1Economic analysis of charcoal value chain

The quantity of charcoal produced per producer in one month and the subsequent income derived from its sale was examined. The One-sample T-test and ANOVAs was used to ascertain the significance and the differences means in output (i.e. average number of bags of charcoal produced).

The gross margin (GMi) of each participant in value chain was calculated as the total monthly revenue for each participant (TRi) minus his total variable costs (VCi). The variable costs included transportation costs, packaging, loading and unloading.

$$GM_i = TR_i - VC_i \quad (3)$$

The producers of charcoal were divided into two subgroups: *farm dependent* and 'c*harcoal-dependent.* Therefore the charcoal gross margin was calculated separately. The labour cost was not included to the calculation because the opportunity cost for labour force was household labour which represented zero in our calculation.

In an effort to calculate the income of the village households (producers of charcoal), there was included the sale of farm goods, forest products. In other phase of value chain (transportation, trade), rather than calculating income it was more suitable to calculate the gross margin for better comparison, converted it into percentages for better understanding. For the calculation of gross margin was used the amount of charcoal recorded at production side.

4.4 Limitations of the thesis

This study was limited in time and extension. The study do not comprise all producing points of charcoal, therefore the deforestation calculated do not reflect the deforestation rate of the all study area. Also the method of snowball sampling is not the best, so there is a difficulty to extrapolate our result to the whole population.

The charcoal consumption per capita calculated do not necessarily express the real consumption per capital of the all provinces even if multiplied by the actual population rate and this limited as well the conversion of the all the consumption into forest losses.

The big limitation of this study was during the data collection. People in the targeted villages were afraid to fill the questionnaire due to the political situation in that time (year of election 2014). People were not willing to fill in any paper during that time, fearing for cramping information.

Triangulation and any mixed methods design which was used in this study, required lengthy time and feasibility of resources (GPS, Cars etc.) to collect all representative sample size which was limited in this study. The quantitative analysis of value chain of charcoal rather than resulting on accessing implication of deforestation, it resulted on the main drivers of charcoal production that accelerate the speed of deforestation.

5. RESULTS

This chapter presents the results of the flow of charcoal value chain in Angola, specifically in Bié province. The charcoal value chain survey started, by accessing the main farm activities of the participants along the charcoal value chain presenting the general characteristic of the respondents. The results cover the value chain's actors at various stages (production, transport, trade and consumption), accessing purchasing and selling prices of charcoal until the profit that each actor make from charcoal. It estimates also the deforestation arising out charcoal production.

5.1 Characterisation of the participants along the charcoal value chain

The charcoal value chain survey was conducted in Bié Province with the objective to find out the influence of charcoal production on forest degradation. The general flow of charcoal value chain in Bié Province has a vertical structure where in each phase government intervention is made (Figure 10).

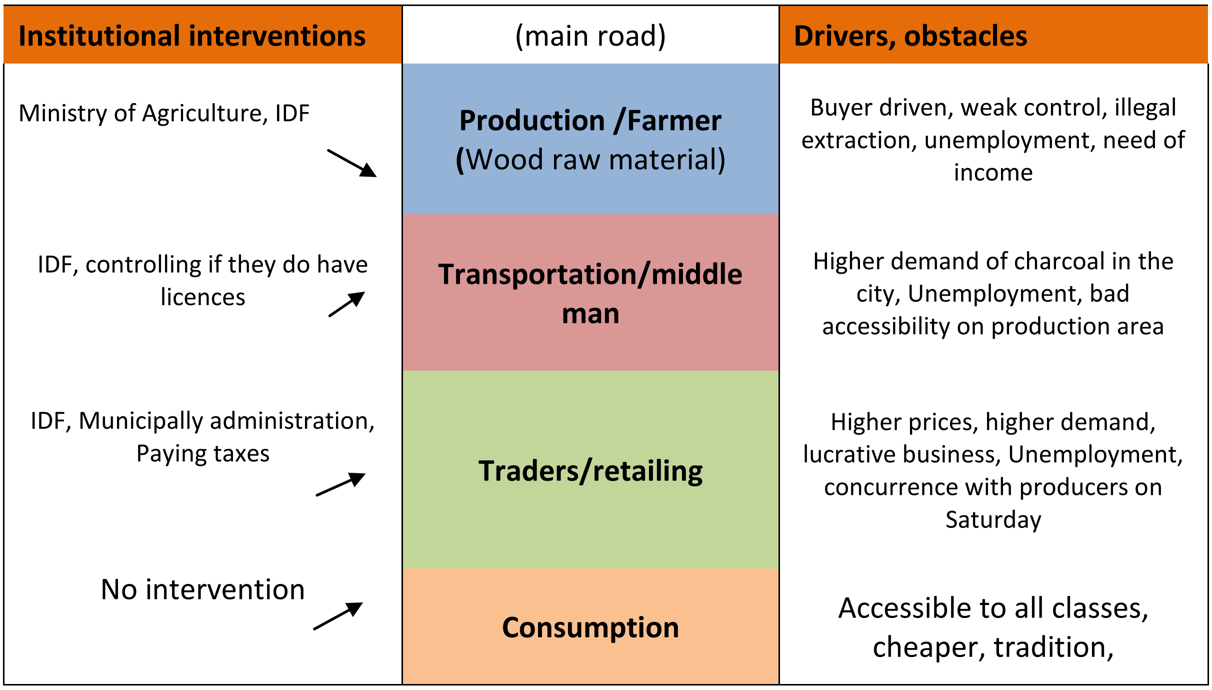

Figure 10- Generic elements of designed basic vertical charcoal value chain map in Bié

The target group at production side were farmers who produce charcoal from trees on their farmlands. However, the activity itself is illegal in most selected villages. The logical explanation to this is that farmers do not ask for permits/licenses to bar charcoal.

The general characteristic of the actor along the value chain is different however, they always have a lot of thing in common like for example the average education level of producer in both three selected villages (Table 3).

Table 3. Description of participants in charcoal value chain survey

Variable	Producers (n=93)	Transporters (n=22)	Consumers (n=198)
Gender (% female)	10	0	90
Age (avg. year)	41	37	*
Household size (person)	6	*	5
Member of household engaged in the charcoal business	2	*	*
Education (avg. year of schooling)	2	6	*
Mobile phone (% ownership)	15	100	*
Radio, TV (% ownership)	60([1])	*	*
Bicycle (% ownership)	18	*	*
Car (% ownership)	1	26	*
Truck (% ownership)	*	32	*
Avg. mean sales per days (number of bags)	8	32	*

*the questions were not included in the survey

The researchers have found that the charcoal in the selected villages is produced for two main purposes: for sale about 96% (by a specific group called "Carvoeiros") and 4% for household (to grill and ironing never for cooking). Majority of respondents in selected villages were farmers and one of their off-farm activities was charcoal production. From the producers two major sub-groups emerged: 'Farm dependent (Canjungo 67%, Nequilo 73%, and Etunda 78% and Charcoal-dependent (Canjungo 33%, Nequilo 27% and 22%). Charcoal-dependent were the most reliant group on charcoal production for their principal income, they are comprised of smaller and young families with fewer economically active members that do participate in production process, do not necessarily live in villages, they produce charcoal two or three time per month with hired labour force and do not cut wood for charcoal production from their own forestland, relying on state forest or private forest.

They do have license from IDF but not every year. Moreover, they can buy charcoal from farm dependent group and sell to the capital market for higher prices.

The other group '*farm dependent*', are farmers fully dependant on agricultural production and they time to time produce charcoal as their secondary source of income. The farming system practiced by this group is for subsistence and partially market oriented, which combine crops production (maize, beans and cassava) and small scale livestock production. The share of the crops oriented to the market is low where the maize represents 29% for Canjungo, 23% for Nequilo and 15% for Etunda village. The main cash crops were vegetables, potato, cassava and beans. The maize is sold by 40 Kwanzas (0.37 USD) in the village while, at the capital city (Kuito) market Chissindo the price is about 60 Kwanzas (0.56 USD) approximately. Cassava, chicken and goat is sold mainly along the roads (Appendix C), it represent the saving that secure the families in hard times**.**

5.2 Dominant species for charcoal production and its size distribution

The logging for production of charcoal is done selectively, therefore, not every tree is been cut for charcoal, however, there are preferences on the species (Table 4) and their size. The preferred size for cut stems was between 10 to 90 cm diameters in average. The main dominant species used for charcoal production in Bié was found to be *Brachystegia spiciformis* due to its availability and good quality. The charcoal made from eucalypt tree is also produced however, only for domestic purposes neither for the market.

There was found also other species like *Diplorhynchus condylocarpon* and *Isoberlinia angolensis* which could be alternatively used for charcoal production, however they are no preferred because they produce a lot of smoke during the burning process. In another hand, local population do not prefer charcoal made of eucalypts, however, this research found it to have higher calorific value (32, 437J/g) as well (Table 4).

In term of size distribution, the trees of bigger size were only found far from the road side. This was confirmed by 78% of respondent interviewed who said that the distance from where charcoal was produced has increased therefore, time to time they have to move to next kiln site due to scarcity of preferred species.

Table 4. Species preferred for charcoal production in Bié and their calorific value

Village	Latin name	Local name	Gross cal. Value (J/g)	Moist.cont. (%)
Canjungo	*Brachystegia speciformis*	Omanda	27,983	3.47
	Brachystegia lujae	Muxovi		
	Cominphora mollis	Mumanga	31,360	2.6
Nequilo	*Brachystegia spiciformis*	Omanda		
	Brachystegia boehmii	Ussamba	32,362	2.7
Etunda	*Brachystegia spiciformis*	Omanda		
	Pterocarpus angolensis	Mubanga, Mako		
	*Eucalyptus gradis**	Okalipi	32,437	1.7

*Eucalyptus charcoal is not used for commercial purposes only domestic uses.

5.3 Effects of charcoal production on forest degradation

By using the country wood biomass density of Miombo forest (in average 76t of wood/ha) and the average quantity of charcoal supplied in the market (57,015,000t/year) and (and we assumed that to 70% of charcoal is sold in Chissindo market since we know that 10% of it is by the trader in their household) and then applying it into the model of Chidumayo and Gumbo (2013) (2); the forest degradation rate in Bié was found to be about 21,000 hectares in 2014.

However, according to IEA (2006), the accepted charcoal conversion ratio for Angola is that 9.6 m³ of wood produce 1 ton (1,000kg) of charcoal by using traditional methods. The charcoal is being produced from clearing forest with capacity of 20 m³ per hectare. By extrapolating these assumption and using this same amount of charcoal (57,015,000t/year) supplied into Chissindo marked in Bié, it was found that about 547,344,000 m³ was converted to charcoal making roughly 27,367 hectares of forest degraded due to charcoal. Moreover, the extent of the deforestation due to charcoal produced is an upper limit since producers do not cut any kind of tree to produce charcoal in the area.

By applying both methods, the degree of forest degradation in Bié province is been in range of 21 – 27 thousand ha per year. Moreover, the magnitude of this degradation is clearly seen on the number of roads opened on the forest to access trucks that do transport charcoal from charcoaling site. A road appearance impact on vegetation is the most visible sign of forest degradation.

By forecasting the amount of charcoal supplied in Chissindo market, it was find that the production trend has a seasonality character (figure 11). The trend line (forecast) indicate that in next year the supply of charcoal in the market tend increase slowly in the same months the observation was made therefore, the higher deforestation is expected in winter month (June a July) and them it increases when the run season starts.

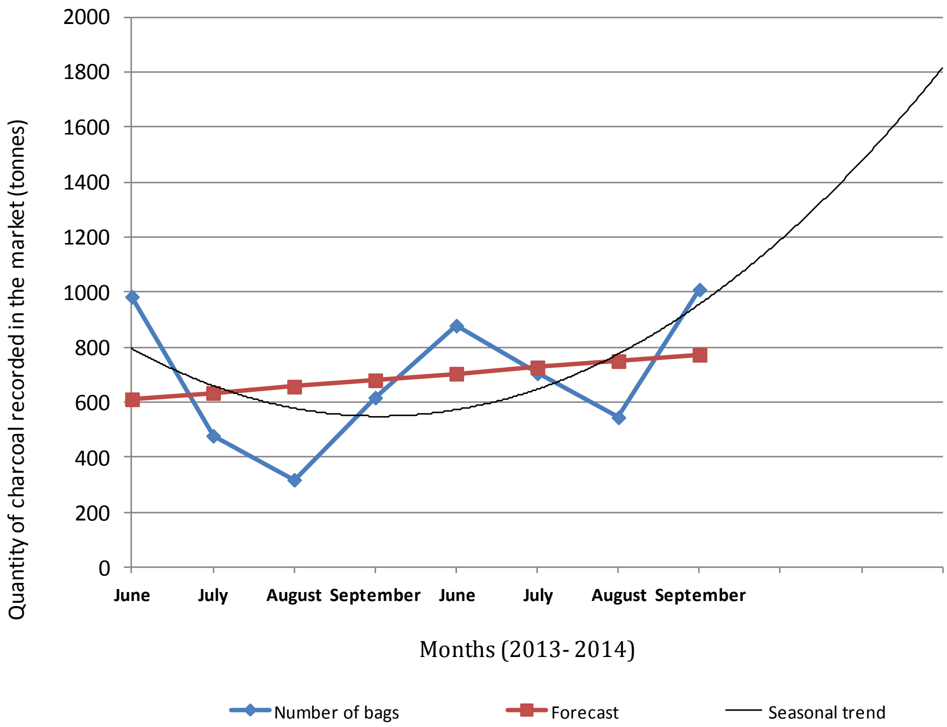

Figure 11- Forecast of charcoal supplied in Chissindo market

5.4 Analysis of the charcoal value chain in Bié Province

5.4.1 Production of charcoal

Producers hold most of their wealth in land which is claimed to be part of their tradition and transferred through inheritance and gifts rather than selling it. Despite difference in land holding size and other assets (Table 4) (bicycles, mobile phone, TV etc.), signs of socio-economic differentiation (differences in dress and house structure and size) are few. However, the differences in production of charcoal in these villages were significant (p=0.007) (Figure 11) as well as the ownership of forest land. Other producers of charcoal do not own forest therefore, they enter in agreement with forest owners that after producing charcoal, 20 % of the production goes to them (bags of charcoal not money).

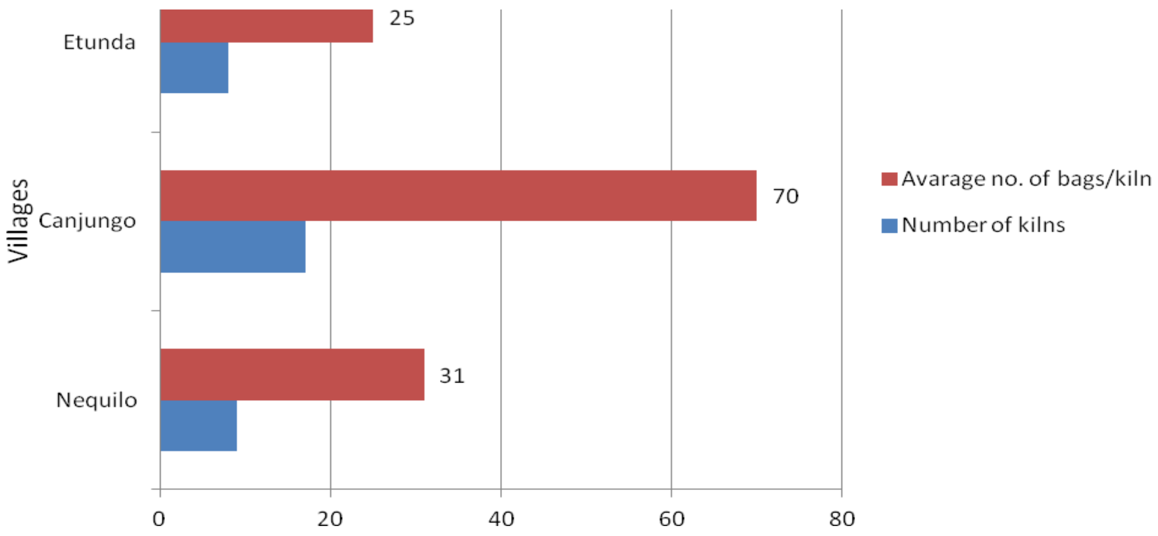

Figure 12- Average production of charcoal in and number of kilns (per month) in selected villages of Bié Province

For one kiln and an investment of 25 days of work, producers were getting about 42 bags of charcoal each in average per month. In extreme case producer can get 180 bags from one kiln. Charcoal producers can expect a profit of 33,000 Kwanzas per month in average in average. The average income estimated was about 32,680 Kwanzas per month.

Table 5. Average prices of forest products in selected villages

Village	Distance (hours)	Price of charcoal per bag (Kz*)	Price of firewood per bundle*** (Kz)	Price of timber per plank** (Kz)
Canjungo (n=45)	2.5	770	650	1,200
Nequilo (n=26)	2	850	350	600
Etunda (n=27)	1	1020	700	930

(*) 1 USD = 107.1 Kwanzas ([4]); 1 bag of charcoal measured 30 -35 kg; **1 Plank has 2 - 3 metre height and 60 -65 cm diameter (Appendix B), therefore, the price timber cannot be compare.

(3) the profit is valid for charcoal dependent group and normal producer group together whose sell the charcoal at village.

There was found also three channels through which charcoal reach consumers. The decision of using one or other channel is strongly related to the amount of charcoal that a producer may obtain. These channels are summarised into:

- **Channel 1:** Producer (*farm dependent*) to producer (*charcoal dependent*).
- **Charcoal 2**: Producer to transporter. Producer sells to transporter and transporter to retailer who sell it to the consumers, usually in 2-4 kg plastic package.
- **Charcoal 3**: Producer to consumer. The consumers are travelling to the villages or buying it along the road.

There was found significant correlation between the prices of one bag and the distance to the market (r= -.353**, p=.002) where it is sold. The more distant is the village

[4] http://pt.coinmill.com/AOA_USD.html#AOA=40 on 07.04.2014

from the provincial market, the cheaper is the purchasing price at production site (Table 6). Therefore the transportation costs was directly proportional as well to the distance from where charcoal has been transported (r=-0.418, p=.002).

The costs that producers incur in the process of making charcoal are related to cost of tools and fees for licenses to IDF. However, it is not in all cases that a producer includes all these costs. From the survey it was found that farmers are not paying feels for licenses that allow them to produce charcoal therefore, their costs are mainly related to packaging and transport.

A considerable variation exists in contribution of charcoal sales to the household income among farm *dependent* and *charcoal dependent.* The farm *dependent* group sell their charcoal in the village avoiding transportation, loading and unloading costs.

The difference between farm dependent and charcoal dependent producer is that *charcoal dependent* group produce 2 -3 times charcoal per month while *farmer dependent* often produce only one in two months, in extremes case only when the family is facing some financial problem. Charcoal dependent group sell the charcoal at provincial market (Chissindo) getting the same profit as traders are getting (Table, 6 and 9).

Table 6- Comparison between farmers and charcoal dependent's Gross profit (margin)

Villages	*Profit margin [Kwanzas]	
	Farmer dependent (Kz)	Charcoal dependent (Kz)
Canjungo	52, 300	85, 915
Nequilo	23, 750	41, 210
Etunda	23, 000	31, 250

*the differences in profit are mainly due to the selling price at different places. Farmer dependent sell charcoal in the village by 880 Kwanzas while charcoal dependent sell in Chissindo market by 1500 Kwanzas.

Table 7. Means costs of tools used for charcoal production

Type of tools*	Quantity per producer	Purchasing price	Time of use (months)	Depreciation per month (Kz)
Axe	2	1500	20	75
Shovel	2	1000	8	125
Machetes	2	1200	15	80
Hoe	1	1000	18	56
Total				**336**

*Producers do not necessarily by these tools for charcoal production purposes; they are normally bought for agricultural activities.

Table 8. Tools used for charcoal production

Production stage*	Tool and materials
Felling and cross cutting	Axe, machetes
Log haulage and piling	Household labour force
Digging soil lumps	Hoe, shovel
Harvesting and bagging	Shovel, rake, bags for packaging

*the time that each phase of production takes depends on season (dry or rain season) and the number of person working on the production of charcoal.

Table 9. Production analysis of charcoal trade

	Items	Unit (Kz)
Nequilo (Avg. Production)	Charcoal: 31.7 bags/kiln; selling market price = 1,500 Kz	47,550
	Total value of production	*47,550.00*
Variable costs	Charcoal: 31.7 bags transportation fee= 100 Kz	3,170
	Unloading: unloading price=50 Kz	1,580
	Package material: purchasing price = 100 Kz	3,170
	Total variable costs	*6,340*
	Gross profit per kiln (Kz)	**41,210**
Canjungo (Avg. production)	Charcoal: 70 bags/kiln; market price = 1500 Kz	105,000
	Total value of production	*105,000.00*
Variable costs	Charcoal: 70 bags; transportation fee= 200 Kz	14,000
	Unloading: unloading price = 50 Kz	3,500
	Package material: purchasing price = 100 Kz	1,585
	Total variable costs	*19,085*
	Gross profit per kiln (Kz)	**85,915**
Etunda (Avg. production.)	Charcoal: 25 bags/kiln; selling price market = 1500 Kz	37,500
	Total value of production	*37,500.00*
Variable costs	Charcoal: transportation fee= 100 Kz	2500
	Unloading: unloading price = 50 Kz	1,250
	Packaging: purchasing price = 100 Kz	2,500
	Total variable costs	*6250*
	Gross profit per kiln (Kz)	**31,250**

*Profit of specialised group is directly proportional to the market price and variable costs. However, the quantities of charcoal sold do not necessarily represent the charcoal they produce; it is only calculated in this way for comparison reason with normal producer that sell charcoal in village.

5.4.2 Transportation

The transporters were in majority young and better educated compared to producers (Table 4). Lower levels of education indicate disadvantage or limited access to market information. Charcoal transporters collect charcoal from the sources that are either on the roadside or directly from the kiln where charcoal has been produced. The average distance of the kiln to the main road was about 3 kilometres therefore, bicycles are used to carry charcoal to the roadside or closer to the points where charcoal were easily loaded to trucks. Charcoal is transported by old trucks and majority of transporters were born in those villages where they practice their business activities. Transporters buy and transfer charcoal from producers to either to the traders in the market directly to consumers. The price of charcoal at producer site are low therefore, farmers that decide to sell directly at the main market (*specialised group*) have to pay transportation cost which was about 150 Kwanzas per bags in average however, it depends on the distance of each village e.g. Canjungo 200 Kwanzas, Nequilo and Etunda 100 Kwanzas.

About 40% of the transporters own the business and play the role of middleman. They sell the charcoal ether to the traders in Chissindo market (1000 Kwanzas per bags in average) or directly to consumer by 1,200 Kwanzas in average. Moreover, those who do not own the business are making about 11, 000 Kwanzas/trip for charging the transport cost.

5.4.3 Trade

Results of interviews and observation in the market found higher trend of charcoal supply in winter months (Figure 8, 9). It also found that charcoal is not only being sold in Chissindo market but also a substantial amount is sold along the highway (about 15%) (Appendix C). When charcoal reaches the market the price was relatively higher, depending on the location where the charcoal has been sold. The price of one bag of charcoal in Chissindo market was found to be 1,500 Kwanzas while, charcoal sold along the roadside was about 1,000 -1,200 Kwanzas. The quantity of charcoal brought into the market comes from different villages however; the main produced centres of charcoal production (Canjungo, Etunda and Nequilo) always showed representative quantities of charcoal in the market. Use of bicycles was found relatively for shorter distances i.e. not for Canjungo village. The observation showed also the producers often use bicycles to transport charcoal directly to consumers. This way was more appreciated by consumers because of cheaper prices (1,000 Kz) if compared to the market price (1,500 kz). June and August months were found with records of trucks and bicycle supplying charcoal to market (Figure 12, 13).

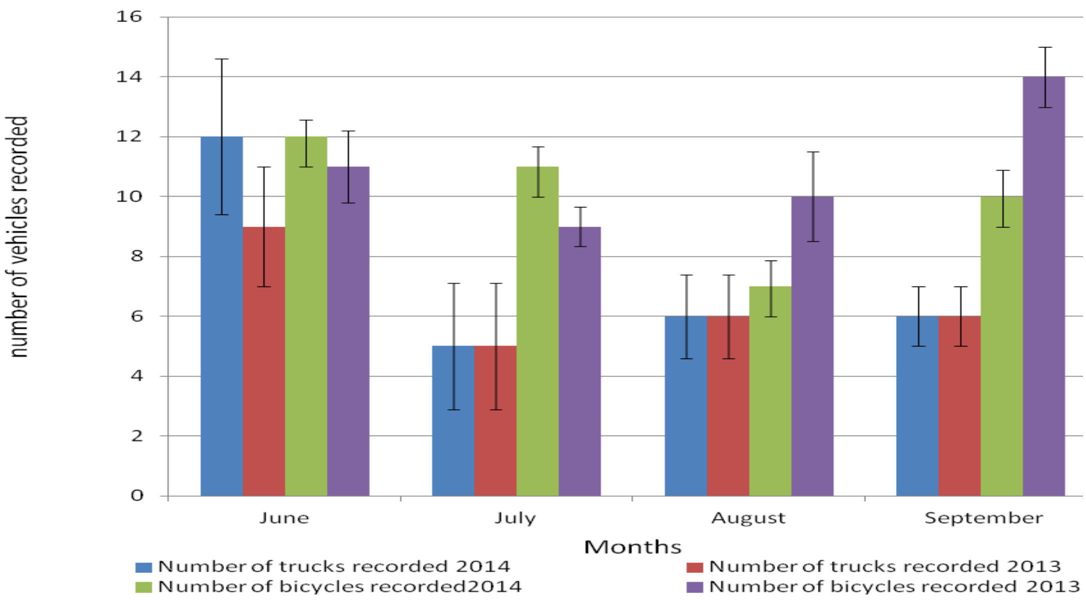

Figure 13- Monthly record of trucks carrying charcoal to Chissindo market

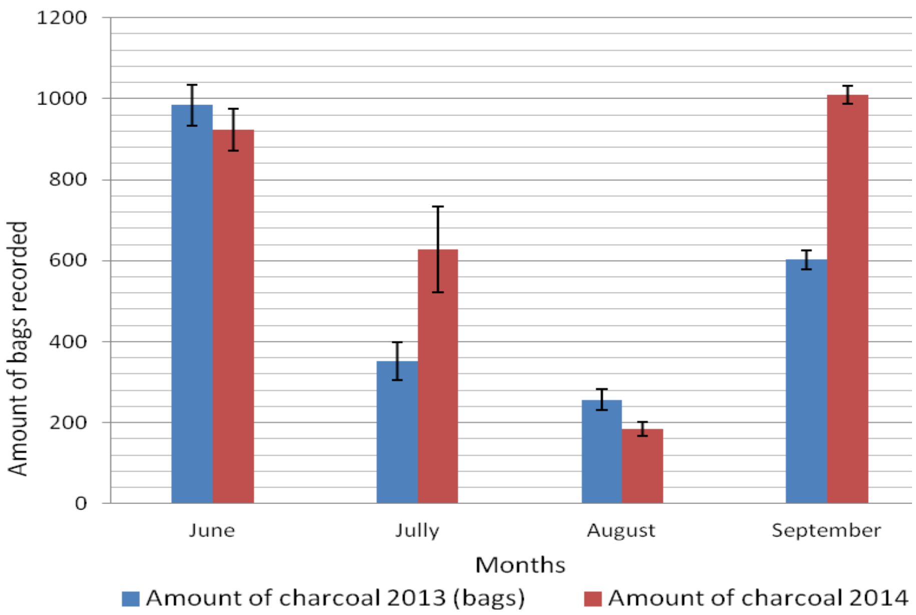

Figure 14- Quantity of charcoal recorded at Chissindo market 2013 – 2014

5.4.4 Consumption

Majority of households in Kuito use charcoal in combination with other sources of energy (gas and charcoal) which represented about 60%. At least one time per day charcoal was been used for cooking and grilling by the household surveyed. On other hand about 7.5% use charcoal for ironing clouds. It was also found be an essential source of domestic energy for several restaurants and public utilities like schools, hospitals and prisons.

The main market of charcoal is Chissindo market where the price was found to be 1,500 Kwanzas and 1,700 as maximum per bag. However, 6% of the consumers prefer to travel and buy charcoal at production site by 600 Kwanzas.

The annual household per capita consumption (Cc) was calculated to be about 4.5 bags per year in average for both districts. Moreover, the utilisation of this commodity depends on the preference of the types of charcoal used, where 68 % of respondents indicated to prefer "*Omanda*" charcoal (charcoal from *Brachystegia spiciformis*). In addition, the decision of a household to use or no t charcoal has been influenced by the number of factor (table 13).

There was a strong correlation between the utilisation of charcoal and utilisation of other sources of energy like gas (LPG) by household (r= 0.67) which was confirmed to be significant by a one-sample T test applied (p=.000).

Table 10. Factors influencing the production of charcoal

Variables in the equation	B. (Logit coefficient)	Sig.	Exp(B)
Frequency of using charcoal	0.21	0.044*	1.234
Place you buy charcoal	-0.065	0.834	0.937
Price of one bag of charcoal (KZ)	0	0.744	1
Quantity of charcoal used per month (Bags)	0.122	0.661	1.129
Householder size	-0.086	0.021*	0.918
Preference on certain types of charcoal	0.251	0.523	1.286
Utilisation of Gas	-0.148	0.804	0.863
Constant	0.293	0.799	1.34

*indicates significance at the 5% leve1

The coefficient interpretation; the individuals that do use charcoal often (in comparison to those that use it only sometime), the price of one bag of charcoal, the quantities of charcoal used per month, and the preference on the types of charcoal are more likely to influence the decision on utilisation of charcoal. While, householder size and Gas utilisation are less likely to influence the charcoal utilisation.

Figure 14 maps and summarise the actors along the value and the intervention that are to be made in each stage of the chain. It also evaluates the share of profit of the participants along the value chain.

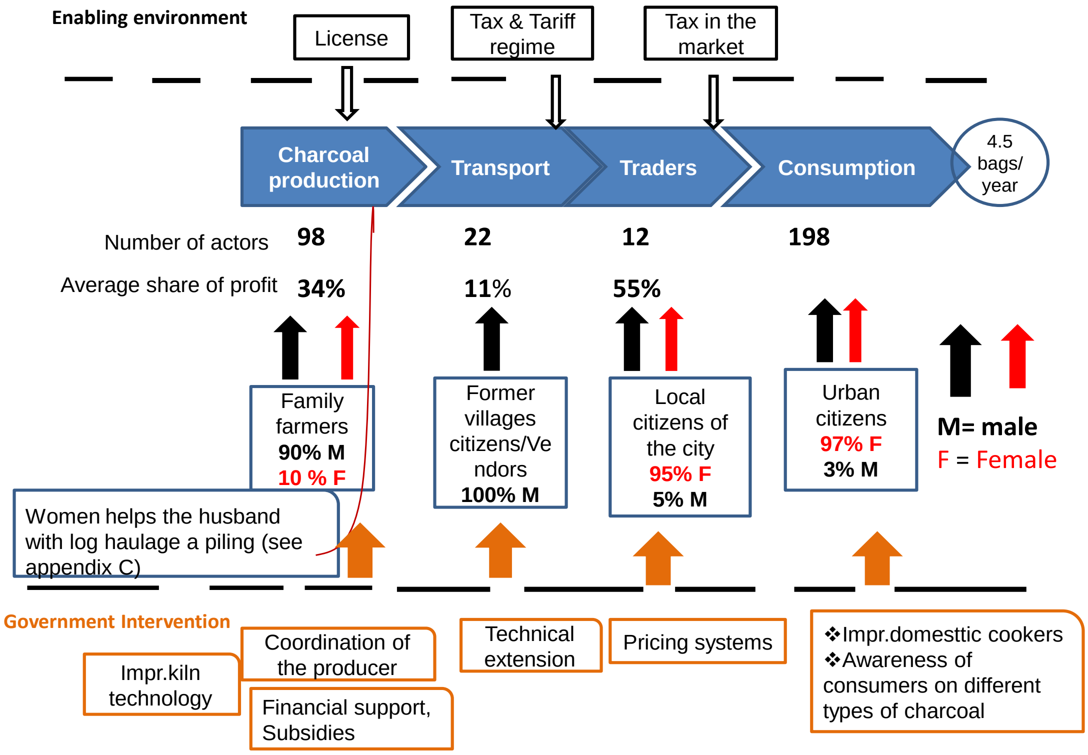

Figure 15-Illustration of the charcoal value chain as well as the enabling environment and intervention

In the charcoal value chain the highest share belong to trader followed by producers. Even with high transportation costs and unloading costs traders are always in relative advantages compared to other actor along the chain.

5 . DISCUSSION

Currently, little is known on the dynamics of charcoal production in terms of ecological and social-economic impacts in Bié Province. The production of charcoal in Bié Province at present serves, and it will for a long time serve as source of income for rural population and source of domestic energy for urban households. One of the questions to ask about charcoal business should be, who really benefits from charcoal trade and how is it related to the government regulation? From the quantitative data collected through literature review on trend of charcoal production it is clearly seen that the reduction on number of licences is directly proportional to the production (Figure 4, 5) which give a good perspective that charcoal can be regulated.

The paradigms that emerged on charcoal production and utilisation are totally crushed; charcoal is not energy for poor. It is produced in rural areas and consumed in urban areas. It is true that charcoal business itself indicates lower position in the society which is easy to link with rural poverty, but it’s only the public perception and discrimination against the charcoal producers. The reasons behind are much stronger than just rural poverty. The paradigm that charcoal production is a poor man’s business should be broken; because according to our findings the average income that the producer can get from charcoal (32, 680 Kwanzas per month) is two times higher if compared to the minimum national wage applicable for agricultural sector (PWC, 2014; Diário da Republica, 2013).

The second paradigm that link charcoal production to deforestation is much contested. The hypothesised statement that charcoal causes deforestation cannot be proven based on our results; however, the calculation found a range of 21 to 27 thousand hectares of forest losses attributed to charcoal in the Province. Nonetheless, because of the discrepancy on the definition of what deforestation is, linked with the insufficiency of data collection concerning the amount of charcoal produced as well as the selection of the preferable species used for charcoaling, it is more convenient to take this percentage as causes of forest degradation and not deforestation. This assumption was confirmed by Chidumayo and Gumbo (2013) who found that charcoal production represents only 7% from the total deforestation in Africa which does not reflect the reality. It is not possible to generalise the findings of this study, however, it is very true that in the areas where charcoal has been produced (Kuito, Catabola, Cunhinga etc,) the forest are being depleted.

Our research also confirmed it by using the satellite map from IDF and Google earth showing the most transformed areas in Bié (Appendix D).

By describing the whole chain of charcoal, it was possible to estimate not only the driving force of charcoal production but also describe for the first time the charcoal overview flows from producers to consumers in the province. The cultural behaviour of consumers on charcoal preference is what drives the increased production of charcoal from the wanted species (*Brachystegia ssp*). The demands of the population on charcoal encourage the commercial production and trade of charcoal. Why? This is because even people who apparently have high economic and social status in the society also use charcoal in alternation with LPG.

The description of the charcoal value chain gave also a panorama of how and where it is possible to intervene (Figure 11), because the production and utilisation of charcoal is not always economical; there is a lot of loss of energy during production and consumption of charcoal and it is possible to develop strategies to intervene in each of the stages of the value chain. In Bié most of producers were found to use traditional earth kiln (which has lower efficiency) to produce charcoal, and these kilns have an average conversion ratio of 5:1 (Bhatarai, 1998) which means five kilograms of air-dried fuelwood burnt produces only one kilogram of charcoal. Part of energy is lost during the production and also during the consumption because the charcoal stoves used by urban households are opened (Appendix C.1) and release the heat.

The price of charcoal in Chissindo market was about 1500 Kwanzas and the purchasing price of one cylinder gas (the net product) was about 500-600 Kwanzas. Why are people still using charcoal? There is no clear reason why some people prefer to use charcoal and others not; however, the most justification is the availability and accessibility of this commodity in the market, and above of all the cultural behaviour and paradigm concepts.

The demand of charcoal is higher in dry season (June and July) and rainy months (September to March) (Figure 12). There are a lot of uncertainties on charcoal market demand: it is difficult to predict to a certain extent the demand and supply situation of charcoal in Bié in the coming years, because there have been no studies to observe this trend. Therefore, any prediction of this demand is a matter of several interrogations. It is only possible to accept the seasonal trend shown on figure 12 which predicts the dry and rainy months with high supply. On another hand, our finding suggests that in futures studies it shall be necessary to correlate the oil and gas prices with charcoal prices to see the effect of increase of oil price (LPG gas price) on the choice of using charcoal as domestic energy in urban households. Our current findings confirmed a statistically negative correlation between the uses of charcoal with other alternative fuels (LPG).

If the consumption per capital was estimated to be 4.5 bags per year, by studying only two districts (Camalaia and Piloto), then in very long perspective, no matter how "possibilist" and optimistic one can be, the future supply and demand of charcoal in Bié Province will increase.

The judgement of the actual situation on charcoal production is a taboo and the dramatic degradation of forest is not possible to stop unless we find alternatives sources for domestic energy. In this point of view we recommend a practical strategy to reduce the degradation arising out of charcoal production: this situation is possible to solve in both short and long term. In the short term it is possible by offering on the local market charcoal from eucalypt or other fast growing species. In fact, eucalypts have higher calorific value compared to the *Brachystegia* that people normally use. The solution can be through awareness and improvement of the efficiency of cooking stoves to minimise energy losses. In the long term, we suggest establishing a timeframe of about 20 years during which other fast growing trees as a communal project in combination with agro-forestry systems.

These communal forests could be used for the production of charcoal and firewood; however, it may work only in the assumption that it will be managed by private sector supported by government. It might probably be the first charcoal company with good management plan. Another possible solution is to offer subsidies to farmers who own forestlands, for conserving it until they reach a harvestable period. In this perspective, it may work because the farmers are only producing charcoal for economic reasons. If the government will provide subsidies, farmers will prefer to protect their forest from charcoal production which then can be more lucrative in the next 6 or 8 years if it will be exploited for timber.

The influence of charcoal production on forest degradation is a problem that even future generations will pay for. The total area of Bié province is 70314 km^2 which correspond to 7,031,400 hectares (MINAGRI, 2012). From the total area 19.5% (IDF, 2007; GEF, 2012), account for deforested area for the year 2000. In comparison with our finding 21 to 27 thousand hectares is lost due charcoal production which represents a range of 1 to 2%. If the trend of 2% increase per year continues about 4200 to 5400 hectares of forest will be degraded every year.

To be able to minimise the impact of charcoal production in the Bié forest, it is necessary to consider this situation as a challenge to the energy sector in terms of the access of urban households to alternative energy sources. In order to achieve this, development projects should be assessed so that the responsibility to protect the forest will extend to private sector too. The only way forward is sustainable production of charcoal, where plantation of fast growing trees shall be established and set special areas for preparation and selling of charcoal. Only if charcoal will be produced from plantation in sustainable manner then the pressure on natural forests will reduce.

6 . CONCLUSION

In this study, great attention was drawn on the impact of charcoal production on the deforestation and the factor that drives this production. The conclusion arising from this study is that charcoal production does not cause deforestation but forest degradation which is easy to link with deforestation due to the change in appearance of forestland after the production of charcoal. About 21 to 27 thousand hectares of woodland are cleared every year in order to supply charcoal in Chissindo market. Moreover, the road appearance inside the forest is probably the most visible prove of this impact.

The most preferred species for charcoal production was Brachystegia speciformis; however eucalypts is not being used for commercial purposes even though it showed higher calorific value.

Charcoal production is a relatively profitable business for the stakeholders involved. The main driving force for charcoal production is income generation by rural farmers. However, the factors influencing choice of urban household to use charcoal were: availability, affordability and reliability compared to electricity and gas in this region.

The management of the forestland where charcoal has been produced from could be possible with the establishment of charcoal companies that will produce charcoal in sustainable manner from fast growing tree plantations.

Charcoal can be an excellent domestic fuel if it could be produced in a sustainable manner. The demand of charcoal is more likely to remain stronger if policies are not aimed to reduce consumption of charcoal.

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