Comparative Analysis of Indigenous and Exotic Fuelwood Species and their Alternative Uses for Rural Tanzanian Communities

(Photo taken by author)

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Larch 499F Studio: Community Design in the Vicinity of Udzungwa Mountains National Park

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Introduction

91% of Tanzania's energy consumption comes from fuelwood (ICUN 2001). Furthermore, the majority of rural Tanzanian households use firewood for cooking (Fleuret and Fleuret 1978). Traditionally, communities have relied on surrounding forests for their fuelwood needs because the wood was an abundant and free resource (NAFT, 1988). However, the population of Tanzania is rapidly growing at 2.9% (World Bank 2009). As Tanzania's population continues to grow and develop, the pressure on the limited forest resources will continue to grow as well. The local communities that depend on these resources for products that have no alternatives (FAO 2010).

Even with the growing demand for this resource, reliable data on the consumption of fuelwood in rural households is very scarce (Fleuret and Fleuret 1978). The purpose of this study was to determine the most efficient fuelwood currently in use by local Tanzanian populations. To accomplish this, the study was conducted in several phases. The first phase was to develop comprehensive tables of various known indigenous and exotic fuelwood species and their characteristics. The listed species were then compared to each other based on a variety of criteria that enabled them to be categorized and ranked. The highest ranked species were then narrowed down to the trees that were determined to be the most valuable using a prioritized index. Finally, the index was applied to create three possible scenarios for fuelwood production and management. The tree species determined to be most efficient would have the potential to provide rural communities with the resources they rely on. Further research on fuelwood species could provide more information for sustainable management for woodlots, forest reserves, forest plantations and other promising agroforestry approaches that are used to manage trees within agricultural land use systems (FAO 2010; Brockerhoff et al., 2008).

Fuelwood Harvesting in Tanzania

Forest fuel, or fuelwood, is forest or plantation wood that is initially used to produce fuel directly through mechanical processing (Krajnc 2015). Forest fuelwood has been the main energy source as the well as the provider for other basic products and services, and the dependence on it is unlikely to change for many years (Puri et al., 1994). Even with the recognized importance of Tanzania's dependence on forest resources, more than 10 million hectares (ha) of land were deforested for other uses between 1970 and 1988 alone (IUCN 2001).

Wood biomass is a renewable and carbon dioxide neutral source of energy that can contribute to a cleaner environment if it is used in a sustainable and efficient way (Krajnc 2015). However, between 27% and 34% of pan-tropical traditional fuelwoods are currently harvested unsustainably (Bailis et al., 2015). When a forest is degraded so dramatically that it can no longer support the various species that it used to, then habitat destruction (specifically habitat fragmentation) becomes the biggest cause of species extinction worldwide (Laurance 2010). With areas of significant biodiversity, like the Eastern Arc Mountains that encompasses Ugzundwa Mountains National Park (UMNP), losing the forest would mean losing high levels of endemic species of plants and birds (Burgess et al., 2007).

If managed effectively, fuelwood has the potential to act a bridge between developing communities and alternative energy sources like solar or wind power while preserving important biological diversity. Participatory forest management (PFM) is a promising form of providing forest resources through two options: Community based forest management (CBFM) or joint management agreements (JFM) (Arc Journal 2007). The CBFM approach is to have villages declare village, group, or private reserves for community use. In contrast, JFM allows communities to enter into agreements with the government or a private owner to share the cost and benefits of forest reserves. Over 3.6 million hectares in 1,800 have been established under PFM, which demonstrates the interest that communities have in establishing their own resources. (Blomley 2008). Other ways of protecting valuable forests include Village Land Forest Reserves and Community Forests designated for either production or conservation. All of these approaches have the ability to be applied to all forest types by reducing deforestation and increasing the direct access to the resources local communities desperately need. However, in practice, limited benefits to the local community limits the success of these programs (Arc Journal 2007). If Tanzania wants to move towards a more sustainable future, there needs to be an overall positive incentive to keep communities engaged in fuelwood management and conservation.

Overview of the Species Tables

The first action of exploring more efficient fuelwood species was to create Tables 1, 2, 3. The tables were developed to provide detailed information on reported fuelwood characteristics, uses, and management information. Table 1 contains the tree species currently held in the UMNP nursery, which provides important insight to the priorities of the surrounding local communities. Table 2 is split into 15 firewood and 15 charcoal species, all of which are indigenous to Tanzania. The species in Table 2 were considered "preferred by local people" for fuelwood use according the sources listed below. Table 3 includes exotic species currently in use in Tanzania for a variety of purposes other than fuelwood.

Exotic and native tree species were included in the lists for comparison purposes. There is an existing theory that people want to use indigenous species for as long as they are available because these species tend to be of higher quality, are known and respected by the users, are generally a common property resource, can be obtained without maintenance or cash payment, and provide products that cannot be duplicated with fast growing species (FAO 2010). However, considering the option to use exotic fuelwood species provides more opportunities to discover efficient fuelwoods that are not indigenous to Tanzania.

Table 1. Properties of Indigenous and Exotic Tree Species found in the UMNP nursery

Key			
c= charcoal	f= firewood	l= land improvement	fi= fibers
m= medicine	f/b= food product or beverage	n= nitrogen fixing	mu= mulch
t= timber	b= attracts bees/provides habitat	fr= livestock fodder	s= spiritual/ritual value

Latin	Common	Swahili/Local	Orgin	Use (s)	Rate of Growth	Avg Wood Density (g/cm^3)	St Deviation	Management
Citrus limon	Lemon	Mlimao	India	f,f/b,m	fast	0.700	0.000	Grafting
Milicia excelsa	Iroko	Mvule	Indigenous	f,c,t,mu	fast	0.650	0.100	None
Grilicidia sepium	Mexican lilac, quick stick, treen of iron	Mtimaji	Central America, Mexico	f,c,fr,b,mu,n,l	fast	0.650	0.150	Pollarding, lopping
Tectona grandis	Teak	Msaji	South-East Asia	f,t	fast	0.650	0.070	Coppicing, thinning, weeding
Khaya anthotheca	African Mahoghony	Mkangazi	Indigenous	f,t,m	fast	0.575	0.085	None
Persea americana	Avacado	Mparachichi	Tropical America	f/b	fast	0.560	0.000	Grafting
Acacia mangium	Sabah salwood, mangium, hickory wattle	Mkesia	Australia, Indonesia, Papua New Guinea	f,c,fr,f/b,fi,t,n	fast	0.540	0.000	None
Mangifera indica	Mango	Muembe	Northern India, Burma	f,f/b,fr,b,mu,l	fairly fast	0.510	0.030	Grafting, direct sowing, seedlings

Table 2. Properties of Tree Species Indigenous to Tanzania Separated into Firewood and Charcoal Categories

Latin	Common	Swahili/Local	Alternative Use (s)	Rate of Growth	Avg Wood Density (g/cm^3)	St Deviation	Management
Firewood							
Acacia lahai	Red thorn	Melelek	c,t,d	slow	1.150	0.000	Lopping
Sorindeia madagascariensis	Sorindeia madagascariensis	Mpilipili doria	f,f/b	fast	1.000	0.000	None

Dichrostachys cinerea	Sicklebush	Mkulagembe	c,m,fr,b,n,l,fi	medium to slow	0.990	0.000	Coppicing, lopping, pollarding
Burkea africana	Wild syringa	Mkarati	c,t,fr,b,m	fairly fast	0.935	0.205	Lopping
Combretum adenogonium	Four-leaved combretum	Mkunguni	c,m,b	fairly fast	0.870	0.000	Coppicing
Brachystegia spiciformis	Bean-pod tree	Mriti	c,t,b,m,fr,fi,d	slow	0.855	0.045	Coppicing, pollarding
Parinari curatellifolia	Fever tree	Mbula	c,t,f/b,m,fr,b	fast	0.855	0.045	None
Croton Megalocarpus	Croton	Ziloi	c,t,m,b,mu	fast growing (in high potential areas)	0.725	0.075	Lopping, pollarding, coppicing
Syzygium cordatum	Water-berry tree	Muvengi	t,f/b,b,m,d,s	fairly fast	0.705	0.195	None
Grewia bicolor	False brandybush	Mkole	t,m,fr,s	slow	0.670	0.000	Coppicing
Acacia albidia (F. Albida)	Apple-ring acacia, winter thorn	Mkababu	c,t,m,fr,n,l,b	slow initially, fairly fast later	0.635	0.075	None
Markhamia obtusifolia	Golden Bean tree	Mtarawanda	t,fr,m,s	fairly fast	0.630	0.000	Coppicing
Albizia gummifera	Peacock flower	Mruka	t,b,m,l,n,s	fast	0.615	0.185	Lopping, coppicing while young
Brachystegia bussei	Large-leaved brachystegia	Miombo	c,t,m,fr,b,fi	slow	0.610	0.030	Coppicing, pollarding
Uapaca kirkiana	Wild loquat	Mguhu	c,t,f/b,m,b	fairly fast	0.580	0.000	Coppicing
Charcoal							
Olea capensis	Elgon olive, East African olive	Ngwe	f,t,m	slow	0.960	0.050	None
Acacia tortilis	Umbrella thorn	Mgunga	f,t,fr,b,l,n,fi	slow	0.905	0.000	Lopping
Terminalia sericea	Silver terminalia	Mbuko	f,t,m,d,b	fast	0.880	0.040	Pollarding, coppicing
Afzelia quanzensis	Lucky-bean tree, Mahogany bean, pod mahogany	Mbambakofi	t,m	fast initally, slow later	0.815	0.085	None
Olea europaea	Brown olive	Mhagati	f,t,m,b,f/b	slow	0.805	0.105	None
Dalbergia nitidula	Glossy flat-bean, purplewood dalbergia	Mjiha	f,fr,d	slow	0.780	0.000	Coppicing
Lonchocarpus capassa	Lilac tree, rain tree	Mvale	f,t,f/b,m,fr,b,s	fast	0.760	0.000	None
Combretum molle	Velvet bush willow, velvet-leaved combretum	Mlama	f,t,m,b,mu	moderately fast	0.760	0.000	Lopping, coppicing
Syzygium guineense	Water berry	Mzambarai	f,t,f/b,m,b	moderately fast	0.725	0.075	Pollarding, coppicing
Diospyros mespiliformis	African Ebony	Mgiriti	f,t,f/b,m,b	slow	0.695	0.035	None
Albizia versicolor	Poison-pod albizia	Mduruasi	f,t,m,b,n	fairly fast	0.665	0.105	Lopping, pollarding

Faurea saligna	Beachwood	Mhenyi	f,t,b,m,mu,d	slow	0.650	0.000	None
Prunus africana	Red stinkwood	Mwiluti	f,t,m,b,mu,f/b	fairly slow	0.600	0.020	None
Vitex doniana	Black Plum	Mfudu	f,t,f/b,fr,b,m,d	medium	0.525	0.095	None
Trema orientalis	Pigeon wood	Mgendagenda	f,fr,b,mu,n,l,f/b	very fast	0.480	0.020	Coppicing

Table 3. Properties of Exotic Tree Species Used in Tanzania

Latin	**Common**	**Swahili/Local**	**Orgin**	**Use (s)**	**Rate of Growth**	**Avg Wood Density (g/cm^3)**	**St Deviation**	**Management**
Dalbergia sissoo	Sissoo	N/A	India	f,c,t,fr,b,l,n,f/b	fast	0.775	0.025	Lopping, pollarding, coppicing
Leucaena leucocephala	White leadtree	Mlusina	Central America	f,c,fr,b,mu,l,n	very fast	0.645	0.195	None
Ziziphus mauritiana	Geb	Mtungutu	South-East Asia	f,c,t,fr,b,l,f/b,d	fast (dry areas)	0.63	0.05	Lopping, pollarding, coppicing, pruning
Tipuana tipu	Pride of Bolivia, tipu tree	N/A	Bolivia, Brazil	f,c,t,fr,b	fast	0.59	0.02	Pollarding, lopping, coppicing, remove wings
Pinus caribaea	Caribbean pine	Msindano	Central America	f,t,fi	fast	0.585	0.235	Pruning, thinning
Grevillea robusta	Grevillea, silky oak	Mgrivea	Austrailia	f,c,t,fr,b,l,mu	moderate to fast	0.575	0.065	Pollarding, lopping, pruning
Parkinsonia aculeata	Jerusalem thorn	Mpakinsonia	Tropical America	f,c,m,fr,b,mu,l	fast	0.565	0.045	Pollarding
Moringa oleifera	Drumstick tree, horse-radish tree	Mlonge	Indian, Himalayas	f/b,m,fr,b,l,fi	fast	0.56	0	Direct sowing, seedlings
Albizia saman (samanea saman)	rain tree, saman tree	Mafura	Central and South America	f,t,f/b,fr,n,l	fast	0.44	0.01	None
Melia azedarach	Bead tree	Mmelia	Western Asia, Himalayas	f,t,m,b,d	fast	0.38	0.01	Seedlings, wilding,direct sowing

Data sources: United Nations Food and Agriculture Organization, Useful Trees and Shrubs for Tanzania

Ranking

The trees listed were initially selected due to their properties as fuelwood. However, every tree species included in Tables 1, 2, and 3 were harvested and used for more than one purpose. For example, *Moringa oleifera* (Drumstick tree) was reported to provide food, medicine, livestock fodder, and bee attracting/ land improvement capabilities. The multipurpose nature of the fuelwood trees listed enabled further comparisons of their alternative uses. The reported uses of the trees were developed into an individual categories and ranked based on the various criteria described below. The species determined to be the most useful in each category were grouped into a list titled "Top 5 Species".

Fuelwood Use

Firewood

The most important characteristics that affect the properties of wood as a fuel are moisture content and density (Petro et al., 2015). Density is positively correlated to caloric value Therefore, the more dense wood is, the more energy it contains. .After comparing those two characteristics, it was found that the moisture content of over half of the species listed were equal. For a better comparison, density was determined to be the better measurement of the energy content of the listed species. The wood basic densities defined as dry mass per unit volume expressed in g/cm^3 were found for every species. Many tree species had densities that fell into a range of minimum and maximum values. To make the analysis easier, the average wood density was calculated using the given range. In addition, the standard deviation of each species was calculated to show the variability of the available data for a measure of accuracy. All three lists were compared to each other to find the five trees with the highest recorded average densities. The resulting data is shown graphically in Fig. 1.

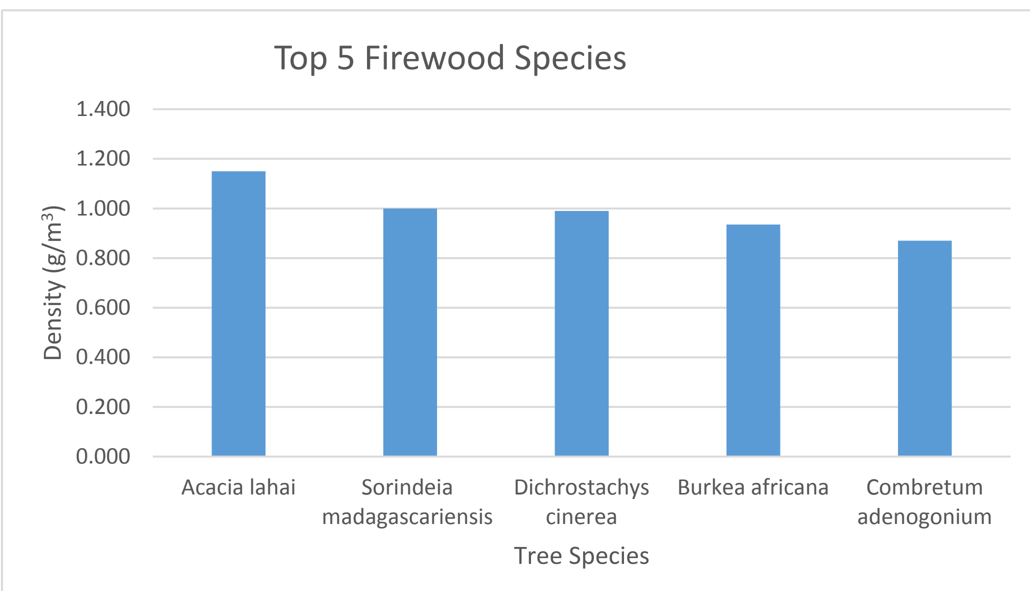
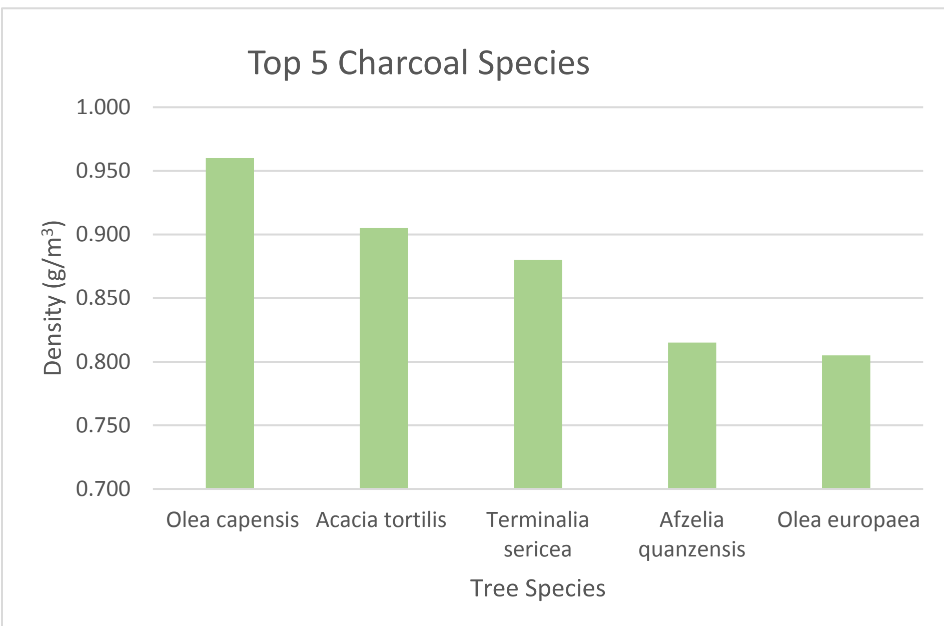


Fig 1. The Top 5 Tree Species Recommended for Firewood Based on Average Wood Density

Charcoal

85% of Tanzania's charcoal users are concentrated in urban areas (Kimaryo and Ngereza, 1989). However, charcoal is still an important fuelwood to consider for rural communities. As more communities grow urbanize, the need for charcoal will grow. Using wood with a higher energy content to make charcoal to will increase its fuel efficiency and decrease the amount needed to be bought and the trees needed to be harvested. The average wood basic density of the trees reported as being preferred for charcoal use were compared with the UMNP nursery list and the exotic tree list to find the five highest values. The trees with the five highest are presented graphically in Fig. 5.

Fig. 2 The Top 5 Tree Species Recommended for Charcoal Based on Average Wood Basic Density



Alternative Uses

Medicine

The majority of child deaths are the result of preventable illnesses like malaria, pneumonia, diarrhea, and malnutrition (World Bank 2009). It is estimated that about 70 percent of Tanzanians use medicinal plants for curing illnesses. Due to the high dependence on forest products for treatment of various illnesses, an important alternative use of fuelwood trees are their medicinal properties. According to the Centers for Disease Control and Prevention (CDC), the top ten causes of death include HIV, lower respiratory infections, malaria, diarrheal diseases, tuberculosis, cancer, heart disease, stroke, STDs, and sepsis. The top five species for medicine were determined based on their medicinal properties related to the biggest causes of death. *Grewia bicolor,* for instance is used to treat stomach problems, snakes bites, and syphilis (FAO 2010). *Dalbergia sissoo* is known for its ability to treat skin diseases like leprosy (Orwa 2009).

Top 5 Tree Species for Medicine

1. Grewia bicolor
2. Olea europaea
3. Lonchocarpus capassa
4. Parinari curatellifolia
5. Dalbergia sissoo

Timber

In 2011, the global timber trade was worth USD246 billion, and tropical hardwood production accounted for 13%. The ranking for timber was determined by the economic value of the identified species. *A. quanzensis*, for example, is locally prized wood (LPW) with a substantial international market (MDCI 2014).Harvesting timber is an important potential source of income for rural communities that may not have many opportunities for employment. Even though timber is a valuable resource, the time needed for trees to reach maturity hinders its usefulness to the daily lives of local people. As a result, species like *Prunus africana* and *Olea europaea* are becoming increasingly rare (FAO 2010).

Top 5 Tree Species for Timber

1. Afzelia quanzensis
2. Tectona grandis
3. Olea europea
4. Prunus africana
5. Khaya anthotheca

Non-timber Forest Products (NTFP)

Non-timber forest products (NTFPs) is a term that includes all biological materials used for purposes besides commercial timber (Henry et al., 2006). For this study, the materials considered to be NTFPs are food products and beverages (including oil), livestock fodder, fabric dye, mulch, and fibers (FAO 2010). Medicine could have been included in this category, but it was separated due to its heavier exploitation (Ndangalasia et al., 2006). NTFPs like mulch are harder to quantify in terms of economic value than timber due to their wide range of prices. Therefore, the trees in all three lists were ranked by the total number of non-wood materials that they provide.

The top five trees shown below each tied for three NTFPs. Interestingly, the UMNP nursery already containers two of the top five species.

Top 5 Tree Species for NTFPs

1. Acacia mangium
2. Brachystegia spiciformis
3. Mangifera indica
4. Trema orientalis
5. Vitex doniana

Land Improvement

Land improvement is essential to Tanzania's population considering that 80% of its people are involved in agriculture (Ramadhani et al., 2001). Access to fertilizer is very poor, especially in rural communities (FAO 2010). To make matters worse crops like maize and sugarcane require large amount of nutrients to grow, and they leave the soil in disrepair once harvested. As a result, farmers have to continually practice shifting cultivation in order to get the same crop yield. Trees that have land improvement qualities are a way of providing families with a relatively simple way of keeping the soil healthy. For this study, land improvement includes soil conservation, improvement, and binding ability. The top five species for land improvement were identified by these reported properties. Because there were more than five species that were found to have land improvement capabilities, the selected species were further ranked by density for further comparison. *D. cinerea* (sicklebush) was the only indigenous species that made the list. However, it had the highest wood basic density of all the species with land improving properties.

Top 5 Tree Species for Land Improvement

1. Dichrostachys cinerea
2. Dalbergia sissoo
3. Grilicidia sepium
4. Leucaena leucocephala
5. Ziziphus mauritiana

Nitrogen Fixation

Nitrogen fixation was evaluated as a subcategory of land improvement because its absence often limits plant growth in tropical areas (Hogberg 1986). Certain tree species have the ability to recycle nitrogen and fertilize the soil, reducing the need for synthetic chemicals. The species selected for nitrogen fixation should be able to grow quickly under adverse conditions (FAO 2010). The top five trees with nitrogen fixation properties where found by reported properties. The list was further narrowed down by growth rate to produce a more effective comparison.

Top 5 Tree Species for Nitrogen Fixation

1. Trema orientalis
2. Albizia gummifera
3. Leucaena leucocephala

4. Albizia versicolor
5. Albizia saman

Bees

Bees have significant importance as efficient pollinators and food producers (Tucker 2014). Many of the tree species studied had properties of attracting bees or providing and providing a habitat for them. For example, *Acacia albidia* (apple-ringed acacia) was placed at the top of list because of its property of attracting hives (FAO 2010). The other trees that made the list have abundant nectar that bees are strongly attracted to or provided suitable habitat (Mbuya 1994).

Top 5 Tree Species for Bees

1. Acacia albidia (F. albidia)
2. Afzelia quanzensis
3. Grewia bicolor
4. Parinari curatellifolia
5. Syzygium guineense

Fuelwood Multipurpose Value Index

Of the 48 total tree species analyzed, 30 species were included in the top five rankings. Each one of these species that are planted need to be continually monitored to collect information on resource extraction, disturbance, and the woodlot health. The data collected is used to make decisions and improve management techniques As a result of the time required to manage community reserves, tree planting initiatives are constrained by project funding and space. If the funding is suddenly cut, participating communities often fail to successfully manage their trees. (Arc Journal 2007).

The Fuelwood multipurpose value index (FMVI) shown in Table 5 was established to further prioritize the species recommended for rural community use based on the established rankings. The aim of narrowing down the species list is to determine trees with the highest potential value based on desired characteristics to increase the chances for sustainable management of programs and initiatives. To develop the index, all the species in the top five categories were given points based on the weighted scale shown in Fig. 3. The maximum number of points that a species could earn was 100 for a perfect score. Average wood density was determined to be the most important property due to its correlation with caloric value. Therefore, average wood density was weighted at 35 points of the total available. Rate of growth was weighted to have a maximum of 20 points. Due to the variability of the average densities and growth rates, these categories were further broken down to allow trees with higher densities and faster growth rates to be given more value (shown in Figures 4a and 4b). Alternative uses of fuelwood were simply awarded the maximum number of points if the species was identified to have that property. For example, the species in the nitrogen subcategory added five points to the land improvement category. Timber was given the lowest priority because of the time required to maintain the trees until they can be harvested. Note that spiritual value was not included in the FMVI. The tree species used in spiritual and ritual values differ between local communities, and therefore are hard to prioritize (FAO 2010).

An important aspect of the FMVI is its ability to be modified according to the user. The scale shown in fig. 6 can easily be changed to match the needs of the local community. For instance, if Man'gula B decided that timber was more valuable than medicine, then the weight could quickly shift to reflect the decision.

Fig 3. The Weighted Scale Used for the Fuelwood Multipurpose Value Index

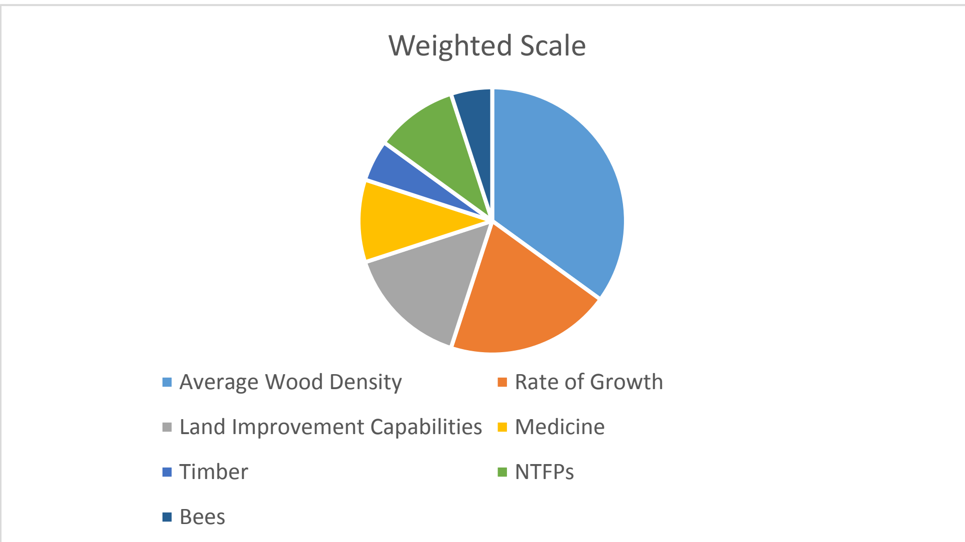


Table 4a. FMVI Point Calculation for Average Wood Density in g/cm^3

Average Wood Density (g/cm^3)	
Density Range	Score
0.4-0.6	15
0.7-0.9	25
1.0 and up	35

Table 4b. FMVI Points Calculation for Rate of Growth

Rate of Growth	
Rate	Score
Slow	5
Moderate	10
Fairly fast	15
Fast and Very fast	20

Table 5. Fuelwood Multipurpose Value Index with Average Density as the Most Valuable Property

Species	Avg Wood Density	Rate of Growth	Land Improvement	Medicine	Timber	NTFPs	Bees	Total FMVI Score
Dalbergia sissoo	25	20	15	10	5	10	5	90
Dichrostachys cinerea	25	10	15	10	5	10	5	80
Albizia gummifera	15	20	15	10	5	10	5	80
Parinari curatellifolia	25	20	0	10	5	10	5	75
Terminalia sericea	25	20	0	10	5	10	5	75
Burkea africana	25	15	0	10	5	10	5	70
Syzygium guineense	25	15	0	10	5	10	5	70
Sorindeia madagascariensis	35	20	0	0	0	10	0	65
Lonchocarpus capassa	25	20	0	0	5	10	5	65
Acacia tortilis	25	5	15	0	5	10	5	65
Albizia saman	15	20	15	0	5	10	0	65
Grilicidia sepium	15	20	15	0	0	10	5	65
Trema orientalis	15	20	15	0	0	10	5	65
Ziziphus mauritiana	15	20	10	0	5	10	5	65
Acacia albidia (F. albidia)	15	5	15	10	5	10	5	65
Brachystegia spiciformis	25	5	0	10	5	10	5	60
Olea europaea	25	5	0	10	5	10	5	60
Acacia lahai	35	5	0	0	5	10	0	55
Combretum adenogonium	25	15	0	10	0	0	5	55
Leucaena leucocephala	15	20	15	0	5	0	0	55
Mangifera indica	15	15	10	0	0	10	5	55
Vitex doniana	15	10	0	10	5	10	5	55
Acacia mangium	15	20	0	0	5	10	0	50
Khaya anthotheca	15	20	0	10	5	0	0	50
Albizia versicolor	15	15	0	10	5	0	5	50
Prunus africana	15	5	0	10	5	10	5	50
Grewia bicolor	15	5	0	10	5	10	0	45
Afzelia quanzensis	25	10	0	0	5	0	0	40
Tectona grandis	15	20	0	0	5	0	0	40
Olea capensis	25	5	0	0	5	0	0	35

Scenarios

httpwww.ngkenya.comfloraacacia_lahai.html

The FMVI index served as an indicator of the most valuable tree species prioritized by density and rate of growth. Upon analysis of the indexed trees, a trend in important characteristics became apparent: species that scored higher in the density category were correlated with a slower rate of growth (and vice versa). As a result of this indication, three scenarios were developed to explore the possibilities of the high-scoring species that could be selected for woodlots, forest reserves, or nurseries.

Scenario 1: Higher density species with slower growth

Acacia lahai (Red thorn)

Red thorn earned the maximum number of 35 points for average wood density, making it an efficient firewood. However, it only earned the lowest score of 5 points for a slow rate of growth. It was determined that slow-growing species were not optimal for rural communities in high immediate for fuelwood. In addition, it had no other reported uses other than fuel and timber, which is why the FMVI total score was only 55 points.

Scenario 2: Fast growing species with low densities

Albizia gummifera (Peacock flower)

httpwww.mozambiqueflora.comspeciesdataimage-display.phpspecies_id=125660&image_id=2

If the priority is to plant trees that will grow quickly, density is often sacrificed. For example, all of the species in the UMNP table were rated as fast growing or fairly fast growing, but none of those species were in the Top 5 category for firewood or charcoal. Peacock flower is a species with relatively low density, which makes it less effective as a fuelwood. However, the quick rate of growth and multitude of alternative uses such as land improvement and medicinal value gives the species 80 points in the FMVI. In comparison to Scenario 1, a fast growing species with a lower density is seen as more efficient due to its variety of purposes in addition to fuelwood.

Scenario 3: Fast growing species with medium density

Dalbergia Sissoo (Sissoo)

The last and most efficient scenario is to focus on a fast growing tree species with medium density. The Sisoo trees is an exotic species from India that was ranked first by the FMVI. It scored 25 points in the average wood density category as well as a 20 points for rate of growth. In addition, its alternative uses like Land Improvement, Medicine, Timber NTFPs, and Bees bought the total score to a 90 on the FMVI.

httpsen.wikipedia.orgwikiDalbergia_sissoo

Local Example: SULEDO

SULEDO stands for the nine villages in the Kiteto District that manage a 167,000 ha Village Land Forest Reserve (Arc Journal 2007). A pilot study was conducted in Sunya Village to access the harvesting processes of the village's 10,000 ha of natural forest. Given the rotational period of the forest at 60 years, it was calculated that 167 ha of land could be harvested sustainably per year. Challenges of the project included insuring that the income generated was enough to economically viable. In addition, it was hard for villagers to commit to such a long management plan.

Taking the challenges into consideration, the FMVI was applied to explore similar calculations. The Sissoo tree from Scenario 3 was chosen due to its position as the highest scoring species in the index. Given a hypothetical scenario of 1 ha of land and a 30 rotational period due to the fast rate of growth, it was calculated that 3, 086 could be grown with a spacing of 1.8m x 1.8m (Orwa 2009). The calculations shown in Fig 4 detail conversions from ha to m^2 and the division of the total area by the area required for one Sissoo Tree. According to the calculations, 102 trees could be potentially harvested each year. If the amount of land dedicated to a forest reserve were to increase in this hypothetical example, then amount of trees available for harvest would also increase.

Fig 4. Number of Sissoo Trees that could be grown on 1 ha of Land

Calculations
1 ha = 10,000 m^2
1.8m x 1.8m = 3.24 m^2/ tree
10,000m^2 / 3.24m^2=3,086 trees

Discussion and Implications

As seen in this study, fuelwood efficiency can be a trade-off between rate of growth and the quality of the firewood and charcoal. However, exploring medium density trees with faster rates of growth could improve the productivity of the energy that so many people depend on. There is a need for further research into the implications of the developed index, the characteristics of the species, and more comparison between indigenous and exotic trees. More quantitative analysis needs to be done to determine the caloric value of the species described and rate of growth in units of length measurement. The ultimate goal of further development of multipurpose, fuelwood efficient trees is to sustainably increase the community's resources and independence. Currently, many forest management plans were implemented by funding from the government or private institutions. The local example used for scenario calculations, SULEDO, was implemented and funded by a Danish company called SIDA (Blomley et al., 2008). To be successful, forest reserves need to be able to continue operating if the funding was suddenly cut from the program.

Furthermore, existing reserve programs will have to manage several challenges before becoming more economically viable. First, increased forest cover will bring increased wildlife closer in proximity to the village (Arc Journal 2007). The organization in control of the forest may need to become both a reserve and a Wildlife Management Area (WMA) to successfully control and benefit from the wildlife in the environment. In addition, planting and maintaining trees has to be economically viable for communities to see the benefits. To further understand the benefits, community members should be involved in the process of collecting data in the form of participatory forest resource assessments. If people can understand the process, then they can question their leaders when necessary to avoid issues like elite capture (Topp-Jorgenson 2005). If these issues can continue to be improved, developing better fuelwood would only help the local community move towards a more economically viable and environmentally friendly future.

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