Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.7, 2015

A Review on Tree Species Suitability for Wood Fuel in Kilimanjaro Region

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Abstract
Wood energy provides 92% of Tanzania's national energy needs. Wood is the standard cooking fuel for the majority of Tanzanian households and also an important energy source for small-scale rural industries. This paper focuses on suitability of tree species as wood-fuel in Kilimanjaro region mainly through literature review. Results show that when choosing wood for heat energy production, wood moisture content and basic density have to be considered as they affect amount of available heat per unit volume of fuel (calorific value). The moisture content or any water in the wood has to boil away before the wood will burn, and this will reduce the net energy released as useful heat. Hardwood species are generally denser than softwood species and dense woods will burn for longer than less dense woods. For the purpose of this paper, wood basic density was used as a criterion for selecting tree species suitable for wood fuel in Kilimanjaro region. The study has revealed that *Acacia xanthophloea, Eucalyptus maidenii, Cordia africana, Casuarina equisetifolia, Terminalia superba, Senna siamea, Bauhinia petersiana, Azadirachta indica, Albizia versicolar* and *Ficus benjamina* are among the tree species suitable for wood fuel in Kilimanjaro by having higher basic density than 500kg/m^3. It is recommended that the suitable tree species for wood-fuel uses should be raised and managed by villagers in order to have enough stock for planting. Establishment of demonstration plots for suitable trees for wood fuel in Kilimanjaro region is also recommended.

1.0 Introduction

Wood fuels including firewood and charcoal account for about 92% of primary energy consumed in Tanzania (SADC, 1993; Ngaga *et al.,* 2004, Monea and Kingazi, 2004). Charcoal consumption in Tanzania is estimated to about 19 million bags of charcoal or about 968,500 tons per year (WWF, 2007).. To produce that quantity of charcoal more than 230,000 hectares of Miombo Woodlands are destroyed per year (Kilahama, 2004). This destruction has been increasing because people are no longer selective when cutting tree species for charcoal production. Charcoal provides 85% of the domestic needs of the urban population while firewood is mainly used in rural areas (Kimaryo and Ngereza, 1989). According to FAO (1984) the amount of charcoal consumed annually per person in urban centres is about 0.8m^3 on average which is approximately 1.6m^3 in round wood equivalent. In Kilimanjaro region in particular, one person uses 350g of charcoal per day equivalent to 127.75 kg per person annually (TAFORI, 2010). Because of the increase of rate of urbanization, charcoal consumption has increased quite rapidly. Woodfuel is mainly used for cooking, water heating, house heating, lighting and other home businesses (Monela and Kingazi, 2004). Households are the most important category in wood energy consumption while the second highest consumer of woodfuel are the cottage industries which include brick making, tobacco curing, fish smoking, and bakeries (Mugo, 2001). Others users include small restaurants/hotels and kiosks and learning institutions. In view of the importance of cottage industries in income and employment generation and wealth creation at the rural population, their energy requirements need specific attention to ensure their sustainability.

The characteristics affecting the properties of wood as a fuel are: heating value, chemical composition, moisture content, density, hardness, the amount of volatile matters, the amount of solid carbon, ash content and composition, the melting behavior of ash and the amount of impurities (Bryce, 1967; Baker, 1982 Neilan and Thompson, 2008; Leslie *et al.,* 2012). However, it was reported that basic density and moisture content are the most factors which affect the properties of wood as a fuel as they affect the amount of available heat per unit volume of fuel (calorific value (CV)) (Neilan and Thompson, 2008). Additionally, tree species grown for fuel wood (firewood or charcoal) should: grow quickly, yield a high volume of wood quickly, and require minimum management time; coppice or sprout well from shoots; produce little and nontoxic smoke; produce wood that splits easily and can easily be transported; produce wood without thorns; yield other products or services that are demanded by the household and produce wood that does not spit or spark when burning (Bryce, 1967; Leslie *et al.,* 2012). However, for the purpose of this paper, wood basic density was used as a criterion for selecting tree species suitable for wood fuel in Kilimanjaro region. There is a close relationship between wood basic density and CV or the amount of available heat per unit of fuel that the higher the wood basic density the higher the CV of the wood. Wood basic density is defined as dry mass per unit volume and is expressed as g/cm^3 or kg/m^3. It was also reported by Ishengoma and Nagoda (1991) that basic density is considered to be the key indicator for

most properties of wood, hence it is important to use it as a criterion for selecting tree species suitable for wood fuel. In addition, criteria used for selecting tree species suitable for wood fuel in Kilimanjaro region, was the possibility of a tree species to grow in the region and its fast growth in lowland and highland of Kilimanjaro region.

Firewood and charcoal in the Kilimanjaro region comes largely from the lowland areas which is occupied by extensive savannah scrubs/bushes and thickets pertaining to a semi-desert. The most preferred species for woodfuel production in the region includes *Acacia xanthophloea, A. polyacantha*, *A. albida* and *Albizia gummifera* (TAFORI, 2010). However, these species are currently very scarce and they cannot sustain the regional woodfuel demand in the long term. Consequently, other tree species which are less suitable for use as woodfuel have been used and this has resulted into an extensive process of degradation and deforestation, with serious negative consequences on the sustainability of forest catchments which are providing drinking water, traditional small holder irrigation and power generation for the National Grid. It is from these bases that the suitability of tree species as wood-fuel review was deemed essential.

2.0 Methodology

2.1 Information gathering

The work presented in this paper is a result of literature review from a range of research work on wood-fuel sector in Tanzania and elsewhere in developing countries. The main method and tools used for gathering information on wood-fuel sector were the internate websites, research journals and proceedings, workshop or seminar papers and books.

2.2 Information analysis

The main body of knowledge presented in this paper is from review of various literatures on wood-fuel, physical and mechanical properties of wood. The information so gathered was subjected into case summary table to portray the suitability of tree species as wood-fuel in Kilimanjaro region. No formal analysis was done; rather report abstractions to address the suitability of tree species as wood-fuel were the main task.

3.0 Results and Discussion

The most tree species suitable for wood fuel are hardwoods (Bryce, 1967). When choosing wood for burning, two significant factors namely; moisture content and wood density needs to be considered (Bryce, 1967; Neilan and Thompson, 2008; Leslie *et al.,* 2012). These factors affect the amount of available heat per unit volume of fuel (calorific value (CV)). The moisture content of wood has by far the greatest effect on CV. Any water in the wood has to boil away before the wood will burn, and this will reduce the net energy released as useful heat. Well seasoned logs can have approximately twice the CV of green logs. Wood density is also important as it largely determines the calorific value per unit volume (Neilan and Thompson, 2008). It is used as an indicator of wood quality and it is an important trait for estimating stored biomass and carbon content (Chave *et al*., 2009). Wood with high basic density is heavier and has high calorific value. Generally basic density is considered to be the key indicator for most properties of wood (Ishengoma and Nagoda, 1991).

Table 1: Tree suitable for wood fuel in Kilimanjaro region

S/N	Botanical name	Common name	Density (Kg/m^3) at 12% moisture content
1.	*Acacia xanthophloea*	Mwerera	900
2.	*Eucalyptus maidenii*	Mkaratusi	843
3.	*Cordia africana*	Mringaringa	833
4.	*Casuarina equisetifolia*	Mvinje	830
5.	*Terminalia superba*	Mwalambe	778
6.	*Senna siamea*	Mjohoro	700
7.	*Bauhinia petersiana*	Mchekwa	670
8.	*Azadirachta indica*	Mwarobaini	646
9.	*Albizia versicolar*	Mduruasi	657
10.	*Ficus benjamina*	Mkuyu	650
11.	*Jacaranda mimosifolia*	Mjakaranda	640
12.	*Eucalyptus peniculata*	Mkaratusi	623
13.	*Grevillea robusta*	Mgrevia	609
14.	*Trichilia emetica*	Mgolimasi/Mti maji	593
15.	*Faidherbia albida*	Mkababu	560
16.	*Albizia gummifera*	Mruka	545
17.	*Terminalia ivorensis*	Mwalambe	540
18.	*Eucalypt* clones	Mkaratus	526 – 634
19.	*Acrocarpus fraxinifolius*	Mtikivuli, Dakika tatu	517
20.	*Gmelina arborea*	Mfundufundu	501

Sources: Bryce (1967); Bolza *et al*. (1972); Fermandes *et al*. (1985); FAO (1993); Mbuya *et al.* (1994); Lambrechts *et al*. (2002); Barnes and Fagg (2003); WAC (2004); Gillah *et al*. (2008); Hemp and Hemp (2008); TAFORI (2010); Carsan *et al*. (2012)

According to Panshin and De Zeew (1970) wood with density of 360 Kg/m^3 or less are considered light/low, 360 to 500 Kg/m^3 moderate and above 500 Kg/m^3 heavy/high. Densities of all tree species listed in Table 1 are high, hence to be considered the most suitable for wood fuel in the region. However, the basic densities data show that *Acacia xanthophloea, Eucalyptus maidenii, Cordia africana, Casuarina equisetifolia, Terminalia superba, Senna siamea, Bauhinia petersiana, Azadirachta indica, Albizia versicolar* and *Ficus benjamina* are the best ten tree species suitable for wood fuel in Kilimanjaro. In addition, tree species listed in Table 1 for fuel wood (firewood or charcoal) are all planted in all seven districts of the region though at different landscapes, they grow quickly, yield a high volume of wood quickly, require minimum management time and ability to coppice or sprout well from shoots immediately when pruned for firewood in both low and highland.

Tree species listed in Table 1 together with others which are locally preferred like *Acacia meansii, Acacia polycantha, Acaia nilotica* and *Terminalia sambesiaca* are also recommended for planting on different landscapes in the Kilimanjaro region. Below are some of the tree species which can be planted in the following areas:

- Trees for planting on river banks include *Acacia xanthophloea, Albizia versicolor, Ficus benjamina, and Faidherbia albida.* The roots of these trees are known to protect the soil against soil erosion and can in turn protect water catchment areas. Although bamboos are not regarded as tree, we also recommend planting them along side river stream as well to prevent soil erosion;
- Trees for planting in open areas include *Acrocarpus fraxinifolia,, Gmelina arborea, Grevillea robusta, Jacaranda mimosifolia, Senna siamea, Delonix regia, Azadirachita indica, Trichilia emetica,* and *Albizia versicolor.* These trees have diverse use but are generally good trees for shade; and
- Trees for planting along side road areas include *Jacaranda mimosifolia, Trichilia emetia, Azadirachita indica, Bahunia petersiana,* and *Casuarina equisetifolia.* These species have good shade and enhance natural elegance and scenery beauty.

4.0 Conclusions and Recommendations

4.1 Conclusions

The study concludes that tree species suitable for wood fuel, selected on basis of wood basic densities of trees include *A. xanthophloea, E. maidenii, C. africana, C. equisetifolia, T. superba, S. siamea, B. petersiana, A. indica, A. versicolar* and *F. benjamina*. All tree species suitable for wood fuel are planted in all seven districts though on different landscapes in the region, they grow quickly, yield a high volume of wood quickly, require minimum management time and ability to coppice or sprout well from shoots immediately when pruned for firewood in both low and highland of Kilimanjaro areas.

4.2 Recommendations

From findings of this study and other reviewed research reports, it is recommended that;

i) provision of training on tree planting and species to plant on specific areas is highly needed in all districts of the region due to current changing in climatic condition;
ii) establishment of tree nurseries of preferred tree species for wood-fuel and other uses and establishment of demonstration plots are encouraged;

Acknowledgements

Authors are gratefully acknowledged the Government of Tanzania, Global Environment Facility (GEF) and UNDP through Sustainable Land Management (SLM) Project in Kilimanjaro for financing this study. We are also indebted to all Institutions and individuals who facilitated our study. Finally, we are thankful to the Project Technical Team from Project Coordination Unit (PCU) at the RAS-Kilimanjaro Office for their useful comments and suggestions.

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