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DOES THE CUTTING OF MIOMBO TREE SPECIES FOR CHARCOAL PRODUCTION DIRECTLY CAUSE DEFORESTATION? A CASE STUDY OF KAPIRI MPOSHI AREA, CENTRAL ZAMBIA

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Abstract

This study assessed the response of miombo woodland tree species to the impact of charcoal production along the Kabwe – Ndola highway in Kapiri Mposhi district, central Zambia and covered the period 2013 - 2017. The main objective of the study was to determine whether all tree species harvested for charcoal production regenerated to answer the question, does tree cutting for charcoal production directly cause deforestation? Factors considered were species cut for charcoal production, height above ground at which the tree was cut, cutting angle and aspect, stump thickness, season of cutting and the number and location of saplings. Vegetation assessments were carried out in 20 m x 20 m quadrats laid out at each sample point in which only trees ≥ 30cm circumference were considered. Height of the stump above ground was taken in cm and cut angle determined by placing a carpenters' square at the lowest end of the cut across the stump to form a perfect horizontal line. Evidence of regeneration through coppicing was carried out by visually examining stumps for regeneration. Results obtained showed that all species regenerated after cutting although only ten (10) species were commonly used in charcoal production mainly of the genera *Brachystegia* and *Julbernardia*. The mean stump height in cm of all tree species was 48 cm. Two categories of cut angle classes were common, acute angle (180^0) 60 % (n = 708 stumps) and straight/flat angle 36 % (n = 425 stumps), obtuse angle 3 % (n= 35 stumps) and other 1% (n = 12 stumps). A difference was recorded in the coppicing period. Species sprouted within four weeks (at least showing a bud) between August and November and during the rainy season but took more than four weeks in ≥ 75% of the cases during the cold season May – July. It was concluded that the cutting of trees for charcoal production was not the direct cause of deforestation, but it was perhaps the greatest agent as more than 80% of the sites cleared for charcoal production were occupied by human settlements at least by end of the second year. Further studies are required to investigate species characteristics that may influence regeneration in addition to moisture and soil nutrients.

Key words*: Miombo woodland, regeneration, fire, factor, stump height, sapling*

1. Introduction

In Zambia, there is growing concern about deforestation. Chitondo (1997) for instance, estimated that 0.5 % of the country's woodlands were lost each year in the 1990s to early 2000. He further estimated that about 0.7% to 1.0% of forest area was lost annually through deforestation resulting from agricultural expansion and charcoal production. The figure could even be higher at the moment. Phiri (2013) showed that although Zambia has the largest forest coverage in the southern African sub region which was estimated at 60 % of the total land area, it also had a high deforestation rate of 250 to 300 thousand hectares of land per year (250 – 300 km^2/yr^{-1}) or 0.03 %, a figure lower than that reported by Chitondo (1997). A precise estimate of the land lost due to deforestation is therefore not precisely known. But factors such as land clearing for agriculture, logging for timber, cutting trees for firewood and charcoal were according to Phiri (2013) on top of the list. He particularly cited charcoal production as the major agent since about 90 % of the population used charcoal in different ways. While this view may be contested, it is clear that around large human settlements, deforestation may be considerably higher. Coupled with fires, particularly those late in the season, could exacerbate the rate of deforestation, while other anthropogenic factors tend to accentuate the rate at which forest cover is lost. In most instances however, charcoal production has been cited as the main and direct cause of deforestation in Zambia, but little effort has been applied particularly in the current decade to investigate the capacity of miombo woodland species to regenerate after cutting for charcoal production. The ZFAP (1997) report showed that no comprehensive forest inventories had been conducted in the last three decades. The earlier 1984 - 86 survey, only being undertaken in a few locations and yielded estimates of the growing stock reported to vary from 40 to 154 m^3/ha., by province being essentially assumptions of changes that had taken place during the last 30 years. The Forestry Department (1999) later reported that the rate of growth of natural forests was rather low, ranging from 0.7m^3 to 2m^3/ha/annum. Hence, the indicative aggregate biomass volume of all forest types was estimated at about 3,700 million tones. However, such estimates did not give reference to any field based detailed survey.

Chidumayo (1987) in his sustained field studies of miombo woodlands stated that plant productivity in the miombo woodland primarily depended on; i) soil moisture; and ii) soil available nutrients and concluded that since rainfall was seasonal and availability of soil nutrients was low, productivity was also expected to be low, but did not provide details on how trees regenerated even with the slow growth. Grundy (1996) on the other hand only provided the importance of tree cover and suggested that vegetation cover intercepts rain drops and reduces its dislodging capacity to the soil. He also noted that vegetation cover increases, through litter fall, the organic matter content of the soil, which plays an important role in making nutrients available and in particular, increases the soil water retention capacity. These factors support plant production and clearly show that good management of vegetation cover is important for the sustainable and increased production of woody and agricultural products. In the same paper, Chidumayo (1987) listed key factors influencing sustained natural regeneration as; i) canopy shading in selective felling systems, ii) inter-shoot competition whereby only the dominant shoots contribute to the next generation, iii) capacity to regenerate (coppice) decreases with age and stem size, iv) late forest fires which kill seedlings and coppices, and v) cutting of seed bearers for wood fuel and saw logs and clearing for agriculture. Seed bearers are usually cut because of their bigger diameters and hence were preferred for timber as saw logs, thus contributing to poor regeneration from seed.

With no reference to the source of damage Chitondo (1997) enlisted the establishment period for natural regeneration as being eight years for both seedlings and coppices, but that this varied between two and 11 years depending on species. Normal establishment period for new crop was estimated at 10 years when stool mortality and different sources of regeneration were taken into account, and the cutting cycle in selective cutting areas was 20 years and 60 years in clear-felled areas. A total of 100 years was regarded as the period needed for a tree in a miombo woodland, under natural conditions, to attain DBH of 30 cm, but that use of silvicultural treatments would reduce this period to 60 years on average quality sites and 50 years on best quality sites (Chitondo, 1987). He also showed that stumps of almost all miombo species had the ability or potential to coppice, with many shoots being produced on one stump. On stumps for valuable species, he suggested singling to be applied to minimize competition among shoots by leaving only one dominant shoot, although this was more in theory than practice as it lacked supervision and control by the Forestry Department.

It is evident therefore, that few local studies have included details on factors influencing regeneration. Most studies have focussed on the extent in hectares of areas cut for charcoal production without examining the potential for regeneration from stumps and roots after cutting. A common practice under forestry policy has been to encourage charcoal producers to cut stems at an angle to prevent rain water from settling on the stump causing it to rot and preventing regeneration. This practice while botanically sound has not been assessed to see whether all tree species are affected in the same way or whether certain species are affected more than others.

I carried out this study to examine the response by natural regeneration of different woody tree species utilised for charcoal production, focusing on stump height, cutting angle, location of coppicing and stump girth. The study focused on woody plants because they are the ones utilised for charcoal and take longer time to grow and mature. Popular woody species that are selected for charcoal production if they do not regenerate, may particularly be vulnerable to over harvesting as also reported by Cunningham (1990, 1991). Nahonyo *et al.*, (1998) in their study of the miombo woodlands of southern Tanzania for instance, recorded that the effects of harvesting of trees for building materials or fuel wood would be more apparent if there was; complete removal of woody biomass, low levels of recruitment and suppression of coppices. They further noted that harvesting of woody plants for poles and laths for instance used much smaller size classes than the timber industry, but nevertheless can impact on tree recruitment and woodland structure (Talukdar 1983; Cunningham 1990).

Developing appropriate management strategies for harvesting of trees for charcoal production on a sustainable yield basis therefore, requires sound ecological knowledge on their response to various human uses which should form the basis for the need to protect them.

2. Materials and Methods

2.1 Location and Description of Study Area

Kapiri Mposhi is situated in the central province of Zambia almost half way between Lusaka the capital city of Zambia and Copperbelt which also have the highest population density (Figure 1) and a high utilisation of charcoal as source of energy mainly for cooking. Mean annual rainfall ranges between 800 - 1,000 mm/yr^{-1} and is situated in the wetter part of Agro-ecological Zone II and partly in Zone III.

Figure 1: Location of Kapiri Mposhi the Study Area in Central Province, Zambia

2.2 Vegetation

The vegetation of the area is typical plateau miombo woodland dominated by the genera *Brachystegia – Julbernardia- Isoberlinia*. Some localities form almost pure *Brachystegia spiciformis*, and in some interspaced with *Julbernardia paniculata* or *Julbernardia globiflora* or both. There are also areas with almost pure *Brachystegia boehmii* woodland occasionally with a fair amount of *Julbernardia paniculata;* pure *Brachystegia* spp woodland with little *Julbernardia paniculata* or *Brachystegia longifolia*. The distinguishing characteristic of the miombo woodland in the study area was its relative low below canopy cover with relatively high visibility.

Less dominant species were various species of *Acacia* in areas with fertile soils, *Burkea africana, Eurythrophleum africanum, Albizia anthunesiana, Azanza garckeana*, several species of the genera *Combretum* and *Terminalia, Bauhinia petersiana, Bobgunnia (Swartzia) madagascariensis*, and others.

In the scrub woodlands common species were; *Pericopsis angolensis*, *Pterocarpus angolensis*, *Xeroderris stuhlmanii, Dalbergia* spp, *Capassa violacea* and various other *Albizia* spp.

2.3 Human Settlements and Livelihood Activities

Settlers were either randomly distributed as determined by water availability or linearly distributed along the Lusaka – Ndola highway. The population was densest near Kapiri Mposhi town and a few isolated localities with facilities such as schools or health centres. It was observed that since 2013, when this study was commissioned, settlements had been spreading along the highway which led to significant changes and transformation of land cover from woodlands to crop fields. All settlements in the study area practiced small scale or subsistence agriculture. Gardening was common in areas near streams or dambos. Others were engaged in retail trade particularly sale of charcoal and bee honey.

2.4 Field Methods

2.4.1 Questionnaire Survey

Areas sampled were within 2 km stretch of the road between Mulungushi River which also forms the southern boundary of Kapiri Mposhi District to the Kashitu area on the Kapiri Mposhi – Ndola highway. This closeness to the main road allowed the assessment to determine the influences local communities might have on the readily available market for charcoal and hence the propensity to venture into charcoal production as a source of income. Households resident at the same locality for no less than 12 calendar months were interviewed. A pre-coded questionnaire was used with the last two questions being open ended, designed to reveal the many facets of the respondents' attitude towards charcoal industry.

2.4.2 Enumerators

Six enumerators with a grade twelve (equivalent to 'O' level qualification) level of education were engaged from within the communities. These were resident in the area along the road, purposely selected because they had information about the charcoal production activities. Enumerators were trained before administering questionnaires and schedules, during which time trial questionnaires and schedules were conducted to determine their social acceptability to the local community.

2.4.3 Participatory Rural Appraisal

The principal researcher and enumerators in certain instances took advantage of public gatherings to meet and discuss with community members. Church meetings, women group meetings, wedding parties, road side markets where charcoal is stored awaiting transportation to the urban markets in Lusaka or the Copperbelt (Figure 2) were used as appropriate fora for PRA. Questions covered, species preferred for charcoal production and season of cutting, number of kilns produced per house hold and others. To ascertain the efficacy of information given by the charcoal producers and traders on the popular species, field visits were carried out to examine charcoal kilns before they were covered by earth lumps. Based on Palgrave (2002), Moll (2011) and Storrs (1995) field guides and personal experience extending over a period of more than thirty years, tree species were identified based on the appearance of the bark and cross section of the cut stem.

Figure 2: Researcher in khaki shirt and cap discussing with charcoal traders, Kapiri-Mposhi to Ndola highway, Zambia

2.4.4 General Vegetation Assessments

Sample points were purposively located within 2km of the high way on each side of the road. Quadrats of the size 20 m x 20m were randomly laid out a long 1 km transect line and were repeatedly revisited during the period 2013 – 2017 (Sensu Mueller-Dombois and Ellenberg, 1974). Some transects were located in areas exposed to charcoal production. Only trees ≥ 30cm circumference were considered. Tree species encountered were identified based on the field guides by Palgrave (2002), Moll (2011) and Storrs (1995). Height of the stump above ground was taken in cm. Diameter of the stump was also measured. Because there was no linear calliper for measuring girth, circumference was taken and converted to diameter by the formula; $C = D\pi$. Thus $D = C/\pi$. The basal area (BA) being calculated as πr^2 while volume was calculated as $\pi . r^2 h \times 1/3$; where C = circumference, D = diameter, h = height, r = radius and pie ($\pi = 3.14$) is a constant.

2.4.5 Measuring Stump Height Cut Angle and Aspect

Measuring stump height above ground level and girth size were done using a 5 metre roll-in steel tape. The tape was held at ground level on the lowest slope side to the highest point of the stump depending on the cut angle (Figure 3).

Figure 3: Measuring stump height and diameter above ground

Cut angle was determined by placing a carpenters' square from the lowest end of the cut across the stump to the other edge which formed a perfect horizontal line. A brick layer's spirit level was placed on top of the carpenter's square to ascertain the straightness of the line. A heavy-duty protractor was then placed on top of the carpenter's square to determine the inclination or angle of the cutting (Figure 4). Aspect was determined by using a prismatic compass and only the major bearings of North, South, East and West were used. If the slope of the cut was facing North then aspect was labelled as N and so forth.

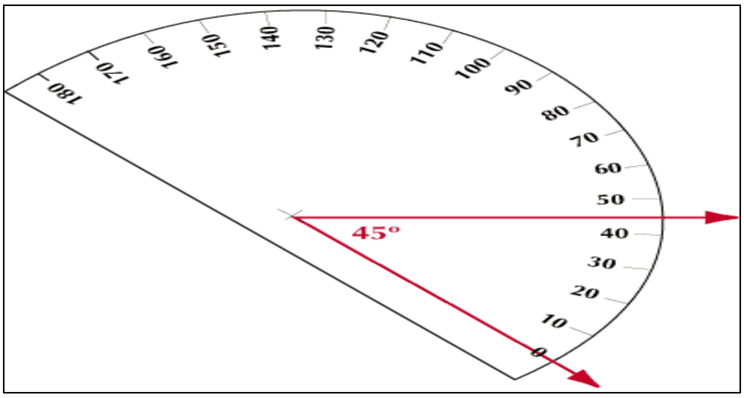

Figure 4: Determination of cut angle using a heavy-duty protractor

The stump cut angle was recorded as flat when the cut part of the stump was approximately 180 degrees or slanting when > 0 but less than 90 degrees (Figure 5). If the cutting did not fit this classification, it was classified as 'V' cut when it had a depression in the middle mimicking letter 'V', rounded top or irregular when it did not have any particular slope. Each stump was examined for coppicing and signs of fire. The number of coppices was counted per stump and root stock, the exercise was repeated after fire to determine the impact of fire on shoot survival.

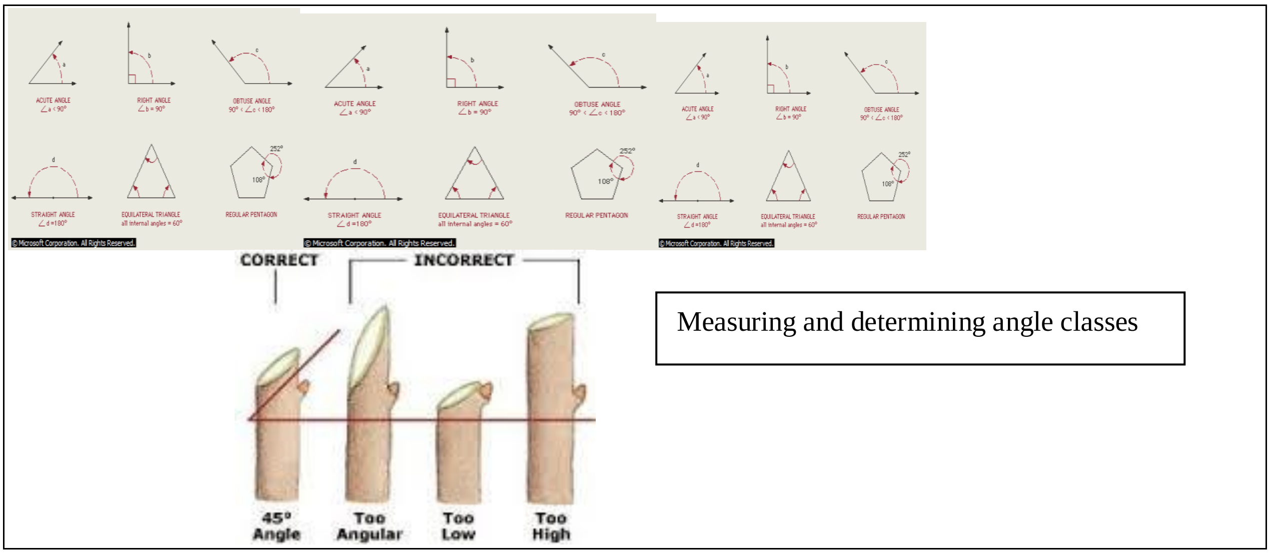

Figure 5: Measuring and determining cut angle classes for tree stumps (Modified after: Microsoft Encarta, 2009).

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2.4.7 Determining Sprouting (coppicing) Patterns

Evidence of regeneration through coppicing was carried out by visually examining stumps for regeneration. The coppices were classified as; on the stump when the regenerated saplings were located on the cut stump to ground level, on root stock when they were located at the ground level away from the stump. The number of saplings were counted and heights taken in cm. In instances where there were two stumps of the same species close to each other, the researcher dug along the roots without harming the tree to establish where the saplings belonged. The roots were then reburied to prevent damage to fire and boring insects.

2.4.8 Determining the Average Number of Trees Cut per Average Sized Kiln and Species Used

Earth mound kilns is the only practicable method used by all charcoal producers in Zambia. To estimate the number of trees cut to build one kiln, the researcher had to be present when the kiln was being piled and all poles classified according to species and counted. This was accompanied by the counting of fresh stumps when the stems had been removed and chopped to desirable lengths (Figure 6). The mean length and girth were taken. The charcoal producer was then permitted to complete the process of piling up all the stems to build a kiln. Before the kiln was buried, the height and length of the kiln were measured (Figure 6). Repeating this exercise in this order provided mean values for the number of poles or stems in each kiln.

Figure 6: Buidling a charcoal kiln, (i) felled tree cut into desirable log lengths and (ii and iii) logs piled to build an earth kiln before pyrolysis

2.5 Limitations

Determining sprouting incidences and classifying growth stage categories of saplings involved in some instances, relatively arbitrary approaches and subjective assignation of numerical values to different criteria. Sometimes it was difficult to determine when the budding and growth of sapling occurred. Although this approach may have been criticized by some researchers, the aim in this study was to obtain and establish relative regeneration response values and species preferences to answer the question does tree cutting for charcoal production directly cause deforestation? and was therefore effective in achieving this goal.

Establishing the extent and dimensions of heart wood and sap wood was for some species a challenge. The name heart wood is derived from the heart or centre part of a tree and is the hardest and strongest part of the tree. It is formed when cells near the centre of the trunk die but remain mostly intact. When the old sapwood age and die they become heart wood. As residues of the once living cells and additional chemical compounds such as resins, phenols, and terpenes accumulate making it more resistant to decay and insect attack. In this study, it was assumed that sapwood was the living outer part while heart wood was the inner wood. That the two parts were distinguished by colour. Sapwood being lighter and heart wood being dark brown, red hues, or simply darker than sapwood. The major limitation to this approach was that colour sometimes was misleading as not all heartwood is dark and not all dark-coloured wood is heartwood. The relative amounts of sapwood and heartwood in a stem can also vary greatly among individuals, species and growing conditions.

For the purpose of this study however, the separation of the two was based on colour distinction, and since the number of species utilized for charcoal production is fairly limited, it was considered to be sufficient.

3. Results

3.1 Species Popular for Charcoal Production

In this study only, species with ≥ 25% frequency were considered. Species with less than 25% frequency were left out at data coding stage and analysis. The exclusion of less popular species reduced the number of species considered in this study to ten (10) and these were in order of importance as follows; *Julbernardia panniculata, Brachystegia spiciformis, Brachystegia longifolia, Julbernardia globiflora, Brachystegia bohemii, Pericopsis angolensis* being the most preferred with frequency appearance in charcoal kilns ≥ 60%. Less preferred species but with frequency ≥ 25% were, *Burkea africana, Albizia anthunesiana, Bobgunnia (Swartzia) madagascariensis,* *Albizia adianthifolia,* while *Parinari curatelifolia* was a borderline case often left out to preserve fruits. A large number of respondents 82 % (n = 53) charcoal producers and 75% (n = 36) charcoal traders confirmed this list as being the most popular.

3.2 Height of Stump above Ground and Cut Angle

The mean stump height in cm of all tree species was 48 cm above ground level. The range was between 35 cm and 85 cm. These stump heights did not vary significantly ($\chi^2 = 3.47$ DF = 9, $\alpha = 0.05$ P >0.05), implying that all stumps were above the upper limit of 30 cm recommended by the Forestry Department. Figure 7 below shows the mean stump height for each individual species.

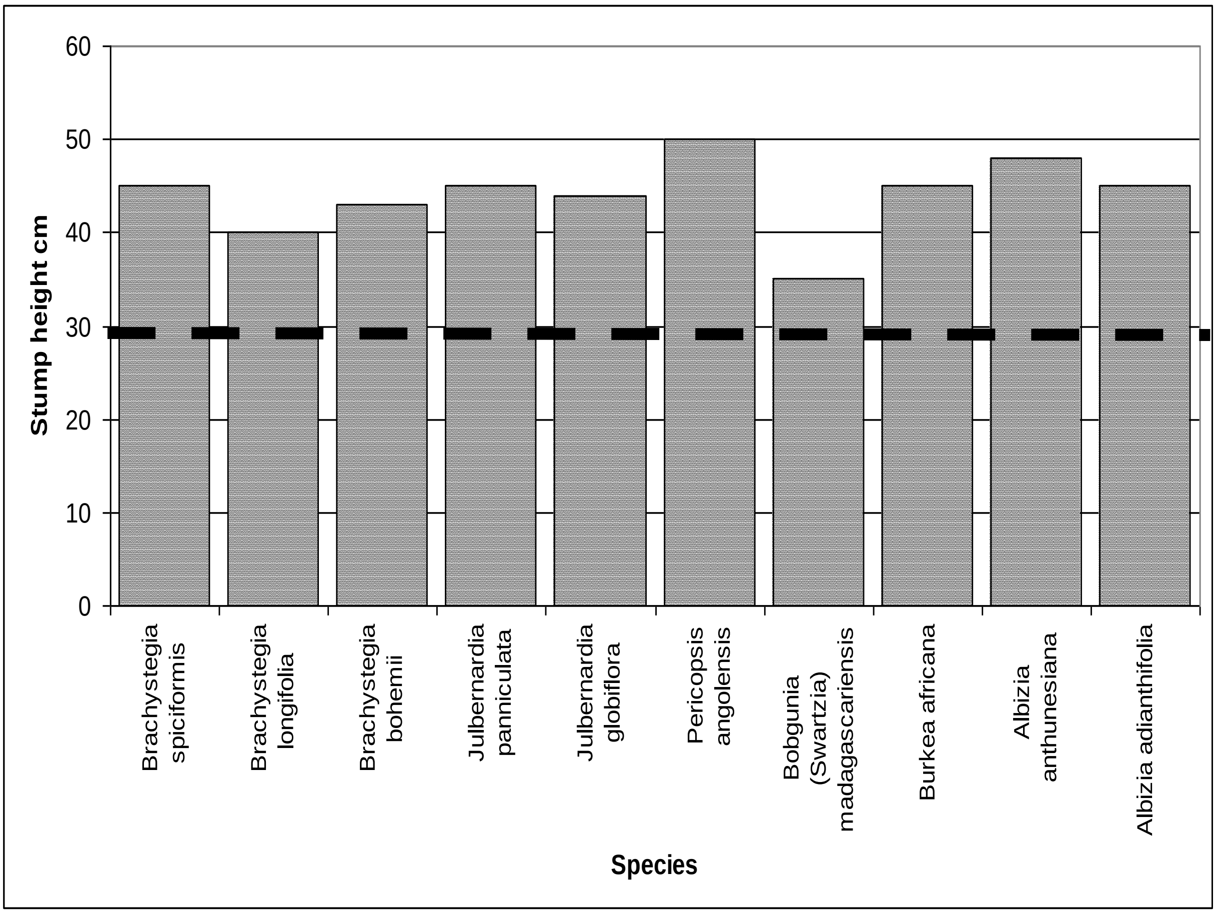

Figure 7 Species specific mean stump height

3.3 Cut Angle and Cut Aspect of Stumps

Two categories of cut angle classes were common; acute angle (180^0) 60 % (n = 708 stumps) (symbol A) and straight/flat angle 36 % (n = 425 stumps) (symbol B), obtuse 3 % (n= 35 stumps) (symbol C) and other 1% (n = 12 stumps) (symbol D) (Figure 8 & 9).

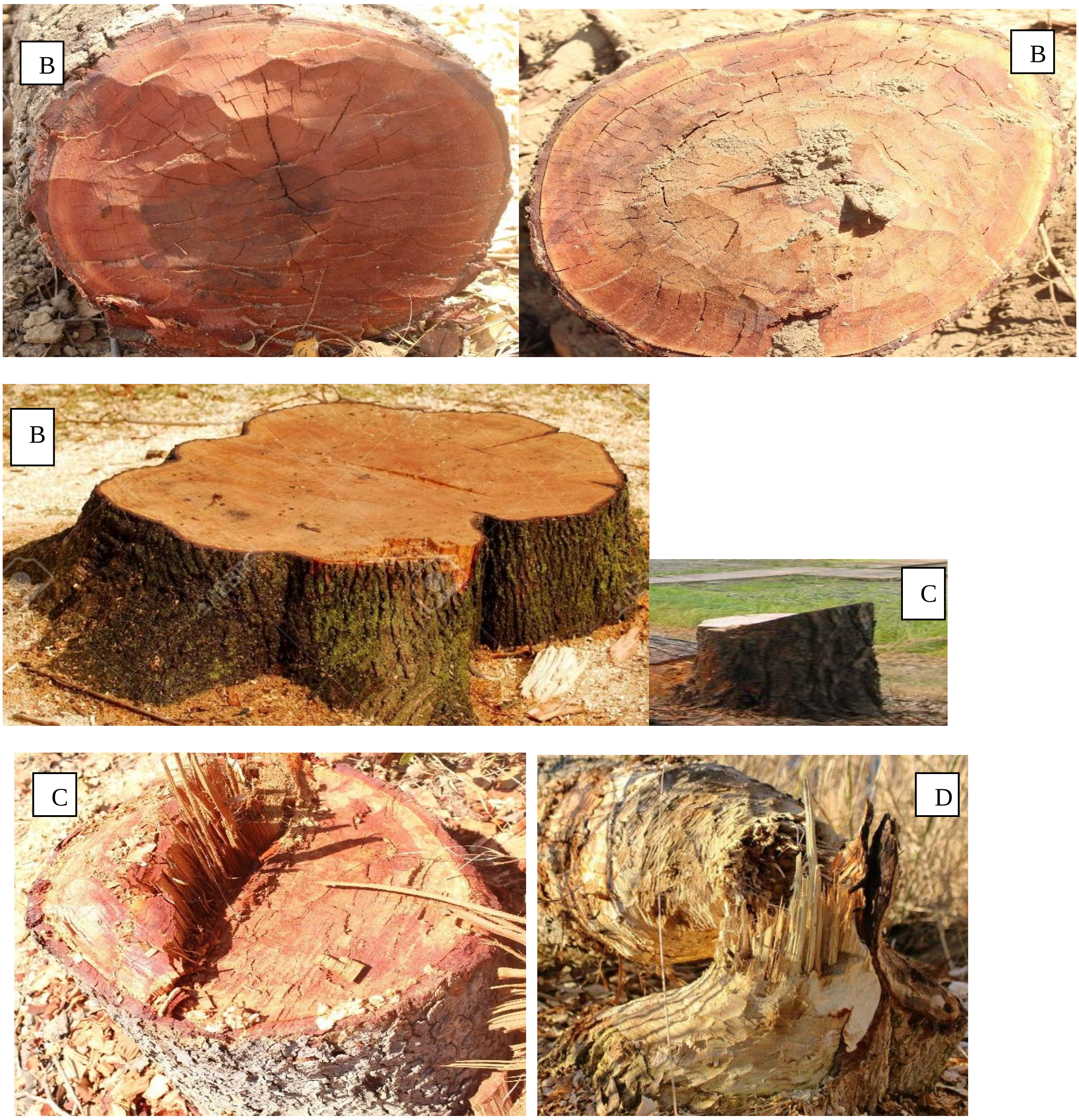

Figure 8: Stump cut angle classes (A) acute angle, (B) flat angle, (C) V cut, > 90 degrees, and (D) other or Unclassified

Hollow heartwood (pith) likely to hold rain water

(c)

Figure 9 Stump cut at 35 cm above ground, 46 cm diameter and flat angle (180^0) but with hollow pith which can likely hold water during the rainy season and cause stump to rot.

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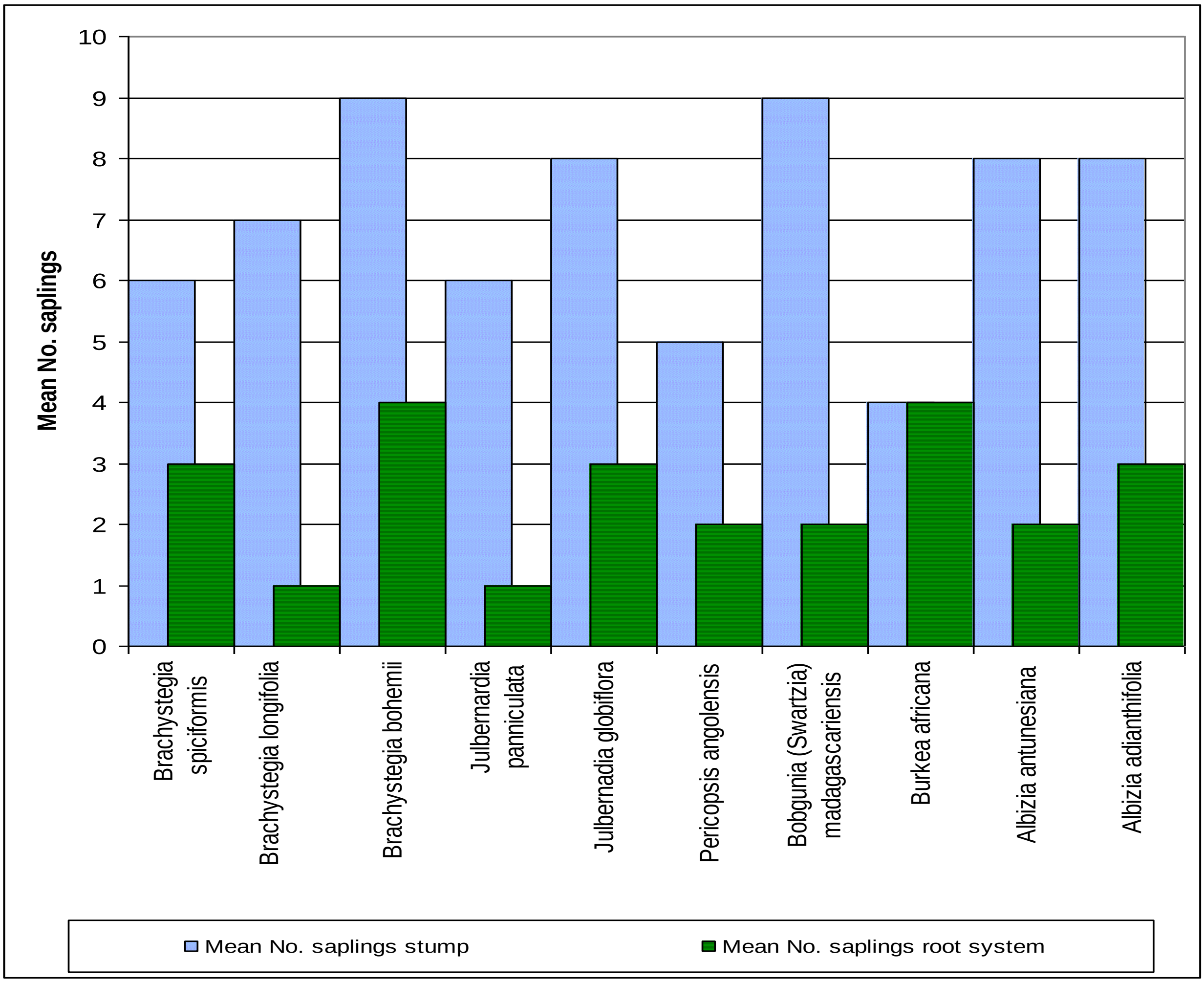
3.4 Season of Cutting and Position of Coppice

Trees cut during the period May – July/early August took more than a month to regenerate. Between September – November and December to April, budding and sprouting was within a month's time.

A comparison of coppicing between stumps and root system showed that stumps had more saplings than root systems for each species. The saplings were recorded after being exposed to fire, implying that only those that survived fire were recorded because these are the ones expected to grow into poles and eventually trees. The difference in the number of saplings between stump and root stock was significant (Mann Whitney U 0.01 < P ($U \geq$ 80 or $U' \leq 77$) 0.02) (Figure 10a,b).

A difference was also recorded in the coppicing period. Species sprouted within four weeks (at least showing a bud of full saplings (Figure 10a, b) between August and November and during the rainy season but took more than four weeks in ≥ 75% of the cases during the cold season May – July.



(a)

(b)

Figure 10: a) Comparison of stump and root system coppicing after three fire seasons (Note that saplings killed by fire were not counted in this regard), b) Coppicing after cutting (i) sprouting on *Brachystegia bohemii* stump and (ii) saplings five weeks after cutting

3.5 Number of Trees per Kiln

The mean size of a kiln in the study area was 10 m long, 5 m wide and 2 m high. Such a kiln contained a mean number of 500 logs cut into 2.5 metres long pieces each. Given a mean number of ten (10) logs obtained from one medium to large sized tree (DBH ≥ 30 cm) each kiln required 50 trees. The mean number of kilns per party of two was one per month. This implies a party of two needed to cut ≥ 600 trees per year,) from which the party would earn a retail price of K120 (USD 12) per bag of about 75 kg in Lusaka (Figure 11). A kiln would earn a maximum of K 6,000 (USD 600). Where the charcoal is sold locally at wholesale price a bag costs K40.00 (approx. USD 4) and a kiln would earn K 2,000 (USD 200). If the density of tree stems /ha., is known it implies clearing large tracks of land for a party of two to meet their minimum number of charcoal kilns per year. As the density of charcoal producers increase, so will the number of trees to be cut per unit time increase.

Figure 11: An estimated 75 kg bag of charcoal fetching K 150 (USD 15) (Larger bags cost more)

4. Discussion

4.1Trees Preferred for Charcoal Production

Six species namely, *Julbernardia panniculata, Brachystegia spiciformis, Brachystegia longifolia, Julbernardia globiflora, Brachystegia bohemii, Pericopsis angolensis* were most popular species for charcoal. The reason for their preference is due to their particular species-specific characteristics rather than perhaps their abundance as also noted by Chansa, (2000) in Mumbwa Game Management Area. The preferred species give good embers, hot fire, and burn easily producing little smoke. Among the four-species selected for charcoal production *Julbernardia panniculata* was the most popular, because in addition to the other qualities, it did not spark (Chansa, 2000). Species which produce a lot of sparks are usually avoided particularly in the cold season when charcoal braziers are not only used for cooking but for heating and keeping homes warm. In the evening families would gather around a charcoal brazier before going to bed. At such moments, species which spark would cause damage to clothes and may also cause minor burns on the skin. The species selection based on these and other factors may continue for some time in the future for as long as sources of species are nearby. However, as population increases and commercial charcoal production increases there would be need for intervention, as certain species may experience un-proportionately higher pressure through selective harvesting than others. In the study area, the popular species were also the most abundant, and this has led to clear cutting which subsequently attracts small holder farmers to establish crop field which eventually suppress eventual regeneration.

The above tree species are also preferred because of their high heat content value and that they last long in burning. Based on the same principle of heat value and durability in burning, preferred charcoal tree species are not so different from those used for firewood. Selectivity in wood fuel tree species has resulted in localized scarcities of the preferred species. However, due to continuously increasing demand for wood fuel and depletion of priority species, current-harvesting methods do not segregate on species and this situation has culminated in complete degradation of certain forest areas. Natural regeneration in these areas has become almost impossible (under current institutional arrangements and economic situation) because re-growths are rarely given a chance to develop into mature trees **-** some are cut immediately they start to show signs of stem rigidity and others are destroyed by late fires which are very common, especially in livestock areas and in areas under the slash and burn (*Chitemene*) system of agriculture.

4.2 Stump Height Above Ground Level

The Department of Forestry recommends a practice of cutting at 30 cm and less agl., with a slope that would not allow rain water to settle on the stump, which prevents rotting. Earlier Chidumayo and Gumbo (2012) had shown biomass accumulation in regrowth miombo woodland under different management levels (see Figure 12).

Figure 12: Above ground biomass t/ ha $^{-1}$ and regeneration after clearing
(Source: Chidumayo and Gumbo, 2012).

To emphasize the need to maintain adequate above ground biomass per ha-1, it is self-evident that when various methods of harvesting woody plants are examined, evidence suggests that those methods which leave more above ground biomass achieve a faster regeneration.

In essence, regarding harvesting methods for charcoal production, the height at which a tree is cut is determined by the method used to cut the tree. When an electric saw is used the tree can be cut as low as 10 cm above ground (Figure 13) as someone can do this while seated or a position that provides some level of comfort.

Figure 13: Cutting at less than 30 cm above ground.
(Modified after http:wwwgoogle search, tree cut)

When an axe is used as is normally the case with most charcoal producers in Zambia, the height of the stump is determined by the level to which a person can bend down and cut a tree relatively conformably, and this is usually about 1meter above ground. This allows the cutter to have enough thrust and energy to cut. This could be the reason why the mean value of stump height obtained in this study was higher than the recommended 30cm and less agl. Arguably, height of cutting affects the nature and rate of regeneration. The higher the tree is cut the less the biomass that is removed and the tree is likely to recover quickly (Frost and Chidumayo, 1996). Pollarding and lopping can be applied in harvesting fuel wood, building poles or obtaining fibre rather than felling the whole tree. Lopped trees regenerate faster producing greater biomass over shorter periods of time than trees cut close to the ground (Grundy, 1996). In fact, selective branch removal could yield wood and leaf products with much less disturbance to the overall woodland than the removal of the whole tree (Chidumayo, 1987). On the aspect of the quality of regeneration, it is evident that clearing for subsistence agriculture, for instance, trees are either stumped or cut at breast or waist height. In this case re-growth stems or branches are invariably defective at the point of cutting. Consequently, the pole and timber value of re-growth is low (Chidumayo, Gambiza and Grundy, 1996). Cutting trees at waist/breast height therefore are not suitable techniques for producing quality regeneration and hence the recommendation by Forestry Department of 30 cm and less. In cutting trees for fuel wood, poles and timber the cutting is usually done close to the ground. In such cases woodland regeneration is mainly by root coppice. If fire does not damage the regeneration, straight poles are produced (Hursh, 1960). Selective thinning can then be practiced to provide building poles in short term and in the long term saw logs. Grundy (1996) suggested that trees should be felled at 15 cm above ground and at an angle of 45^{o} using a sharp axe or saw to encourage vigorous re-growth from the stump. Deep ploughing on the other hand would increase the stocking rate by causing root suckers to develop but only when the fallow period is long (Strang, 1966).

4.3 Stump Height and Diameter of the Stem

The part of the bark that causes the tree to grow in diameter is the cambium. During the growing season the cells of the cambium, like those of the stem tip and root tip, divide rapidly. They produce xylem, or wood cells, toward the center of the trunk, and they produce phloem, or food-conducting cells, toward the bark. At places the cambium also produces rows of thin-walled cells that run horizontally through the xylem and the phloem. Known as *rays*, these horizontal cells conduct and store water and nutrients.

However, like other attributes, girth size alone, as a single factor is seldom the main factor but, rather, a combination of factors interacting to determine the rate at which regeneration takes place. It is clear that large size in animal species has certain reproductive and adaptive advantages. It is not so clear yet what advantage large stump size has for regeneration other than a higher capacity for food-and-water storage capacity of a tree, which may therefore impart ability to resist stress and drying than smaller stems.

4.4 Differences in Sprouting Between Dry and Wet Seasons

The differences in the sprouting between seasons, is best explained by the uptake of water and mineral nutrients from the soil. Naturally water uptake from the soil by root cells is passive, in that water may be pulled into the root by low xylem pressure and also follows osmotic gradients caused by the mineral nutrients, which are taken up actively, with the expenditure of metabolic energy across root cell membranes. As the mineral nutrients (the ions - charged components) of inorganic salts are taken up, they are largely incorporated into organic molecules (Encyclopaedia Britannica 2010). Thus, the solutes in xylem sap are mostly complex organic substances, sometimes of a specific nature. In the Encyclopaedia Britannica (2010) it was noted for example that nicotine synthesis takes place in the roots of tobacco plants, where nitrogen is incorporated into compounds that have moved to the roots through the phloem as sugars. If a tomato shoot is grafted onto a tobacco rootstock for instance, nicotine-containing tomato leaves are formed. On the other hand, a tobacco shoot grafted onto a tomato rootstock results in a plant with nicotine-free tobacco leaves. Many other specific nitrogen-containing substances originate in the roots; in most plants, however, nitrogen is transported to the leaves from the roots in the form of compounds known as amino acids and amides.

In the savannah areas of Africa where there is a distinct dry season and wet season, products of photosynthesis (primarily sugars) particularly for deciduous plants move through phloem from leaves to growing tissues and storage organs before they lose leaves.. The areas of growth may be newly formed leaves above the photosynthesizing leaves, growing fruits, or pollinated flowers. Storage organs are found in roots, bulbs, tubers, and stems. Thus, the movement in the phloem is variable and under metabolic control (whereas movement in xylem is always upward from the roots). Towards the end of the dry seasons the food reserves are retrieved to support new growth and the re-sprouting of leaves. At this time of the year re-sprouting is quicker than the earlier months. This explains why regeneration was much quicker during the period September – November. Whether these could be the only factors promoting quick re-sprouting in the late dry season and wet season is not very clear and may not be entirely satisfactory based on the results of this study.

The other explanation relates to the mass-flow hypotheses including the pressure-flow hypothesis, which states that flow into sieve tubes at source regions (places of photosynthesis or mobilization and exportation of storage products) raises the osmotic pressure in the sieve tube; removal of sugars from sieve tubes in sink regions - i.e., those in which sugars are removed or imported for growth and storage - lowers it. Thus, a pressure gradient from the area of photosynthesis (source) to the region of growth or storage (sink) is established in sieve tubes that would allow solution flow (Encyclopaedia Britannica, 2010). The electro-osmotic hypothesis postulates that solution is moved across all sieve plates (areas at which individual sieve elements end) by an electric potential that is maintained by a circulation of cations (positively charged chemical ions), such as potassium. The transport hypotheses on the other hand postulates solute movement independent of solvent water include the spreading of solute molecules between two liquid phases and the active transport of molecules by a type of cytoplasmic movement that is often referred to as cytoplasmic streaming.

Thus, cutting down trees after stored resources have been used during leaf flush reduces growth during the first growing season and this accounts for the delayed re-sprouting observed during the cold months May – end of July. Fires also affect the active regeneration of miombo woodlands as most of the stumps exposed to fire did not have coppices and this was common in instances where the branch lets remained around the stump after the stem was cut and taken to the kiln. Branch lets dry quickly and provide fuels for surface fires which burns stumps and kills the bark inhibiting the transportation of nutrients from the soil.

In earlier studies particularly those by Chidumayo (1987), it was shown that tree cutting height was found to affect the nature and rate of regeneration and the quality of wood products e.g. pollarding, stumping and uprooting lead to regeneration with specific wood qualities. The season of cutting affected wood production, especially during the first year after cutting, depending on the phenological phase in which a tree is during the time of cutting. For instance, during the period September to October, the trees are in leaf flush and are using or have used resources stored particularly in the root stock. Between September and December there is shoot elongation arising from the exploitation of stored reserves and photosynthesis in the new leaves. Between September and March, there is stem expansion through stored resources supported by actively photosynthesizing leaves. This phenological calendar explains the differences in sprouting recorded in this study. Similar to these findings, Chidumayo (1997) also suggested measures that would be appropriate in ensuring sustainable tree regeneration. He listed among others the following; (i) time of cutting/harvesting to be preferably during the months of May to August if maximum production during the first growing season after leaf flush is to be achieved, (ii)that in old growth forms of miombo, clear-cutting close to the ground could be a good practice because it yields regrowth of better quality poles and timber, (iii) to minimize negative environmental impacts, clear-cutting in miombo should be done in strips or coupes with shelterbelts. After the coupes have regrown, the shelterbelts can then be cleared. This practice would also ensure that seed bearing mature trees are preserved which may support growth through seedlings, (iv), and in selectively cut areas, trees could either be clear-cut thereafter, or, trees around the cut stumps should be cleared to create larger canopy gaps which permits light to reach the ground and improve regeneration and species composition. The role of leaves and photosynthesis is critical though not fully understood yet. What is known is that during the life of a leaf, its role as a sink or a source changes. A young developing leaf before it is photosynthetic is a sink for sugars produced by older leaves. After the leaf begins to expand and turn green, it is both a sink (importer of sugar) and a source (exporter of sugar) as a result of its own photosynthetic capacity. When mature and fully expanded, the leaf then becomes a source of sugar production. Again, the role of season in influencing these activities as factors enhancing re-sprouting is yet to be fully understood.

4.5 The Myth that Charcoal Production is the Direct Cause of Deforestation

The antiquity of this breath-taking chemical engineering artwork suggests that charcoal was probably the first synthetic material produced by man (Antal and Gronli, 2003) many millennia. Man employed shallow pits of charcoal to smelt tin needed for the manufacture of bronze tools and other metals. In Zambia, iron smelting kilns centuries years old are still abundant in which firewood and charcoal were used to smelt iron ores (Kasonde, 1953). Even today there is near universal agreement that it is a preferred source of energy for cooking than firewood or kerosene. No wander, charcoal use in Zambia is widespread particularly in urban areas, although no one can offer a true estimate of the amount of charcoal produced in the country. It is also a multitiered important informal economic sector benefiting various levels of the community. As earlier elucidated by Mwampamba *et al.*, (2013), the proportion of revenue captured by different stakeholders along the charcoal commodity value chain in Kenya showed that about 0-3% landowners, 20% charcoal makers, 2 % local brokers, 3% local government, 16% transporters, 8-18% buyers, 20-30% police (bribes), 2 % city brokers and 20% vendors. In Malawi 33% retailer, 12% private taxes, 3 % market fee, 25% transport, 6% packer, and 21 % producer.

Because charcoal is usually produced using inefficient kilns and the production process is routinely associated with high emissions of greenhouse gases (GHGs) it is generally linked to deforestation and forest degradation. The deforestation myth is deep rooted in most developing countries that depend on wood energy and has driven intervention and policy response to the sector for the last half a century or so. For example, Chitondo (1997) recommended the usage of wood fuel such as chips, pellets and/or charcoal briquettes, sawdust and wood shavings from carpentry workshops, as alternatives. He however, cautioned that this too may encounter some resistance from wood fuel end-users because of the ‘seemingly’ abundant solid volume of wood stocks that currently exist on the ground. Even in highly populated and thus high wood fuel consumption areas, residents still see a supply source in adjacent rural areas. It is also a perception traditionally held by policy makers, conservation organizations, practitioners, and researchers despite the fact that the links to deforestation have been rebuked by several studies and reviews since the 1990s (Zulu and Richardson 2013). Country bans in particular on production and trade of charcoal are a good example of policy response linking charcoal to deforestation (Chidumayo and Gumbo, 2013).

About 17 years ago, for instance, the Forestry Department (1999) reported that charcoal production was the single most direct depleting agent of forest resources due to the continuous nature of its operations, which run throughout the year. They showed that rates of harvesting were very high, which when weighed against a poor monitoring and control system caused serious forest losses but did not explain how this occurred and how charcoal would be considered to be the fore most direct cause than commercial agriculture and logging. They showed that on average, 2.5 - 3.5 kg of wood fuel is used per household per day in rural areas. This consumption when extrapolated to annual figures and in segregating between charcoal and firewood, amounts to not less than 72.76 kg per person per annum and 1025.37 kg per person per annum for charcoal and firewood respectively. Again, the two energy sources were treated together when they are in fact different.

Most studies demonstrate against the myth and show that deforestation was the direct result of other forces, namely agricultural expansion, human permanent settlements and logging and that charcoal was merely a by-product of these processes, although in some cases as was in this study the leading agent. It is of no doubt that the charcoal production as driver of deforestation misconception persists because it is extremely complicated to quantitatively demonstrate the sustainability or non-sustainability of traditional production systems. The complex analyses, tools, and methods that would be needed to make one claim or the other are seldom applied. On the same note, it would be equally harmful to claim that charcoal production cannot be a driver of deforestation. Rapid urbanisation and the lucrative nature of the charcoal business often involving multiple stakeholders are strong economic forces that could by themselves translate into sufficient motives for large scale forest clearing for charcoal as also earlier recorded by Mwampamba *et al*., (2013).

The persistence of the other interpretation of the myth that deforestation in charcoal producing areas actually occurs – might be a question of semantics. It is only recently that forest sectors worldwide have begun to make distinction between the process and drivers of deforestation versus those of degradation. Deforestation is the long-term loss of forest cover while forest degradation is the temporary removal of all or part of forest biomass (Sasaki *et al*., 2011), curbing either process requires very different approaches (Skutch *et al*., 2011). Charcoal production tends to consist of complete and indiscriminate clearing of all standing biomass (Chidumayo, 1993; Castillo - Santiago *et al*., 2013; Chidumayo and Gumbo 2013) such that the immediate visual impact is easily likened to deforestation. In many cases however, these areas regenerate as was the case in this study and can sometimes produce subsequent cycles of charcoal (Chidumayo 1993; Ribot, 1999; Bailis, 2009). Hence forest degradation rather than deforestation is the more probable direct outcome of charcoal production. But there are still those who contend with the claim that charcoal production is the direct cause.

As a result of this myth, direct interventions along the supply chain have focused primarily on the demand end rather than the supply end solutions. There have been numerous improved stove programmes than there have been improved kiln efficiency improvement projects or sustainable forest management interventions specifically addressing charcoal production. Yet, we know very well that charcoal production is one of the oldest chemical engineering talents coined by man and probably the first synthetic material produced by man (Antal and Gronli, 2003). For instance, the manufacture of bronze tools in Africa and elsewhere used charcoal, although the most popular use now is for cooking.

In this paper it is strongly suggested that there should be a shift in emphasis from the use end to the production end of the supply chain, to pyrolysis stages and forest conservation. At the point of pyrolysis, the thermal chemical equilibrium calculations indicate that carbon is a preferred product of biomass pyrolysis at moderate temperatures, with by-products of carbon dioxide, water, methane and traces of carbon monoxide. Traditional kilns mainly in Africa including Zambia realise efficiencies of only 8 – 9% while elsewhere efficiencies are in the range of 8 – 36% (Antal and Gronli 2003). It is this low production efficiency of charcoal production that makes it to be treated as the principal agent of deforestation in Zambia and other tropical countries. Reflecting on the wasteful use of wood to manufacture charcoal given the low efficiency levels compels many environmentalists to feel that charcoal production should be banned.

An explanation for the low efficiency of conventional charcoal kilns is due to the pyrolysis which abruptly transforms wood into a tarry vapour containing a complex soup of organic compounds mixed with non-condensable gases including $CO_{2,}$ CO, $H_{2,}$ $CH_{4,}$ and heavier hydrocarbons at temperatures ranging between 250 – 400^{oC}. In support of this theory Klason, *et al*., (1909) more than a century ago showed that the tarry vapours quickly escape the heated region of the reactor without establishing equilibrium and without forming charcoal. They represented these observations in the following approximate stoichiometric reaction for the carbonisation of wood at 400^{O}c;

$$2C_{42}H_{60}O_{28} \longrightarrow 3C_{16}H_{10}O_{2} + 5CO_{2} + 3CO + C_{28}H_{34}O_{9}$$

The yield of charcoal ($C_{16}H_{10}O_2$) in this equation is 36.7 wt. % an efficiency figure much higher than what is realised in sub-Saharan Africa and that the tarry vapours ($C_{28}H_{34}O_9$) constitute a significant loss of carbon. Because the cost of the wood feed stock (see Figure 6) comprises about 50% or more of the cost of producing charcoal in a conventional kiln. To improve efficiency, there is great economic incentive to transform these tarry vapours into charcoal and thereby reduce the consumption of biomass. Moreover, a high carbonisation efficiency reduces the amount of feed stock consumed, the transportations costs (where applicable) of the feed stock to the kiln and the release of the tarry vapours to the environment as GHGs. Increasing the efficiency would greatly reduce the consumption of wood fuel used to produce the globally popular charcoal. While this view appears to be the most popular, particularly given the current environmental concerns of global warming, it is also worth mentioning that there are no reliable true estimates of the amount of charcoal produced in Zambia and the world in general.

In this vein, stopping the production of charcoal may be a very difficult intervention route to take. This is because charcoal and other biocarbons contain virtually no sulphur or mercury. Relative to their fossil fuel cousins biocarbons are very low in ash. Consequently, many carbonized charcoals are purer forms of carbon than most graphites. Antal and Gronli (2003) additionally showed that unlike graphites, biocarbon's are extremely reactive. Consider for instance that the transformation of biomass to charcoal involves the loss of 60% or more of the substrate's mass with the evolution of nearly 4 mol., of gas per mole of monomer. During this transformation the molecular framework of the sugar moieties composing biomass is grossly rearranged to form aromatic structures. Because the transformation does not involve a liquid phase, many bonds are left dangling, giving rise to a carbonaceous solid that is inherently porous at the molecular level and highly reactive. This purity and reactivity of charcoal enable it to command a premium price as a metallurgical reductant. Other properties as elaborated elsewhere by Antal and Gronli (2003) cause charcoal to find applications in a surprisingly wide range of fields. For example, the biocarbons manufactured from charcoal often have high surface area and are therefore preferred adsorbents for air and water treatment. Biocarbons are also amorphous thus there are only hints of a turostratic structure in their X-ray diffraction spectra. They can also be used to form electrodes. In contrast with other renewable fuels such as hydrogen and ethanol, charcoal is easy to store and cheap to produce. Similarly, when compared with conventional fuels, biocarbons are benign. On the health aspects, charcoal has been injected into the intestines of poison victims to save their lives by adsorbing fatal toxins.

The volatile matter content of good quality charcoal depends on its use. For instance, way back Charturvedi (1943) showed that charcoal intended for domestic cooking typically contains 20 – 30 % volatile matter (VM) with a value of 40% being marginally acceptable, whereas metallurgical charcoal often contains 10 – 15 % or less VM. The ash content of a good quality charcoal typically lies between 0.5 – 5 %, resulting in a range of calorific values between 28 and 33 Mj/kg. An insightful description was earlier given by Charturvedi (1943) as 'charcoal of good quality retains the grain of wood; it is jet black in colour with a shining luster in cross section. It is sonorous with a metallic ring and does not crush, nor does it soil the fingers. It floats in water, is a bad conductor of heat and electricity and burns without flame. The other quality of charcoal can also be represented by a plethora of other qualities such as; moisture content, calorific value, elemental composition, hardness (abrasion resistance) compressive strength, bulk and true densities, surface area, porosity and pore volume distribution, electrical resistivity and reactivity. Above all good charcoal retains the form and structure of the wood from which it was produced to such an extent that the appearance of the charcoal can be used to identify its origin (Klar, 1925; Antal and Gronli, 2003.)

Because charcoal has a readily available market, the question of yield is not one to which they give a great deal of attention. Provided the wood is plentiful, the question of labour costs and the length of time taken for carbonization are seen to be far less important under the current policy frameworks. In most studies if any, charcoal yields of the process are not defined. Usually the values of the moisture content of the feed lots and the charcoal are also not reported, yet these are critical issues if the production of charcoal is to be improved. That is why Antal and Gronli (2003) concluded that despite our more than 38,000 years of experience with charcoal, its secretes continue to captivate us. We have not yet fully understood it.

5. Conclusion

This study reveals that the term deforestation is vaguely defined and loosely used in the public domain. For instance, the Encyclopaedia Britannica (2010) defines deforestation as 'to remove trees from an area of land'. Encarta dictionary (2009) on the other hand defines it as 'indiscriminate or unselective cutting or over-harvesting of trees for lumber or pulp, or to clear the land for agriculture, ranching, construction, or other human activities'. The Robert Hine Oxford dictionary of biology first defines and then elaborates on deforestation as 'the extensive cutting down of forests for the purpose of extracting timber or fuel wood or to clear the land for mining or agriculture'. It adds that forests are often situated in upland areas and are important in trapping rainwater. Deforestation in these areas, particularly in India and Bangladesh, for instance has resulted in the flooding of low-lying plains; it has also led to an increase in soil erosion and hence desert formation, resulting in crop loss and economic problems for local communities. The felling and burning of trees releases large amounts of carbon dioxide, thereby increasing global carbon dioxide levels and contributing to the 'greenhouse effect'. Rainforests, particularly those of South America, are rich in both fauna and flora; their removal leads to an overall decrease in biodiversity and the loss of plant species that have potentially beneficial pharmaceutical effects. These largely incoherent definitions do not necessarily directly link charcoal production to deforestation.

These definitions do not also largely refer to loss of soil cover but just refers to cutting trees'. No mention is made of loss of canopy cover and to what extent such reduction of canopy cover constitutes deforestation. However, there appears to be a general understanding that removal of trees can fragment habitats, lead to loss of biodiversity, reduce soil cover and disrupt the hydrological cycle. In catchment areas however, it does not state the role of non-woody plants such as the members of the family poaceace in providing effective soil cover and interception of rain drops. The current debate on the carbon sequestration appears to be the main driver in the current opinion regarding removal of trees as deforestation. In actual sense, deforestation should be the long-term removal of trees from a forested site to permit other uses, and therefore, viewed from this angle, the cutting of trees followed by regeneration is not deforestation (Dunster and Dunster, 2000).

From this line of thought, charcoal production by itself does not directly cause deforestation, because all trees cut regenerate either from the stump or root stock as was recorded in this study. Debarking of trees, particularly ring barking or debarking of trees for making beehives coupled with other factors such as fire and boring insects could accentuate tree mortality than the singular act of cutting trees for charcoal production. Furthermore, debarked patches on trees are later burnt by fires making the tree hollow and reducing their value for timber and other uses (Chansa, 2000). Commercial agriculture therefore, should be treated as an important direct cause of deforestation perhaps of more impact than charcoal production. Commercial agriculture removes both above and below ground biomass, and each subsequent year, regeneration is suppressed through continuous removal of saplings and all roots are removed as these would hinder tractor ploughing and harrowing. Tree cutting for charcoal production does not have deleterious effects on regeneration of miombo woodlands. Strang (1974) also noted that the dominant trend in regenerating miombo woodland in the absence of frequent hot fires or other intense disturbances is towards woodland. Unless plants have been thoroughly uprooted during the initial disturbance, most of the subsequent development of woodland derives from re-growth of coppice from surviving stems and rootstocks. However, he also noted that marked changes in composition and very slow if any, recovery to the original state is likely in areas where *Brachystegia, Julbernardia* and other Caesalpiniodeae have been eradicated because these trees have extremely low ability for seed dispersal and their seeds are short lived. It is not easy, however, to eradicate these species anyway. In this survey, contrary to the general perception, all species that were cut for charcoal production regenerated within six months.

These findings however, do not in any way suggest that commercial charcoal production is not an important factor to consider in woodland depletion; this is because charcoal production tends to be rather intensive due to wide ranging search for suitable species as also earlier noted by Chidumayo (1987, 1988). It is the pressure exerted on selected species due to the rising demand for charcoal that gives no chance for trees to recover. Late fires and other subsequent human activities prevent trees from fully recovering and maturing before they can be cut down again. Cutting trees for charcoal production can also cause habitat fragmentation which may negatively affect some habitat specialists and hence biodiversity. Selective use of species can also change species composition and structure as the less preferred species invade areas previously occupied by preferred species.

Although charcoal production may not in many circumstances directly cause deforestation as earlier stated, the practice of clear cutting can offset several other negative domino effects. For example; i) the clear cut areas are often taken up and used as gardens for a wide range of crops which subsequently suppress regeneration, ii) the opening up of crown cover when trees are cut encourages grass growth which then becomes fuel for surface fires which kill coppices, iii) clear cutting eliminates old and mature trees eliminating the possibility of regeneration through seed germination, iv) the small branch-lets not often incorporated into the charcoal kiln due to their small size act as kindling fuel for surface fires which in many instances either kill the stump making it impossible to regenerate or kill the coppice, and finally v) the clear cut areas are usually taken up by human settlements.

With respect to the number of trees cut and the size of the kiln, this study, showed that the average size of the kiln was 2 metres high, five metres wide and ten metres long. Depending on the girth size of trees on site this would take between 30 – 50 mature trees and each charcoal producing family claimed to prepare at least a kiln per month producing 100kg x 50 bags of charcoal each sold at K70 (USD 7) and therefore earning the family USD 350. This amount compels a family to make at least a kiln each month for them to earn an annual income of USD 4,200. In years of drought and soaring prices of artificial fertilisers, charcoal producing families can earn more income than their counterpart small scale maize farmers. This becomes an incentive for charcoal producers to devastatively clear large areas for increased charcoal production to feed the ever-growing demand.

5.1 Average Number of Trees Cut per Average Sized Kiln

Clear cutting was used when all trees in the vicinity of the kiln were cut unselectively. This was common in the study area because most of the areas along the Kabwe – Copperbelt highway are earmarked for human settlements and charcoal was used to open up areas for new settlements, particularly in anticipation of the construction of a dual carriage way. The number of 50 trees per kiln obtained in this study is indicative of relatively mature woodlands now being opened up for human settlements. In secondary or regenerating woodlands there could be more than 50 trees cut down to provide feedlot for kilns. This explains the clear cut physical appearance of most of the study sites. In areas where there were no plans for immediate human settlements or fields, there were selective cutting where only certain trees were cut leaving others untouched giving a patchy appearance in canopy.

6. Recommendations

The average establishment period for natural regeneration has been calculated at 8 years for both seedlings and coppices, but that this varies between 2 and 11 years depending on species. Normal establishment period for new crop is best regarded at 10 years when stool mortality and different sources of regeneration are taken into account

(Chitondo, 1997). The cutting cycle in selective cutting areas is 20 years and 60 years in clear-felled areas. 100 years are regarded as the period needed for a tree in a miombo woodland, under natural conditions, to attain DBH of 30cm. Silvicultural treatments have proved to reduce this period to 60 years on average quality sites and 50 years on best quality sites (Chitondo, 1997).

The major problem that has been associated with charcoal production, however, is in the way it is produced and the kind of losses incurred in its production. The earth kilns used are mostly 10% efficient, implying that in the process of producing charcoal from wood, 90% by weight is lost. From 100 tons of wood, therefore, one only expects to get 10 tons of charcoal (Kapiyo, 1996).

With regard to regeneration, results obtained in this study showed that all species have the potential to regenerate. On the basis of these two important factors the following intervention measures have been recommended;

(i) Charcoal Production Process

Management interventions should examine the entire charcoal production value chain, in particular the use of more efficient kilns rather than earth kilns which have low efficiency.

(ii) Post-harvest Management

To manage the effects of fire on stumps and coppices. All discarded wood debris including branchlets should be removed as suggested in earlier studies and kept away from the stumps as these act as ground fuels for surface fires which can kill the stump or saplings. Appropriate fire regimes be applied for the first few years until full recovery is achieved. Where possible encourage traditional authorities to develop community-based fire management plans to reduce the impact of fire on the young shoots and allow saplings from seed to get established.

(iii) Sustainable Regeneration

As earlier stated by Chidumayo (1997), natural regeneration of forests is through seed, stumps (coppices) and roots. In post management of areas cut for charcoal production, land holders or traditional authorities or whichever authority is responsible for the land should keep track of the number of shoots per stump and thin them according to the primary goal of the forest. Thus, those being managed for timber production may require fewer or at best only one dominant shoot to be retained to minimize competition for light, water, minerals and other resources.

(iv) Tree Cutting Height and Season

The tree cutting height has been found to affect the nature and rate of regeneration and the quality of wood products. For example, pollarding as in *Chitemene system*, stumping and uprooting will as in clearing for agriculture lead to regeneration with specific wood qualities. The time of cutting also affects shoot production. This is because the phenological phase of a plant would determine its ability to regenerate vegetatively. Thus, cutting down trees after stored resources have been exhausted during leaf flush reduces growth during the first growing season and the duration of the growing season is also reduced and should be regulated.

(v) Emerging Human Settlements

The Forestry Department and other land administering agencies should secure forests along the Kabwe – Ndola road. With the planned dual carriage way between Lusaka and Ndola being a reality, it is very likely that this area will attract a lot of commercial and small holder settlements. With increased levels on human settlements, forest regeneration is more likely to be suppressed.

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