DOCTORAL (PhD) DISSERTATION

University of Sopron

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Ethnobotanical Study on Some Tree Species Used as Bioenergy, Sudan

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1 Introduction

The sustainable and environmentally friendly nature of biomass makes it a viable answer to global energy problems in the face of environmental challenges, increasing energy demand and decreasing availability of other energy sources (Solarin et al., 2018). Several countries, especially in Africa, are increasing their biomass production for energy generation. About 87% of primary energy consumption in Sudan comes from biomass as reported by (Galal, 1997). Biomass serves as the predominant source of energy in rural and urban parts of Sudan that have limited access to LPG. It is used for a range of household purposes including cooking, heating, bakeries, and brick making. The United Nations Environment Program (UNEP, 2008) has emphasized that the increasing demand for energy in Sudan, caused by population growth and internally displaced people, has led to overexploitation of forest resources and a decline in species used for energy purposes.

The transition from conventional species with favourable energy properties to novel species with poorer energy quality poses a risk to the latter and therefore requires the restoration of degraded species. Before selecting species as a biomass feedstock source, it is important to prioritize restoration as it has a significant impact on the different fuel qualities (Neves et al., 2011; Jacob-lopes et al., 2019). Assessing the quality of biomass is crucial for its practical use, as combustion is the most important process for converting biomass fuel into electricity in Sudan. It is important to focus on key characteristics such as moisture content, density, and ash content. It is important to keep the moisture content below 20% to minimize problems related to transportation, storage, and energy value. Experts (Meincken et al., 2014) recommend the high density of the

biomass as it is favourably linked to the calorific value. In addition, reducing the ash content is crucial as it has an unfavourable relationship with the calorific value (Ahmed, 2021).

Careful selection of species with efficient energy qualities and sustainable biomass supply is crucial, especially when considering government programs for energy plantations. To meet the increasing demand for biomass feedstock, it is imperative to use alternative sustainable methods. In this research, ethnobotanical techniques were used to collect information from local people about the desired characteristics of plants for local energy production and to systematically record these discoveries using scientific means. Therefore, the research uses these findings to make suggestions.

1.1 Research objectives

The objective of this research is to conduct an ethnobotanical study focusing on tree species used as bioenergy sources in Sudan. The study aims to explore and document the traditional knowledge and practices associated with the utilization of specific tree species for bioenergy purposes in the region. By achieving this objective, the research intends to contribute to the understanding of the sustainable use of bioenergy resources, while also promoting the conservation and management of tree species in Sudan. Specifically, the following sub-objectives will be pursued:

I. Provide ethnobotanical information on preferred local energy tree species based on biomass characteristics.
II. Identify and document the tree species commonly used for bioenergy purposes in the study area, considering their traditional and scientific names.

III. Investigate the ethnobotanical knowledge and practices related to the collection, and utilization of these tree species for bioenergy among local communities in the study area.

IV. Evaluate the sustainability of the current bioenergy practices and their potential implications for the long-term conservation of tree species and forest ecosystem in the study area.

V. Provide recommendations for the development of effective policies and conservation strategies that support the sustainable utilization of tree species for bioenergy in the study area, considering the perspectives and needs of local communities and the broader environmental context.

2 Literature

The literature review section of this research extensively explores the current knowledge and identifies gaps in research for the ethnobotanical study of tree species used for bioenergy purposes. It assists the researcher in determining the relevance of their topic, developing acceptable research goals, designing the research process, and contributing to the field's existing knowledge.

3 Research methodology

3.1 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).

3.2 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 of3:1:1, 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.

3.3 Data analysis

The questionnaire data has been transformed into codes. The Statistical Package for Social Sciences (version 26) and Excel Sheel software's were used in data analysis (Ahmed et al., 2023). The qualitative

information obtained from the respondents was analysed using frequency distribution and percentage as a tool for interpretation. The use value was computed to determine the tree species most often utilized for energy. It was calculated by the following equation 1:

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

Where UV is the aggregate value of energy trees species, U represents the number of usage reports mentioned by each respondent for a certain species, and n represents the total number of respondents surveyed for a particular species. The fidelity level (FL) was calculated to obtain the relative significance of energy tree species for each consumer group within the research region. Formula 2 was employed in the calculation:

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

Where NP represents the count of use reports cited for a certain species and usage, whereas N is the overall count of use reports referred for any energy species. The factor informant consensus (FIC) was also computed to determine the tree species that are often used for energy purposes. Equation 3 can be used to compute the FIC:

$$FIC = \frac{\mathrm{nur-nt}}{\mathrm{nur-1}} \qquad (3)$$

Where FIC represents the informant consensus factor, nur represents the number of usage citations in each category, and nt represents the number of species utilized (Khan et al., 2014).

Multiple linear regressions were used to assess the impact of the sociodemographic factors on the biomass fuel consumptions in the study area. The multiple regressions were mathematically expressed according to the following equation 4:

$$R_i = a_0 + a_1 A_i + a_2 C_i + a_3 E_i + a_4 F_i + \varepsilon_i \qquad (4)$$

Where R was the daily biomass fuel consumption during the survey period in 2021, i represented the dependent and independent variables. α1-4 represented the coefficient of the variables; α0 represented the intercept term, and ε was an error term. A, C, E and F represented age, gender, level of education and family size, of biomass fuel consumers, respectively (Ahmed et al., 2020).

4 My New Scientific Results

4.1 The common tree species utilized for energy purposes in the study area

Based on my research I found that 18 indigenous tree species from 14 genera and 11 families are used for energy in study area. The plant family Fabaceae contributed the highest number of energy tree species 9 followed by Combretaceae with 3 tree species. And the use values (UV) results showed that *Acacia mellifera* 0.51 followed by *Acacia nilotica* 0.42 are found to be the most important energy tree species than others local tree species.

4.2 The traditional knowledge and practices associated with the selection of tree species for bioenergy

I employed Factor Informant Consensus (FIC) and Fidelity Level (FL) to examine the traditional knowledge and practices associated with bioenergy use in the study area. The FIC results revealed that sustainable combustion scored the highest FIC value of 0.89, indicating that it is a highly prevalent and important property in the local context. Following closely behind sustainable combustion, combustibility obtained an FIC value of 0.88. Another notable property that received a high FIC value was ignitability, with a score of 0.85. The fact that sustainable combustion, combustibility, and ignitability were not only identified as the top recorded biomass properties preferred by informants but also obtained the highest

FIC values further emphasizes their significance in the study area. While FL results revealed that among the energy species that I examined, *Acacia seyal* exhibited the highest FL value of 83%. This species is characterized by high combustibility. *Acacia nilotica*, with an FL value of 69%, also showed a relatively high level of fidelity and combustibility. *Albizia amara*, on the other hand, had a lower FL value of 34% but was characterized by sustainable combustion. *Vachellia tortilis* had an FL value of 56%, indicating moderate popularity among local people. This species was found to possess characteristics of haste ignitability. *Acacia mellifera* had a relatively lower FL value of 36%.

4.3 The preferred tree species for different bioenergy applications among local communities

Among the total energy tree species that I documented, *Acacia seyal* is the most preferred species for domestic use, with 60% of the respondents stating their preference for this species. Among the bakeries surveyed, *Acacia mellifera* was the most preferred species, with 72% of the respondents indicating their preference for this species. In the case of brickmakers, *Acacia nilotica* was the most preferred species, with 70% of the respondents indicating their preference for this species.

4.4 The perception of local communities about biomass fuel consumption

Based on my research I found that there is a strong perception among respondents regarding the relationship between the increasing consumption of biomass fuel for energy purposes and the decline of forest area in the study area. Out of the total respondents surveyed, 90% acknowledged that the use of biomass fuel has led to a decline in forested areas, while only 10% of the respondents disagreed with this notion.

On the other hand, I conducted a multivariate regression analysis to examine the relationship between sociodemographic variables and

biomass fuel consumption. I found that the sociodemographic variable coefficients had the predicted indications, showing their effect on biomass fuel consumption. Among the four sociodemographic factors analysed, family size positively and statistically significantly ($p < 0.01$) effects on biomass fuel consumption. The positive correlation shows that biomass fuel consumption increases significantly with family size.

4.5 Novelty and Significance

My research contributes to the existing ethnobotanical literature, particularly in the context of bioenergy and Sudanese plant diversity. By documenting the traditional uses of tree species for bioenergy, my study adds valuable data to the scientific knowledge regarding ethnobotany, bioenergy systems, and the cultural significance of plants in the study area. And it also provides insights into the tree species with bioenergy potential, enabling the identification of suitable species for afforestation and reforestation programs. Such initiatives can contribute to carbon sequestration, ecosystem restoration, and climate change adaptation strategies at local and regional levels.

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