Ethnobotanical Study on Some Tree Species Used as Bioenergy in South Darfur State, Sudan

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Abstract – This study provides ethnobotanical information on preferred local energy tree species based on biomass characteristics. The survey used a stratified sampling technique. The questionnaire covered different issues related to the consumers and biomass characteristics for energy utilization. The study computed use value, fidelity level, and factor informant consensus for the most frequently used energy tree species. According to the highest use values, respondents in the study area identified *Acacia mellifera* and *Capparis decidua* as the most vital energy tree species. Sustained combustion is the most desired property for brickmaking, while bakeries and homes prefer haste ignition. Further research and laboratory testing of tree characteristics of selected species in energy plantations and agroforestry programmes in Sudan could help confirm the study results.

ethnobotany / biomass / energy utilization / sustained combustion

Kivonat – Etnobotanikai tanulmány néhány bioenergiaként használt fafajról Dél-Darfúr államban, Szudánban. Jelen tanulmány célja az volt, hogy a biomassza jellemzői alapján jelentős etnobotanikai információkat nyújtson az energetikai célokra preferált helyi fafajokról. A felmérés rétegzett mintavételi technikával készült. A kérdőív a fogyasztókkal és a biomassza energiahasznosítási jellemzőivel kapcsolatos különböző kérdésekre terjedt ki. A leggyakrabban használt fafajoknál az energia, használati érték, hűségszint és faktorinformátor konszenzust számoltuk. A legmagasabb használati értékek szerint a válaszadók megemlítették, hogy a vizsgált területen az *Acacia mellifera* és a *Capparis decidua* a legfontosabb energiafafaj. A tartós égés a legkívánatosabb tulajdonság a téglagyártásnál, míg a pékségekben és a háztartásban a gyorsgyújtást részesítik előnyben. Ezért a vizsgálat eredményeit a kiválasztott fajok jellemzőinek további kutatásával és laboratóriumi ellenőrzésével kell megerősíteni. Annak érdekében, hogy beépítsék őket az energiaültetvényekbe és az agroerdészeti programokba, mint jövőbeli energiafajokat Szudánban.

etnobotanikai / biomassza / energiahasznosítás / fenntartó égés

1 INTRODUCTION

Biomass can help solve global energy problems because it is renewable and environmentally sound (Solarin et al. 2018). Many countries, including those in Africa, are increasing their biomass production for energy use. About 87 % of primary energy consumption in Sudan originates from biomass (Galal 1997). Biomass is the chief energy source in rural areas and

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towns, particularly those with less *LPG* (liquefied petroleum gas) distribution in Sudan. Biomass energy serves numerous domestic purposes, including cooking, heating, bakeries, and brick production. Increasing energy needs in Sudan due to the growing population and IDPs (internally displaced people) has caused significant overexploitation and depletion of forest resources and has affected the species used for energy, as stated by United Nations Environmental Program (UNEP 2008). The change from conventional species with traditionally favourable energy properties to new species with low energy quality may put the new species under pressure and deplete species with desirable energy properties. Thus, rehabilitating the degraded species is required shortly after; however, it is particularly crucial before selecting species selection as a biomass feedstock source because of the effect on the different fuel properties (Neves et al. 2011, Jacob-lopes et al. 2019). Assessing biomass quality is vital to its utilization feasibility because combustion is a dominant feature of converting biomass fuel to energy in Sudan. Some significant biomass combustion properties deserve attention, including biomass moisture content, density, and ash content. When high moisture content affects transport, storage and energy content, the proper moisture content ratio for combustion must be less than 20%. Concerning biomass density, it has a positive relationship with heating value. For this reason, experts state it should be as high as possible (Meincken et al. 2014), while ash content should be as low as possible due to its negative heat value correlation (Ahmed 2021).

Along with state plans for energy plantations, appropriate species with ideal efficient energy and sustainable biomass supply properties must be selected. Alternative sustainable approaches are needed to keep pace with the growing demand for biomass feedstock. This study pursued ethnobotany methods to gain knowledge from local people concerning the desired properties of local energy production species and document this scientifically. Consequently, the study bases its findings and suggestions on consumer preferences, which may be valuable for decision-makers in predicting suitable and preferable species.

2 MATERIALS AND METHODS

2.1 Study area

The study area was selected based on UNEP (2008) reports which revealed information on biomass fuel consumption in Sudan. We selected South Darfur State (*Figure 1*), which is reported by UNEP (2008) as having the highest wood fuel consumption and population in Sudan. The study area extends between latitudes 8°30′ to 13°′N and longitudes 23°15′to 28°E (Abaker et al. 2017) in open thorn savannas with sparse arboreal cover. Acacia species is the dominant plants formations in the study area. The selected area lies in a subtropical steppe climate where the average temperature during the hottest month of April is 41 °C (105 °F), while the average low temperature during the coldest month of January is 15 °C (59 °F). The region receives low rainfall amounts, with most precipitation falling from July to September. The annual average precipitation is approximately 311 mm (12 inches) and falls in erratic and unpredictable patterns. Dust storms occur during the dry season, especially in March and April (Morton 2005).

Figure 1. Study area location in Sudan

2.2. Data collection

Primary and secondary data were gathered using combined qualitative and quantitative data collection methods. Field survey was conducted in September 2021 to collect primary data from Kalma IDP Camp, Nyala District, South Darfur State, Sudan. Key informants, including experts from the Forest National Corporation (FNC) and individuals who have first-hand information, such as firewood dealers, were interviewed to collect information about the appropriate bioenergy species. A stratified random sampling technique was employed to collect information from three respondent strata; households, brick kiln owners and bakers with sample ratios of 3:1:1, respectively. The questionnaires were designed to cover different issues related to major energy species, preferences energy characteristics and consumption categories. Ninety-two respondents of different ages and sex (males and females) were interviewed. Furthermore, group discussions were held with the local leaders to complement and verify the data collected through the consumer survey.

2.3. Data analysis

The questionnaire data were transformed into codes. Statistical Package for Social Sciences (version 26) software was used in the analysis. Frequency distribution and percentage were calculated as an analysis tool for interpreting the qualitative information collected from the respondents. The use value was calculated to discover the proportional importance of energy tree species to each consumer category in the study area. It was calculated by the following equation 1:

$$\mathrm{UV} = \frac{\sum \mathrm{Ui}}{\mathrm{n}} \quad (1)$$

Where *UV* stands for the total use value of the energy trees species, while *U* refers to the number of use reports cited by each respondent for a given species, and n stands for the total number of respondents interviewed for a given species Fidelity level (*FL*) was also computed to determine the *FL* values of the most frequently used tree species for energy. Formula 2 was employed in the calculation:

$$FL = \frac{\mathrm{NP}}{\mathrm{n}} \quad (2)$$

Where *NP* stands for the number of use reports cited for a given species for a particular use, and N refers to the total number of use reports cited for any given energy species. Factor informant consensus (*FIC*) was also calculated to identify the tree species widely used for energy. The FIC can be calculated using equation 3:

$$FIC = \frac{\text{nur}-\text{nt}}{\text{nur}-1} \quad (3)$$

Where *FIC* = informants consensus factor, nur = number of use citations in each category, and *nt* = number of species used (Khan et al. 2014).

3 RESULTS AND DISCUSSION

This study documented 18 indigenous tree species in 14 genera and 11 families used for energy purposes (*Table 1*). The plant family Mimosoideae contributed the highest number of energy tree species (6), followed by Combretaceae (3) and Fabaceae (2) (*Table 1*). Among the total documented energy tree species, respondents stated that *Acacia seyal* (60%) is the most preferred species for domestic use, followed by *Calotropis procera* 22 % (*Figure 2*). *Calotropis procera* is of lower quality than other species such as *Acacia seyal*, *Acacia mellifera* and *Acacia nilotica*; however, they are utilized because the degeneration of desirable species forces households to use lower-quality wood. This result agrees with the UNEP report (2008), which noted the overexploitation of local tree species due to energy needs, causing significant depletion in forest resources and changes concerning the species typically used for energy. Results showed that bakeries prefer *Acacia mellifera* 72%, *Acacia nilotica* 16% and *Albizia amara* 12 % (*Figure 2*), whereas brickmakers preferred *Acacia nilotica* by a 70% ratio, followed by *Acacia mellifera* 17 % and *Vachellia tortilis*13 % (*Figure 2*). Brickmaking and baking require a particular biomass property; for example, about 56% of respondents named sustainable combustion the most desired brickmaking property (*Figure 3*). Sustainable combustion is the time between flame extinction and residence time. Prior et al. (2018) state that brickmakers prefer long fuel combustion residence time. USAID (2008) reported that brickmakers prefer slow-burning fuel because bricks take much longer to bake than bread. Brickmakers will occasionally also use green wood instead of dead wood for this purpose. Bakeries preferred haste ignition and low smoke, 52% and 27%, respectively (*Figure 3*). Individual interview statements cite ignitability as a vital property for bakeries because baking bread does not take long. However, bakeries consider high smoke levels from pollutant emissions such as NO_2 and SO_2 undesirable because they pose potential health risks to bakery workers (Ahmed 2021). People in the study area assign priority to some traditional energy tree species, including *Acacia mellifera*, *Acacia nilotica*, *Acacia seyal*, *Vachellia tortilis*, *Albizia amara*, *Calotropis procera*, *Balanites aegyptiaca*, *Hayphaene thebaica* and *Dalbergia melanoxylon* (*Table 1*). The use values (*UV*) results revealed that *Acacia mellifera* 0.51 and *Acacia nilotica* 0.42 are the most important energy tree species compared to other local tree species (*Table 2*).

Table 1. The common energy trees species in the study area

No	Family	Species	Local name
1	Arecaceae	*Hyphaene thebaica*	Dom
2	Asclepiadaceae	*Calotropis procera*	Oshar
3	Capparaceae	*Capparis decidua*	Tundob
4	Combretaceae	*Anogeissus leiocarpa*	Sahab
5	Combretaceae	*Combretum ghasalense*	Habil
6	Combretaceae	*Guiera senegalensis*	Khebash

No	Family	Species	Local name
7	Fabaceae	*Acacia mellifera*	Kiter
8	Fabaceae	*Acacia nilotica*	Sonut
9	Fabaceae	*Acacia senegal*	Hashab
10	Fabaceae	*Acacia seyal*	Talah
11	Fabaceae	*Albizia amara*	Arad
12	Fabaceae	*Faidherbia albida*	Haraz
13	Fabacea	*Dalbergia melanoxylon*	Abanus
14	Fabaceae	*Prosopis chilensis*	Miskeet
15	Fabaceae	*Vachellia tortilis*	Seyal
16	Rhaminaceae	*Ziziphus muritania*	Sider
17	Salvadoraceae	*Salvadora persica*	Arak
18	Zygophylaceae	*Balanites aegyptiaca*	Higlig

(Table continued from pevious page)

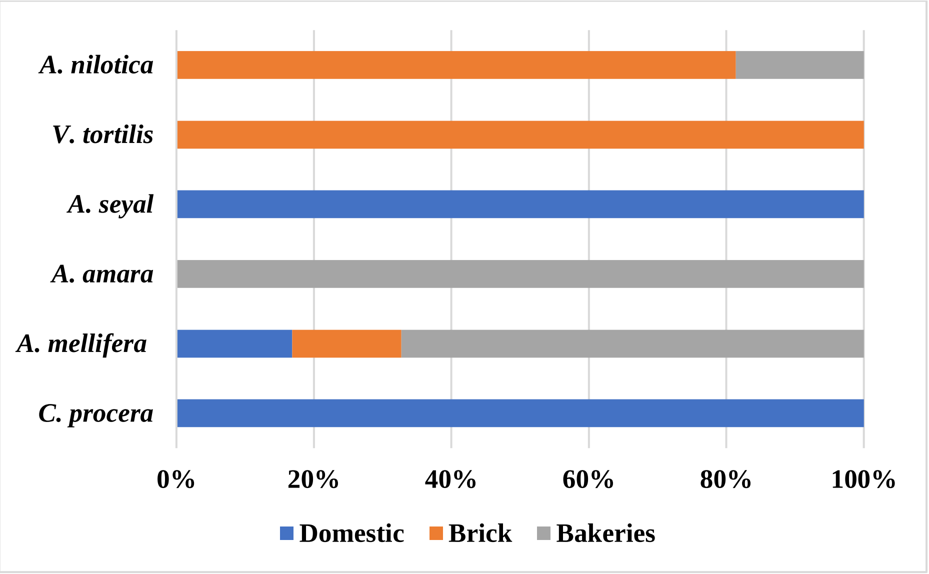

Figure 2. Preferred energy tree species according to utilization categories

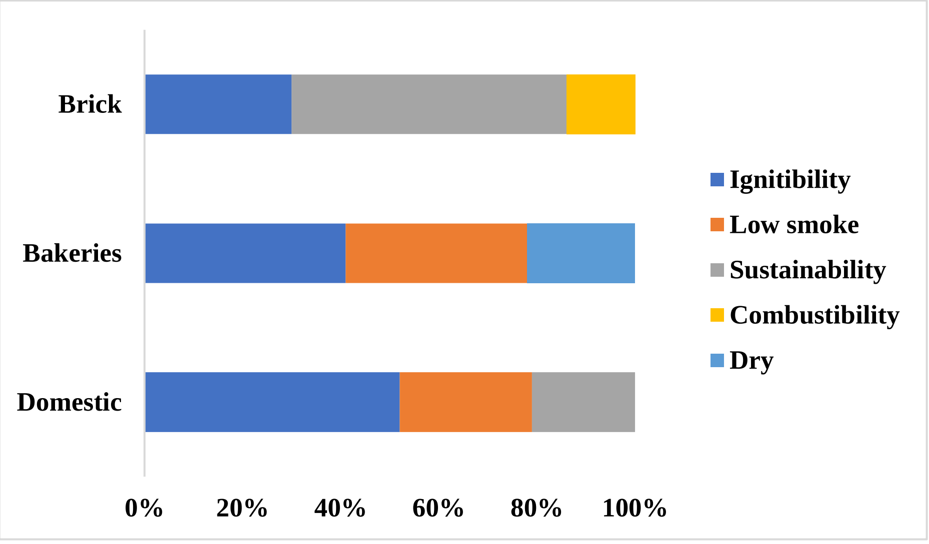

Figure3. Preferred energy characteristics by utilization categories

Table 2. The use values (UV) of local energy tree species

No	Species name	Number of use reports $\sum$ Ui	Use value UV
1	*Calotropis procera*	27	0.29
2	*Acacia mellifera*	47	0.51
3	*Albizia amara*	23	0.25
4	*Acacia seyal*	1	0.01
5	*Dalbergia melanoxylon*	37	0.40
6	*Vachellia tortilis*	7	0.07
7	*Acacia nilotica*	30	0.33
8	*Capparis decidua*	39	0.42
9	*Anogeissus leiocarpus*	2	0.02
10	*Balanites aegyptiaca*	2	0.02
11	*Ziziphus muritania*	12	0.13
12	*Guiera senegalensis*	3	0.03
13	*Faidherbia albida*	1	0.01
14	*Acacia senegal*	6	0.07
15	*Salvadora persica*	1	0.01
16	*Hayphaene thebaica*	5	0.05
17	*Prosopis chilensis*	1	0.01

Informant consensus factor (*FIC*) results show that sustainability scored as the highest *FIC* value (0.89), followed by combustibility (0.88) and ignitibility (0.85), which were also the top recorded biomass properties preferred by informants (*Table 3*). A high *FIC* value indicates that these properties are more prevalent in the study area.

Table 3. FIC values of traditional energy trees species properties in the study area

Properties categories	Number of species (*Nt*)	Number of properties report (*Nur*)	Consensus factor
Sustainability	11	90	0.89
Combustibility	11	84	0.88
Ignitibility	9	54	0.85
Dry	3	9	0.75
Low smoke	5	12	0.64

Energy species local people widely use have higher FL values than those of less popular species. FL values in this study varied from 34% to 83%. *Acacia seyal* has a high value of 83 %, characterized by high combustibility, followed by *Acacia nilotica* at 69 % and *Albizia amara* at 34 %, characterized by sustainable combustion. *Vachellia tortilis*, 56 %, and *Acacia mellifera*, 36 %, are characterized by haste ignitability (*Table 4*). Physicochemical biomass properties varied. The variation relates to biomass quantity, quality, moisture content and aeration, which influence flammability. For instance, biomass quantity increases combustion but likely enhances sustainability as larger fuel quantities take longer to burn. Moisture content is the main influencer on ignitability, and species with higher moisture contents took longer to ignite and burn slower (Simpson et al. 2016).

Table 4. Fidelity level value and properties of commonly reported energy tree species

Species name	Properties category	Citation for properties	Fidelity level (%)
Acacia seyal	Combustibility	31	83%
Acacia nilotica	Sustainability	27	69%
Vachellia tortilis	Ignitibility	17	56%
Acacia mellifera	Ignitibility	17	36%
Albizia amara	Sustainability	8	34%

4 CONCLUSIONS

The study results prove that local people exploit their traditional knowledge to select energy species based on their properties. Among the most important local species used for energy production were *Acacia mellifera*, characterized by ignitibility, and *Acacia nilotica*, characterized by sustainable combustion. Based on their properties, these species are considered favourable for all biomass energy consumers in the study area, including domestic households, bakeries, and brick producers. Consequently, the interest in these species is enormous and may lead to degradation or extinction. Strengthening the results of this study with further research and laboratory verification of the characteristics of the selected species is required. Rehabilitating degraded species in energy plantation and agroforestry programs should be a priority.

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