Ethnobotanical Assessment of Culturally Important Firewood Species Used for Cooking in Nyakelang Section of the Lemondokop Village, Limpopo Province, South Africa

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Research

Abstract

Background: Rural South Africa areas depend on forests for firewood, yet the systematic documentation of the most-used and culturally important species remains limited despite notable annual consumptions. This study addresses this gap by documenting culturally salient firewood species and their selection criteria among Nyakelang section households in Lemondokop Village, Limpopo Province, South Africa.

Materials and Methods: Using the free-listing method within the Cultural Domain Analysis framework, alongside Smith's salience, Use Consensus (UC), and Informant Consensus Factor (ICF), the study examined how traditional ecological knowledge, and socio-economic factors shape firewood use.

Results and Discussion: Data were collected from 128 households. Participants were mostly females (73%), aged between 36-45 years (26%), with secondary education (54%), and unemployed (27%). Thirty-eight firewood species were mentioned, and piecewise linear regression identified a salience breakpoint at 2.25, distinguishing core species; *Dichrostachys cinerea* (L.) Wight & Arn., *Combretum zeyheri* Sond., and *Combretum apiculatum* (Hochst.) Engl. & Diels. The UC confirmed these species as broadly recognised, while the ICF revealed a strong agreement on selection criteria; "burns well" (ICF = 0.828), "availability" (ICF = 0.822), and "burns for a long time" (ICF = 0.738). Other criteria showed moderate-to-low consensus, indicating variations in knowledge or preference.

Conclusions: Species preference was primarily driven by availability and necessity rather than cultural significance, reflecting women's knowledge in salience rankings. Moreover, poverty and limited education undermined sustainable firewood use, while legal frameworks remain misaligned with community practices. Energy policies should therefore integrate indigenous knowledge, promote sustainable resource use, consider community realities, and reduce firewood dependence to mitigate health and environmental risks.

Keywords: Domestic energy, Criteria of selection, Use consensus, Informant Consensus Factor, Smith's salience index

Background

Plants and their derivatives have historically played significant and purposeful roles throughout human existence, influencing various aspects of livelihoods, particularly in rural areas of developing countries. One prominent example is their heavy dependence on firewood for domestic energy (Pearce & Pearce 2001, Watson *et al*. 2018, Motti *et al*. 2023). For many rural and indigenous communities, preferred firewood species not only serve as a primary source of energy, but also form the foundation for traditional knowledge, cultural identity, social practices, and spiritual values (Mokuku & Mokuku 2004, Jakes 2024). For example, in Argentina (Doumecq *et al*. 2023, Sackser *et al*. 2025) and Ghana (Naah 2020), firewood species are chosen for their intrinsic properties and are central to both the daily lives and cultural practices of households. In South Africa, about 32% of the population, mostly in rural households rely on firewood for cooking and heating (Shackleton *et al*. 2022). The use of firewood even in electrified households (Madubansi & Shackleton 2007, Masekela & Semenya 2021), reflects its enduring cultural resonance in South African households and other rural and indigenous communities globally (Trac 2011, Gupta & Pelli 2021).

The continued reliance on firewood for domestic energy is closely related to both the ecological conditions and the embedded cultural or traditional knowledge systems that guide the selection and use of certain species (Sinthumule 2023, Kumar *et al*. 2025). This knowledge is accumulated through generations of direct interaction with the environment and its resources (Kimmerer 2002, Sackser *et al*. 2024) and often pertains to the desirable intrinsic properties of the preferred firewood species (Jiménez-Escobar & Martínez 2019).

Moreover, the cultural importance of firewood goes beyond its usefulness as a source of energy; it encompasses symbolic, emotional, culinary, and economic aspects that contribute to household well-being (Démurger & Fournier 2011, Doumecq *et al*. 2023). Symbolically, certain species are preferred for sacred fires, rituals, ceremonies or social gatherings within indigenous communities (Sackser *et al*. 2024). Emotionally, firewood fosters a sense of home and family cohesion by evoking comfort and familiarity (Lopez 2015, Karlsson *et al*. 2020). Culinary preferences are influenced by the specific flavours certain firewood species impart on certain dishes (Piochi *et al*. 2024). Economically, firewood consumption is closely tied to household wealth, where poorer rural households rely more heavily on it for energy, while wealthier households reduce usage or switch to alternatives (Démurger & Fournier 2011). Collectively, the multifaceted roles demonstrate that firewood use reflects not only its desirable intrinsic properties but also the cultural, emotional, and economic well-being of rural households. This underscores that the extent to which a particular plant species is used depends on its perceived ethnobotanical value within a specific community (Mwambo & Chuba 2024). Therefore, understanding the cultural salience of firewood species within a community is fundamental to quantitative ethnobotanical research.

Despite this established backdrop, the systematic documentation of which firewood species are most important and the degree of shared knowledge within South African communities remains limited. This is notable, given that rural communities in South Africa consume on average 3.3 tonnes of firewood per household per year, even with widespread electrification (Shackleton *et al*. 2022). The geographical variation in plant species distribution, which affects the availability, selection, and use of firewood across different regions further complicates this knowledge gap. This study addresses these gaps by documenting and identifying the most culturally salient firewood species used for cooking and the quality criteria guiding their selection in Nyakelang section of the Lemondokop Village, Limpopo Province, to understand how traditional ecological knowledge and socio-economic factors shape firewood use. Such research can contribute to understanding the energy needs of rural households and thus provide evidence for designing culturally sensitive, sustainable energy strategies that improve livelihoods while conserving biodiversity in communities still reliant on traditional resource use.

Materials and Methods

Study area

The study was conducted in Nyakelang section of the Lemondokop Village located in northeastern South Africa at geographical coordinates -23.440813 S and 30.162331 E. The study area is located in the Greater Letaba Local Municipality, a Category B4 municipality within the Mopani District Municipality in Limpopo Province (Figure 1) (Greater Letaba Local Municipality 2024). Category B4 municipalities are predominantly rural, and dependent on natural resources (Department of national treasury 2011, Municipal demarcation board 2018). The Lemondokop Village is a farm that was proclaimed in 1984 with a land area of approximately 3.29 km². It falls within ward 14 of the Mamaila Kolobetona Tribal Authority (Miller 1968, Ramaboka 2014, Computeraid 2024, Greater Letaba Local Municipality 2024).

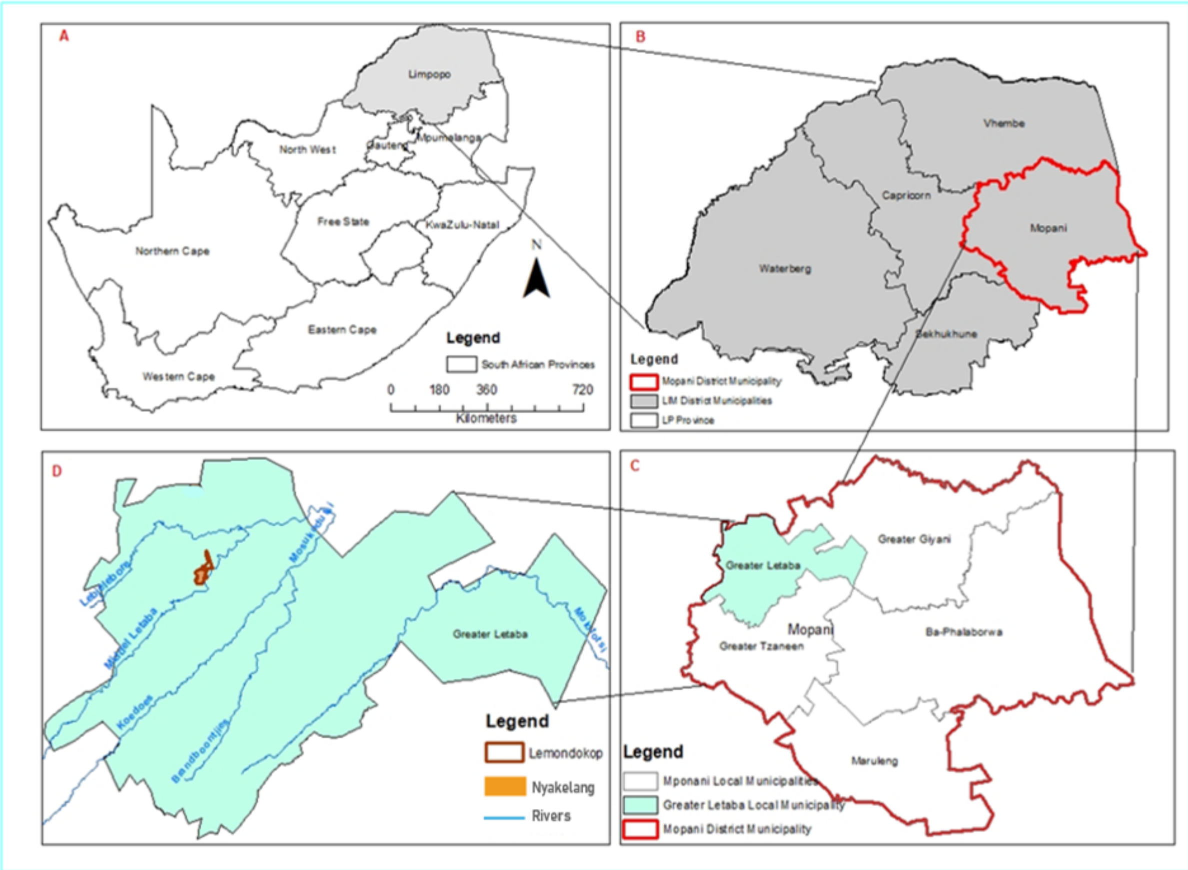

Figure 1. Locality map of Nyakelang section and its location in Lemondokop; the map of South Africa (A) shows the location of the Limpopo Province (B), where the Mopani District Municipality is located (C), and within that is the Greater Letaba Local Municipality (D) within which the study area is located

Cultural Diversity

According to Friman (2024), firewood practices are shaped by a combination of historical, institutional, cultural, and everyday norms, which together influence the practical implementation of forest governance. This framework is reflected in the Mamaila Kolobetona traditional community practices which is among the 829 recognised traditional communities in South Africa and operates under the current democratic governance structure. Historically the community fell under the jurisdiction of the former Lebowa Government, largely due to the widespread use of the Sepedi language. The Mamaila Kolobetona traditional community was part of the broader Balobedu ethnic group; however, they separated from the Balobedu ba Modjadji in the 1920's and formed their own independent tribe. The Lemondokop area is culturally diverse, with the Bapedi people being the main ethnic group. The dominant languages of this area are Sepedi and its dialects (Khelobedu, Sebirwa, and Setlokwa), Xitsonga, Afrikaans, and English (Ramaboka 2014). Collectively, these historical, cultural, and institutional factors shape firewood use in the context of local traditions and resource use.

Vegetation

The majority of the natural vegetation in the Greater Letaba Local Municipality is characterised by tall shrubland formations and is part of the Savanna Biome, specifically in the Granite Lowveld (Department of Water Affairs *et al*. 2001, Mucina & Rutherford 2006). According to Mucina and Rutherford (2006), some important taxa in the area include;

- Tall trees: *Senegalia nigrescens* (Oliv.) P.J.H. Hurter and *Sclerocarya birrea* (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro.
- Small trees: *Combretum apiculatum* (Hochst.) Engl. & Diels, *Combretum imberbe* Warwa, *Combretum zeyheri* Sond., *Peltophorum africanum* Sond., *Pterocarpus rotundifolius* (Sond.) Druce, *Terminalia sericea* Burch. ex DC., and *Combretum collinum* subsp. *Suluense* (Engl. & Diels) Okafor.
- Tall shrubs: *Combretum hereroense* Schinz, *Dichrostachys cinerea* (L.) Wight & Arn., *and Euclea divinorum* Hiern.

Climate

The Mopani District Municipality falls under the Cwa climate (humid subtropical climate with dry winters and hot, wet summers) according to the Köppen-Geiger climate classification system. The district's subtropical climatic conditions are influenced by both its topography and geographic location. Warm temperatures are experienced throughout the year, ranging between 20°C and 24°C, with higher averages in the eastern lowveld (Council for Scientific and Industrial Research, 2023). During summer, the maximum temperatures range from 28 - 38°C (mean ~30°C) and minimum from 16 - 22°C (mean ~19°C), while in winter, maximum temperatures range from 19 - 26°C (mean ~23°C) and minimum from 5 - 11°C (mean ~8°C). Rainfall patterns in the Mopani District vary significantly due to its complex topography. On average, the region receives 612 mm of rainfall annually, with the bulk (85%) falling during the austral summer, from October to March (Fitchett *et al*. 2016, Nembilwi *et al*. 2021). According to the Environomics Environmental Consultants (2009), the Cwa climate supports the ecological conditions required for granite lowvelds, where vegetation has adapted to the hot summers and dry winters. These climatic conditions directly shape species distribution and availability, influencing both ecological resilience and household firewood selection in this region.

Energy Sources

Energy sources in the Greater Letaba Local Municipality include electricity, solar energy, paraffin, wood, and liquified petroleum gas. The Electricity Supply Commission (Eskom) is the primary provider of electricity in the municipality (Greater Letaba Local Municipality 2024). According to the Greater Letaba Local Municipality (2025), 96.6% of households in Municipality had access to electricity. However, despite relatively high electrification in the Letaba Local Municipality, many of its rural communities continue to rely on alternative energy sources like wood, which is commonly used for cooking and heating. This is due to the high cost of electricity, prompting poor households to supplement their energy needs with wood (Greater Letaba Local Municipality 2024, Greater Letaba Local Municipality 2025). Additionally, the Greater Letaba Local Municipality implements a Free Basic Electricity (FBE) program, allocating qualifying households to consume up to 50 kilowatt-hour (kWh) per month, with 144 beneficiaries currently benefiting under the municipality's license (Greater Letaba Local Municipality 2025). In rural provinces such as Limpopo, 32.9% of households continue using wood and coal for cooking, indicating that these resources remain widely available and often more affordable than electricity (Statistics South Africa 2022). Moreover, the Mamaila Kolobetona Tribal Authority area is one of the areas affected by deforestation for fire purposes (Greater Letaba Local Municipality 2025), which explains the high firewood consumption rates in the municipal area.

Research design

The study used a cross-sectional ethnobotanical survey design to explore local knowledge, preferences, and selection criteria related to firewood species in the study area. Several ethnobotanical studies including, Ocampos (2022), Bamogo *et al*. (2023), Ndlovu *et al*. (2024), and Beressa *et al*. (2024) have successfully used cross-sectional ethnobotanical surveys to document plant use knowledge, making this design type appropriate for this study. Additionally, this design facilitates the identification, documentation, and analysis of culturally significant plant-use practices, thus providing a basis for generating hypotheses to be explored in future research (Simkus 2023).

Sampling and participants

This study employed purposive sampling to first identify households that use firewood for cooking. Random sampling among these households was then applied to reduce bias. This approach allowed for the intentional inclusion of households that have a high probability of yielding relevant data, which is common in ethnobotanical research (Kelly 2010, Tongco 2007). Therefore, random sampling was applied to improve representativeness by avoiding the dominance of a particular subgroup (Marshall 1996). Additionally, within each selected household, participants included adult members (>18 years) who actively engage in firewood collection, preparation, and use as well as household heads of all genders forming the sampling unit (Medeiros *et al.* 2014).

Sample size

The sample size was determined using Krejcie and Morgan (1970)'s standardised system for determining sample size. For a population size of 440 households in Nyakelang section (Frith 2011), the calculation yielded a sample size of 128 households. The statistical basis was complemented by achieving the full target of 128 households, randomly selected from the diverse population of Nyakelang thereby mitigating limitations of representativeness. The equation is as follows:

$$S = \frac{X^2 NP\,(1-P)}{d^2(N-1) + X^2 P\,(1-P)}$$

Where;
S = Required sample size
X^2 = 3,841
N = Population size
P = Population proportion (expressed as decimal) (assumed to be 0.5) (50%)
d = Degree of accuracy (5%), expressed as a proportion (0.05) is the margin of error

Ethnobotanical methodological frameworks such as the Cultural Domain Analysis (CDA) can be employed to systematically identify the culturally salient species within a shared domain. By analysing free-listing data, CDA reveals which species are most cognitively prominent, reflecting local priorities and perceptions (Cruz-Garcia 2014). Other indices that complement the CDA are the Use Consensus (UC) and the Informant Consensus Factor (ICF). The UC is an indirect measure of cultural importance and popularity of each species, by reflecting the proportion of respondents who mention a particular species, while the ICF assess the degree of agreement among respondents on species use (Moerman 2007, Musa *et al*. 2011, Morales *et al*. 2017, Trotter & Logan 2019). These quantitative indices help researchers understand and identify the strength of collective knowledge about culturally important species within a community (Arora & Lohar 2019). In the context of firewood selection and use, the UC and ICF reflect the collective accumulated knowledge embedded in local communities, who evaluate and use plant species not only based on availability but also on the physical and combustion properties of each species (San *et al*. 2012, Guta *et al*. 2024). This study therefore applied this integrated approach to highlight the importance of specific firewood species and to elucidate shared knowledge patterns and reasons behind species selection, considering both ecological realities and cultural values.

Data collection

Questionnaire survey

According to Gerique (2006), a highly structured questionnaire is an appropriate method to quantify ethnobotanical knowledge and assess the degree of consensus among participants' responses. In this study, a standardised questionnaire was administered to households' in Nyakelang, Lemondokop Village. Participants were asked to list all firewood species used for cooking in order of recall and the criteria used when selecting each species. Narrowing the domain in this way helps produce more complete free lists, as broader domains tend to yield incomplete and scattered responses (Quinlan 2017). Follow-up questions were asked to encourage elaboration and improve data validity (Jones 2008). This free-listing format as per Cruz-Garcia (2014), was applied within the CDA framework for subsequent calculation of the salience scores as well as UC and ICF, to evaluate both individual and collective knowledge patterns. The questionnaire also gathered demographic information of participants (each participant represented a household) including age, gender, household size, education level and employment status to contextualise patterns of species selection and knowledge variation. This was done to improve representativeness of local firewood knowledge and reduce selection bias. Since the Nyakelang community is multilingual, the questionnaire was translated into Sepedi, the researchers' native language, which is widely spoken in the study area. Alexiades (1996) notes that this is important because it shapes cultural understanding. Services of a local translator were employed where necessary to ensure clarity and cultural appropriateness.

Firewood species identification and classification

The reported firewood species were identified using local vernacular names in Sepedi, Xitsonga and Tshivenda. Species were then taxonomically verified using the South African National Biodiversity Institute (SANBI) PlantZAfrica info-base as well other published ethnobotanical studies of the Limpopo Province that used similar local names such as Liengme (1981), Mongalo and Makhafola (2018), Mogale *et al*. (2019), Semenya and Maroyi (2019) and a review by Chakale *et al*. (2024). Cross-validation was conducted through triangulation, which included a forest walk with the local firewood vendor at Modjajiskloof – Goudplaats (23, 52375°S and 30, 05412°E) where firewood is often harvested. During this walk, 68.4% of the 38 species reported by households were visually identified through direct observation of live or standing trees. This practical verification was to ensure accurate taxonomic classification and avoid misidentification. The remaining species were not encountered during the survey due to low local abundance and the need to travel further from the Modjajiskloof – Goudplaats forest, which was not feasible at the time of the survey due to safety reasons. The species were instead validated through triangulation with the literature and database sources indicated above. The combination of vernacular name usage in three languages, database references, and published literature minimised potential taxonomic errors despite the encountered fieldwork constraints.

Ethical Considerations

This study was ethically cleared by the University of South Africa – College of Agriculture and Environmental Science Health Research Ethics Committee with ethical clearance reference number 2025/CAES_HREC/6601. The study adhered to all guidelines in the clearance certificate. Permission to conduct the study was obtained from the Greater Letaba Municipality and the Mamaila Kolobetona Tribal Authority. Informed consent was then sought from all participating households in Nyakelang section. Before participation, the researcher explained the study objectives, procedures, and potential implications in clear and accessible terms to ensure that participants fully understood what the research entailed. Participation was entirely voluntary, without any form of pressure or coercion, and participants were reminded that they could withdraw from the study at any stage without providing a reason and without facing any negative consequences. To protect anonymity and confidentiality, personal identifiers such as names were not collected, and all responses were handled securely and reported only in aggregate form.

Data Analysis

Data was gathered, organised, and revised using Microsoft Excel. Descriptive statistics, including frequencies and percentages, were used to summarise demographic data and overall species use. To analyse the cultural importance of firewood species within the community, both cultural domain analysis and ethnobotanical consensus indices were applied as detailed below:

Smith's Salience Index

To determine the cultural significance of firewood species mentioned by the participants, Smith's salience (Smith's S) index was applied. This index measures species saliency by averaging the inverse rank of each species across the free-list data of the responses, weighting each list by its total number of items (Smith 1993, De Munck 2009). The equation is as follows:

$$S_i = \frac{\sum_{i=1}^{N} \frac{L_i + 1 - K_i}{L_i}}{N}$$

Where;

S_i is Smith's salience score for species *i*

L_i is the length of a participants' free list

K_i is the order in which a specific item was listed

N is the total number of participants

Smith's S values range from zero to one. Values closer to one indicate species that are frequently cited and tend to appear early in most lists, signifying high cultural importance. Earlier mentioned species by the participants reflects stronger cognitive prominence (Winkielman *et al.* 2005). To determine the most culturally important firewood species, a scree plot was constructed using Smith's S scores in descending order against their rank order as observed in Barg *et al*. (2009) and Fiks *et al*. (2011). This visual tool helps identify the breakpoint (elbow) in the distribution, which serves as an empirical threshold to distinguish highly salient species from those that are less culturally important (Borgatti & Halgin 2013). However, the visual identification of the breakpoint can be subjective (Chaves *et al*. 2019). To remedy this, a piecewise linear regression analysis of the scree plot was applied using the python library on Google colab notebook, as recommended for threshold detection in ecological studies (Shea & Vecchione 2002, Ficetola & Denoël 2009). This method fits two linear segments where the salience scores slope changes significantly (Ryan & Porth 2007). Species with salience scores above this break point were considered core firewood species with cultural importance.

Ethnobotanical use-consensus (UC) of the firewood species

The UC was calculated to determine the relative popularity or cultural importance of the species by the proportion of participants who cited it (Doumecq *et al*. 2023). It is calculated as:

$$UC = \left(\frac{n_i}{N}\right)$$

Where;

ni is the total number of participants who cited species i.

N is the total number of participants

Higher UC values indicate that there is a greater recognition of a species within the community.

The Informant consensus factor (ICF) based on criteria of selection

The ICF was used to assess the degree of agreement between participants regarding the selection criteria of the most salient species (Trotter & Logan 2019). It is calculated as follows:

$$ICF = \frac{n_{ur} - n_t}{n_{ur} - 1}$$

Where,

n_{ur} is the total number of citations under a specific criterion across all participants

n_t is the number of species cited for a distinct criterion.

The ICF values range from zero to one. Values approaching one indicate a strong consensus, meaning most participants use the same species for a given selection criterion, whereas values approaching zero indicate a weak consensus, indicating that the participants use many species for a specific criterion (Gazzaneo *et al*. 2005).

Results and Discussion

Participant demographics

Age distribution of participants

The age distribution in Table 1 reveals a broad representation of different generations with the majority group (26%) being middle-aged at 36 - 45 years old. Over 32% of the participants were older participants aged between 56 years to over 75 years old. A small proportion (4%) did not know their age; these, however, were older persons that indicated to have no prior education and were unable to read nor understand how to calculate age. The latter proportions represent groups that are traditional custodians of local ecological knowledge and experience embedded in cultural practices of firewood use (Singleton *et al*. 2023). Similar findings were observed in Hailemariam *et al*. (2021), where older participants were more informed about indigenous trees and were likely to retain more detailed traditional knowledge on firewood species. The younger generation (18 - 35 years) had a relatively low representation of 22%. This generational variability reflects ongoing cultural and environmental knowledge erosion and a potential gap in intergenerational transfer of knowledge due to lifestyle changes, urban migration, or reduced reliance on traditional firewood use in younger generations (Nepal 2021, Abdullah & Khan 2023). Consequently, much of the community's knowledge may be lost once the older generations pass, potentially undermining the continuity of firewood use. This suggests that the knowledge being documented reflects a vulnerable, non-stable cultural system and a practice in decline. Additionally, Machaba (2018), alluded that the use and adoption of traditionally important plant species is declining among younger generations due to their lack of interest in inheriting traditional knowledge and practices. Therefore, salience studies of plant species in rural energy contexts risk overemphasising tradition or culture when in actuality the observed patterns and practices reflect ecological, regional, and necessity-driven influences that are largely shaped by the memory of older generations rather than active intergenerational practices. It is, therefore, recommended that intergenerational learning initiatives on culturally important species be implemented through community social gatherings to preserve species-specific firewood knowledge. Additionally, indigenous knowledge preservation should be aligned with clean energy policies such as the Just Energy Transition to avoid cultural loss during energy transitions.

Gender distribution of participants

Rural-based females in Africa are known to have dominant roles in firewood collection and cooking (Lenfers *et al*. 2018, Njenga *et al*. 2021, Bapfakurera *et al*. 2024). In this study, high female participation (73%) (Table 1) reflects this dominant role, which is central to a woman's role in household energy management. These findings are consistent with historical studies such as Kainer and Duryea (1992), who reported that women participate in cultural practices and resource management, gaining extensive botanical knowledge and skills with plant management and use. Moreover, the daily domestic tasks managed by women such as open-fire cooking and food preparations, give them intimate knowledge of the species that are suitable for such activities. The relatively low male participation (27%) reflects a social reality in many rural communities, where men may be less involved in daily firewood activities (Semenya & Machete 2019). However, males tend to engage more in firewood collection when transport options such as a donkey cart are available, often motivated by income generation (Omari 2010, Ketlhoilwe & Kanene 2018), rather than household energy security. The gender-specific nature of species selection for cooking means that salience rankings predominantly capture a female perspective, potentially underrepresenting the male perspective or uses of firewood. This gendered distribution of knowledge suggests that analyses based solely on domestic use may reflect a partial or one-sided view of species importance. It may also underrepresent the ecological and commercial drivers behind species use, consequently misleading policy recommendations that are made solely on household-level use rather than the full socio-ecological use of firewood. Future research should adopt gender-inclusive sampling approaches to ensure that both male and female perspectives are equally represented, to avoid bias in species valuation and management outcomes.

Level of education distribution of participants

A large proportion of the participants (54%) attained secondary education, while a significant share (36%) had only primary or no formal schooling. A notably lower proportion (9%) attained tertiary education and 2% attained Adult Basic Education and Training (ABET) (Table 1) which is equivalent to grades 3 - 9 (Limpopo Department of Education n.d.). The introduction and implementation of formal education systems often unintentionally disrupt the transmission of traditional ecological knowledge by prioritising western scientific paradigms, thereby neglecting indigenous knowledge systems (Tang & Gavin 2016, Nepal 2021). This displacement can accelerate the erosion of culturally embedded knowledge on firewood species selection and management. For example, formal schooling limits the time the younger generations spend engaging in local ecological practices, reducing opportunities for experiential learning from elders. Kaddau *et al*. (2025) further illustrate this trend, reporting that reliance on firewood for cooking correlates with an 84% decrease in school attendance. The findings reveal a pattern or system that lacks in integrating traditional and scientific knowledge but rather replaces one with the other. This creates a void, where indigenous ecological knowledge is eroded and awareness of the health and ecological risks, which scientific education may provide remains absent. This dynamic is also reflected in the demographic distribution, where many older participants reported to having either little or no formal education. Consequently, households may continue unsafe firewood use practices without guidance from either traditional or modern scientific knowledge. Moreover, as noted by Kaddau *et al*. (2025), firewood dependence undermines education, while formal education simultaneously undermines the continuity of indigenous practices, thereby producing a structural contradiction that intensifies community vulnerability. Indigenous ecological knowledge should therefore be integrated into local school curricula, while community engagement projects from institutions of higher learning should incorporate vocational learning to strengthen the underexplored field. Such initiatives should promote co-learning between elders and educated youth to ensure that traditional and scientific perspectives mutually reinforce each other.

Employment status of participants

The employment status distribution of the participants in Table 1 reveals that 27% were unemployed, 24% were pensioners receiving old-age social grants and pensions, while 15% were dependent on social grants, mainly the child support grant. These economic constraints suggest that many households rely on freely available firewood rather than purchased fuel alternatives, as they do not have the luxury to purchase alternative fuel choices (Joos-Vandewalle *et al.* 2018). This pattern is common in rural communities facing economic hardships, where firewood use is influenced more by affordability and availability than choice (Ogidan 2014). This indicates that firewood use persists not because it is freely chosen, but because it is freely available, thus positioning cultural salience matrices more as a proxy for economic hardship rather than genuine preference or culture. Such dependence on cost-free locally accessible and available firewood species or trees can elevate the salience of readily available species, even when they are not preferred or have no cultural significance. This risks romanticising poverty and deprivation as cultural choice. Consequently, as observed earlier, the distinction of certain species in cultural salience matrices may reflect accessibility and necessity rather than actual preference or traditional value, emphasising the need to consider socio-economic contexts when interpreting the cultural significance of firewood. Moreover, if energy poverty is not addressed, households will continue to exploit protected species and deplete RED data listed “least concern” species, irrespective of legal restrictions, ecological sustainability, or health consequences. This study recommends that the FBE allocation be revised alongside the National Energy Regulator of South Africa (NERSA)-approved tariff increases to maintain its real value and effectiveness. While qualifying households still receive 50 kWh, rising tariffs increases the cost of additional electricity, reducing the proportion of their energy needs covered by the FBE. Without adjustment, qualifying households may be forced to use alternatives such as firewood, which undermines the social protection intended by the FBE policy. Therefore, aligning FBE with tariff changes would help ensure that the policy continues to provide meaningful relief, support equitable access to electricity, and reduce the health and environmental risks associated with firewood use.

Table 1. Frequency and percentage distribution of the household demographics in Nyakelang section

Demographic characteristics	Frequency (n)	Percentage (%)
Age		
18 - 25 years	12	9
26 - 35 years	17	13
36 - 45 years	33	26
46 - 55 years	21	16
56 - 65 years	19	15
66 - 75 years	17	13

75+ years	4	3
Does not know	5	4
Gender		
Male	34	27
Female	93	73
Prefers not to say	1	1
Level of education		
No formal education	31	24
Primary level	15	12
Secondary level	69	54
Tertiary level	11	9
ABET education	2	2
Employment status		
Employed	16	13
Unemployed	34	27
Self employed	18	14
Casual labourer	8	6
Social grant	19	15
Pension	31	24
Student	2	2

Priority firewood species within the Nyakelang community

The Nyakelang community relies on 38 firewood species across 14 botanical families (Table 2). The species distribution analysis across families indicates that the majority of firewood species belong to the Fabaceae (29%) followed by the Combretaceae (24%), and Anacardiaceae (8%). The dominance of firewood species from Fabaceae, Combretaceae, and lastly Anacardiaceae aligns with broader regional observations in the Limpopo Province, as reported in Rasethe *et al*. (2013) and partially in Makhado *et al*. (2009) and Mudau (2023), where Fabaceae and Combretaceae species were dominant firewood. The continued reliance on species from these families across the Limpopo Province reflects not only their ecological abundance but also their resilience to repeated harvesting pressure. However, this also exposes a hidden local ecological vulnerability, in which highly cited species despite being classified as "least concern" in conservation status may face risks of over-exploitation through constant use, which could create a cycle where availability today undermines sustainability tomorrow. The high citation frequency of the Fabaceae species, particularly *D. cinerea*. illustrates this phenomenon. The characteristics that make *D. cinerea* desirable ensure that it is subjected to chronic overuse. Similarly, the substantial representation of Combretaceae species such as *C. zeyheri, C. apiculatum,* and *T. sericea*, as well as *Diospyros mespiliformis* Hochst. ex A.DC. from Ebenaceae highlights their importance as key firewood resources. However, salience matrices risk equating deeply rooted cultural traditions with frequent use, while many choices are actually dictated by availability and household survival. This may lead to misleading conclusions about preference. Interpreting firewood preference data, thus requires careful consideration of socio-economic constraints alongside ecological and cultural factors.

From a conservation perspective, most species listed in Table 2 are classified as least concern (87%), while 13% have not been evaluated on the International Union for Conservation of Nature (IUCN) Red List of threatened species. This data deficiency could put species that are widely used at risk of unsustainable exploitation. Among the least concern species, 4.6% are protected under the South African National Forests Act, 1998 (Act 84 of 1998), which means such species may not be "cut, disturbed, damaged, or destroyed" (Department of Forestry, Fisheries and the Environment 2023). Two such species with high citations are *D. mespiliformis* and *S. birrea,* indicating that the law in practice, is not adhered to at household-level. However, Algotsson (2009) notes that the Act exempts local communities from using natural resources only if the purpose is entirely for domestic, cultural, health or spiritual purposes, "but the exemptions do not include the use of species that are listed as protected". This creates a difficult contradiction where households have access to such species, but the species are simultaneously illegal to exploit, which raises questions of what alternatives should households use. These findings also highlight a gap in the dissemination and communication of policies to the relevant local custodians. This situation emphasises that prominent species in cultural salience matrices often reflect accessibility and necessity rather than actual preference, traditional value and conservation status as noted by Freitas *et al*. (2020).

Table 2. Key firewood species used by the Nyakelang community, showing the botanical families, scientific names, vernacular names (in Sepedi, Tshivenda, and Xitsonga), and their South African conservation status with their Smith's salience index and use consensus values.

Botanical family	Scientific name	Vernacular name	Conservation status in South Africa	Number of citations	Smith's salience index	UC
Anacardiaceae	*Sclerocarya birrea* (A. Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro.	**Morula** (S)/ **Mufula** (TV)/ **Nkanyi** (XT)	Least Concern (Protected)	17	0,0431	0,13
Anacardiaceae	*Mangifera indica* L.	**MoMango** (S)/ **Munngo** (TV)/ **Mangwa** (XT)	Not Evaluated	3	0,0074	0,02
Anacardiaceae	*Ozoroa paniculosa* (Sond.) R.Fern. & A.Fern.	**Monoko** (S)/ **Mudumbula** (TV)	Least Concern	1	0,0006	0,01
Apiaceae	*Heteromorpha arborescens* (Spreng.) Cham. & Schltdl.	**Mothatha** (S)/ **Muthatha-vhanna** (TV)	Least Concern	4	0,0136	0,03
Chrysobalanaceae	*Parinari curatellifolia* Planch. ex Benth.	**Mmola** (S)/ **Muvhula** (TV)/ **Mbulwa** (XT)	Least Concern	1	0,0013	0,01
Combretaceae	*Combretum zeyheri* Sond.	**Moduba** (S)/ **Mufhatela** (TV)/ **Mafambaborile** (XT)	Least Concern	48	0,2463	0,38
Combretaceae	*Combretum apiculatum* (Hochst.) Engl. & Diels	**Mokhuditshwane** (S)/ **Mugarasaka**, **Xihlalavhana** (XT)	Least Concern	39	0,1551	0,30
Combretaceae	*Terminalia sericea* Burch. ex DC.	**Mogonono** (S)/ **Mosusu (TV)/ Nkonola** (XT)	Least Concern	28	0,1464	0,22
Combretaceae	*Combretum hereroense* Schinz	**Mokabe** (S)/ **Mugavhi** (TV)/ **Xikhavi** (XT)	Least Concern	12	0,0462	0,09
Combretaceae	*Combretum molle* R.Br. ex G.Don	**Mokgwethe** (S)/ **Mugwiti** (TV)/ **Xikukutsi** (XT)	Least Concern	5	0,0180	0,04
Combretaceae	*Combretum imberbe* Warwa	**Mohwelere-tšhipi** (S)/ **Mudzwiri** (TV)/ **Mondzo** (XT)	Least Concern (Protected)	4	0,0257	0,03
Combretaceae	*Combretum erythrophyllum* (Burch.) Sond.	**Moduba-noka** (S)/ **Muvuvhu** (TV)/ **Mbvuva** (XT)	Least Concern	2	0,0019	0.02
Combretaceae	*Combretum collinum* Fresen.	**Modubana** (S)/ **Muvuvha** (TV)/ **Ndzuva** (XT)	Least Concern	2	0,0048	0.02
Combretaceae	*Combretum kraussii* Hochst.	**Modubamadi** (S)/ **Muvuvhu-wannda** (TV)	Least Concern	1	0,0117	0.01
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A.DC.	**Motlouma** (S)/ **Musuma** (TV)/ **Ntoma** (XT)	Least Concern (Protected)	35	0,1427	0,27
Ebenaceae	*Euclea divinorum* Hiern	**Mohlakula** (S)/ **Mutangule** (TV)/ **Nhlangula** (XT)	Least Concern	9	0,0436	0.07
Fabaceae	*Dichrostachys cineria* (L.) Wight & Arn.	**Moretshe** (S)/ **Murenzhe** (TV)/ **Ndhenga** (XT)	Least Concern	124	0,8713	0,97
Fabaceae	*Peltophorum africanum* Sond.	**Mosehla** (S)/ **Musese** (TV)/ **Ndzhuva** (XT)	Least Concern	27	0,1097	0,21
Fabaceae	*Senegalia nigrescens* (Oliv.) P.J.H.Hurter	**Moritidi (**S)/ **Mudhaya** (TV)/ **Nkayi** (XT)	Least Concern	23	0,0788	0,18
Fabaceae	*Pterocarpus rotundifolius* (Sond.) Druce	**Mohwahlapa** (S)/ **Muathaha** (TV)/ **Miyataha** (XT)	Least Concern	11	0,0442	0,09

Fabaceae	*Vachellia karroo* (Hayne) Banfi & Gallaso	**Mooka** (S)/ **Muunga** (TV)/ **Munga** (XT)	Least Concern	7	0,0343	0,05
Fabaceae	*Philenoptera violacea* (Klotzsch) Schrire	**Mpatha** (S)/ **Mufhanda** (TV)/ **Mbhandzu** (XT)	Least Concern (Protected)	3	0,0076	0,02
Fabaceae	*Vachellia rehmanniana* (Schinz) Kyal. & Boatwr.	**Mosibihla** (S)/ **Musivhitha** (TV)/ **Musivithi** (XT)	Least Concern	3	0,0073	0,02
Fabaceae	*Mundulea sericea* (Willd.) A.Chev.	**Moloahlagantsha**, **Moholobisa**, **Mosita-tlou** (S)/ **Mukundandou** (TV)/ **Mbolovhisani** (XT)	Least Concern	2	0,0110	0,02
Fabaceae	*Piliostigma thonningii* (Schumach.) Milne-Redh.	**Mokgoropo** (S)/ **Mukolokote (TV)/ Nkokotso, Xidengana** (XT)	Not Evaluated	1	0.0054	0,01
Fabaceae	*Colophospermum mopane* (J.Kirk ex Benth.) J.Kirk	**Mohlanare** (S)/ **Mupani** (TV)/ **Nxanatsi** (XT)	Least Concern	1	0,0044	0.01
Fabaceae	*Vachellia sieberiana* (DC.) Kyal. & Boatwr.	**Mphoka** (S)/ **Musaunga** (TV)/ **Nkowankowa** (XT)	Least Concern	1	0,0011	0,01
Heteropyxidaceae	*Heteropyxis natalensis* Harv.	**Mmasepha** (S)/ **Mudedede** (TV)/ **Nthathasani** (XT)	Least Concern	3	0,0115	0,02
Kirkiaceae	*Kirkia wilmsii* Engl.	**Modumela** (S)/ **Mubvumela** (TV)/ **Mvumayila** (XT)	Not Evaluated	1	0,0039	0,01
Malvaceae	*Eucalyptus camaldulensis* Dehnh.	**Moplikomo** (S)	Not Evaluated	6	0,0260	0,05
Malvaceae	*Dombeya rotundifolia* (Hochst.) Planch.	**Mohokobu**, **Mokgokobu** (S)/ **Tshiluvhari** (TV)/ **Nsihaphukuma** (XT)	Least Concern	2	0.0032	0,02
Moraceae	*Ficus sycomorus* L.	**Mogoboya (S)/ Muhuyu** (TV)/ **Umkhiwubovana (XT)**	Least Concern	1	0,0039	0,01
Moraceae	*Ficus burkei* (Miq.) Miq.	**Moumo** (S)/ **Muumo** (TV)/ **Xirhomberhome** (XT)	Least Concern	1	0,0015	0,01
Myrtaceae	*Eucalyptus grandis* W.Hill ex Maiden	**Mubomo** (TV)	Not Evaluated	1	0,0019	0,01
Olacaceae	*Ximenia Caffra* Sond.	**Motshidi** (S)/ **Muthanzwa** (TV)/ **Ntsengele** (XT)	Least Concern	1	0,0036	0,01
Pinaceae	*Hyphaene coriacea* Gaertn.	**Mophaene** (S)/ **Mulala** (TV)/ **Nnala** (XT)	Least Concern	1	0,0039	0,01
Sapindaceae	*Pappea capensi* Eckl. & Zeyh.	**Morobaseepe**, **Morotolodi** (S)/ **Tshikavhavhe** (TV)/ **Xikwakwaxu** (XT)	Least Concern	5	0,0169	0,04
Sapindaceae	*Ziziphus mucronata* Willd.	**Mokgalô** (S)/ **Mutshetshete** (TV)/ **Mphasamhala** (XT)	Least Concern	5	0,0181	0,04

Legend: S=Sepedi, TV=Tshivenda, and XT=Xitsonga.

Smith's salience index and use consensus of firewood species

Analysis of the free-list data using Smith's S index and the UC in Table 2 further revealed a hierarchy of culturally important firewood species within the Nyakelang community. *D. cinerea* was the most salient species, with a notably high Smith's S of 0.8713 and a corresponding high UC of 0.97. This emphasises its role in daily household energy needs in Nyakelang. Several other species also demonstrated moderate levels of cultural prominence. These include *C. zeyheri* (Smith's S = 0.2463, UC = 0.38), *C. apiculatum* (0.1551, 0.30), *T. sericea* (0.1464, 0.22), *D. mespiliformis* (0.1427, 0.27), and *P. africanum* (0.1097, 0.21). These species represent key secondary firewood species that contribute substantially to the community's firewood resource base and provide substantial support to local energy needs.

The piecewise linear regression analysis applied on the ranked Smith's S scores demonstrated a strong fit to the data, with an R^2 value of approximately 0.9842; a steep negative slope of approximately -0.625, and a considerably less steep slope of approximately -0.0032 before and after the break point, respectively. This analysis identified a breakpoint of salience at approximately 2.25 (see Figure 2). For ease of interpretation, the breakpoint was rounded up to three. This breakpoint indicates a shift in the rate at which Smith's S decreases with increasing species rank. This breakpoint defines the core firewood species cluster, comprising of *D. cinerea*, *C. zeyheri*, and *C. apiculatum,* while many others are relatively peripheral. This pattern is consistent with general findings in ethnobotany that plants that are frequently cited most often have the highest salience ranking (Chaves *et al*. 2019, Zenderland *et al*. 2019).

Moreover, the strong alignment between high Smith's S and high UC justifies the benefit of combining frequency-based and consensus-based matrices. As noted by Zenderland *et al*. (2019), use-value like matrices such as the UC tend to highlight few prominent species with widespread agreement among informants. The three breakpoint-defined species, *D. cinerea*, *C. zeyheri*, and *C. apiculatum* also had the highest UC values, reflecting their practical importance and widespread cultural recognition. However, the reliance on certain core species concentrates extraction and/or harvest pressure on a few taxa, prompting the need to constantly evaluate the conservation status of such taxa at local levels.

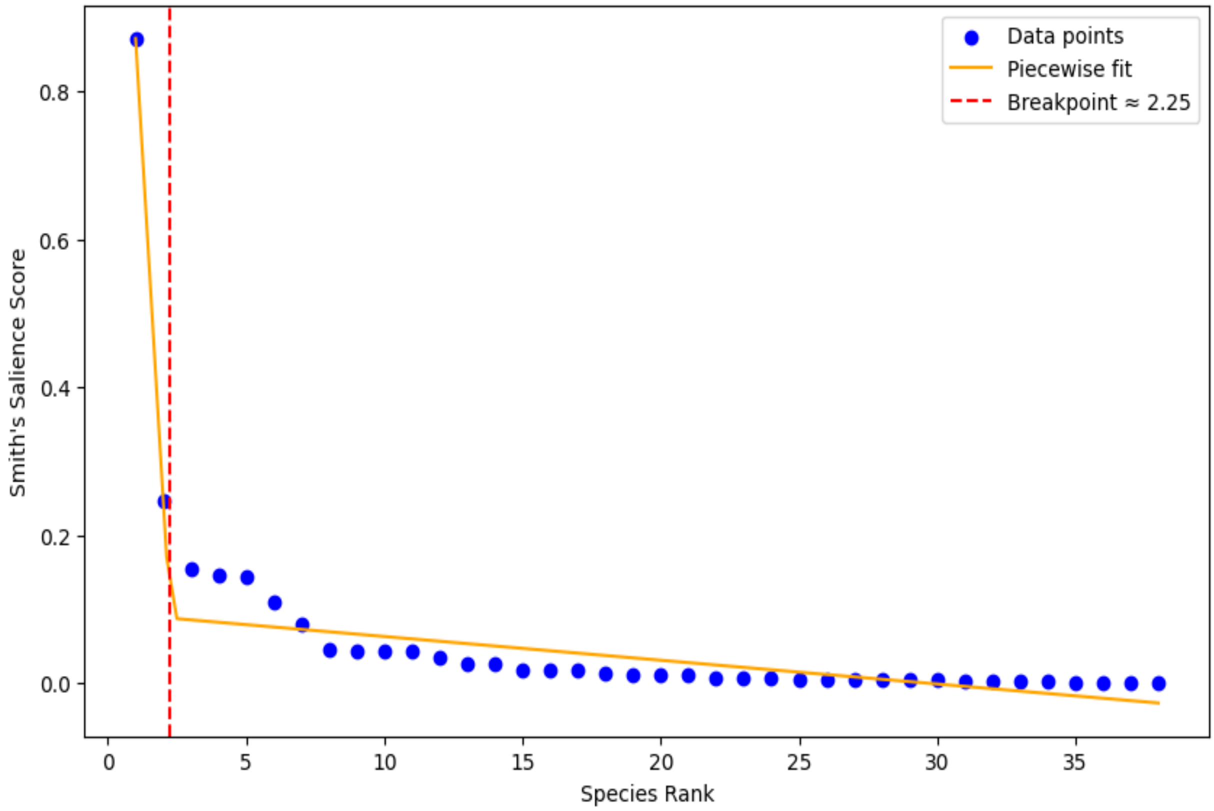

Figure 2. Piecewise linear regression of Smith's salience scores

The ICF of firewood species selection criteria

The firewood selection criteria reported in Nyakelang (Table 3) reflect a combination of combustion efficiency, practicability, health considerations, and socio-cultural significance. The most frequently prioritised attributes fall within the combustion efficiency category and show the strongest ICF agreement. These criteria include “burns well,” which denotes a strong, steady flame that cooks food evenly, and “burns for a long time,” reflecting prolonged combustion with minimal refuelling, with ICF values of 0.828 and 0.738, respectively. Other related criteria such as “forms good embers,” “cooks food faster,” “easily ignites,” “burns well after long storage,” and “high bark content for ignition” had moderate to low consensus, ranging between 0.6 and 0.0. The high consensus values suggest a strong agreement within the community that efficient combustion is essential. For example, in Argentina, households emphasize flame intensity as a key factor (Sackser *et al*. 2024), while in Ethiopia, efficient heat production is among the main priorities (Bahru *et al*. 2021). Similarly, in Limpopo, South Africa, Semenya and Machete (2018) found high heating value to be a priority criterion for firewood selection. These similarities confirm the importance of the heat value of firewood species for domestic energy needs, such as cooking and heating.

The most salient firewood species in Nyakelang also had high citation under these combustion efficiency criteria “burns well” and “burns for a long time” (see Figure 3). These attributes explain the consistent preference for dense hardwoods like *D. cinerea*, known for its high calorific value (Lubwana *et al*. 2021). Sackser *et al*. (2024) reported that communities prefer this species for its long-lasting embers, strong flame, and low smoke output. Reyes *et al*. (2022) further note that *D. cinerea* is highly versatile and valuable as firewood in many rural areas. Meanwhile, *C. zeyheri* is appreciated for its strong flame due to a high wood density of 580 kg/m³ (Sackser *et al*. 2024), and *C. apiculatum* is a major firewood species in former Gazankulu (Liengme 1983) and is also highly preferred for its high fuel value index in Malawian communities (Abbot & Lowore 1999). While combustion efficiency is important in Nyakelang, Zhang *et al.* (2025) argue that traditional firewood use often results in low energy efficiency and indoor air pollution, threatening the health of users.

Practicability also emerged as an important firewood selection attribute in Nyakelang. This entails “availability” (quantity of firewood species present and ready for use), “accessibility” (ease of obtaining firewood without restrictions or obstacles), “nearby availability” (spatial proximity), “easy to harvest” (labour effort in cutting and carrying), and “burns even when wet.” Availability was also highly prioritised (as compared to the latter criteria) by households with an ICF value of 0.822. Availability has also been identified as a key selection criterion in studies by Semenya and Machete (2018) and Bahru *et al*. (2021). Brouwer *et al*. (1989) and Doumecq *et al*. (2023) who highlighted that firewood availability remains crucial for rural households in developing countries, serving as the primary energy source for various domestic needs. However, when firewood becomes scarce, households adopt coping mechanisms that often require more labour, such as collecting wood from farther away, and preparing meals with lower nutritional value, all of which negatively impact the well-being of women and children the most (Brouwer *et al*. 1989, Waswa *et al*. 2020).

Criteria with moderate to low consensus (ICF values between 0.5 and 0.0) included storage, health-related, and cultural and medicinal attributes. Storage criteria such as “does not rot easily”, “does not retain moisture”, and “burns well after long storage” had moderate ICF values between 0.5 and 0.0. Health-related criteria, including “emits less smoke” and “has healing properties,” had the lowest ICF values of 0.333 and 0.0, respectively. Cultural and medicinal criteria such as “cultural purposes,” “healing properties,” and “preference” (perceived suitability as firewood) also had very low ICF values (0.0), suggesting less uniformity in knowledge or lower priority across the community, thus diluting overall agreement.

Overall, local knowledge and cultural practices significantly influence firewood selection, with communities developing classification systems based on combustion properties and other household-specific conditions (Sackser *et al.* 2024, Jimenez-Escobar & Martínez 2019). The findings in Nyakelang align with broader African and global patterns, where households prefer locally available hardwoods that produce a strong flame, high heating value, and good ember formation (Abbot *et al*. 1997, Jiménez-Escobar & Martínez 2019, Bahru *et al*. 2021, Sackser *et al*. 2024).

Table 3. The ICF values for firewood species selection criteria among the Nyakelang community.

Selection criterion (category)	n_{ur} (Total citations for species under this criterion)	n_t (Total number of species cited for this criterion)	ICF
Burns well	94	17	0.828
Availability	136	25	0.822
Burns for a long time	81	22	0.738
Forms good embers	33	13	0.625
Dries quickly	17	8	0.563
Easily ignites	10	5	0.556
Burns even when wet	13	7	0.500
Does not rot easily	13	7	0.500
Does not retain moisture	6	4	0.400
Burns rapidly	9	6	0.375
Emits less smoke	7	5	0.333
Accessibility	12	9	0.273
Cooks food faster	9	7	0.250
Burns fairly	7	6	0.167
Nearby availability	4	4	0.000
Cultural purposes	3	3	0.000
Easy to harvest	3	3	0.000
Has healing properties	4	4	0.000
Burns well after long storage	2	2	0.000
High bark content for ignition	2	2	0.000
Preference	1	1	Undefined

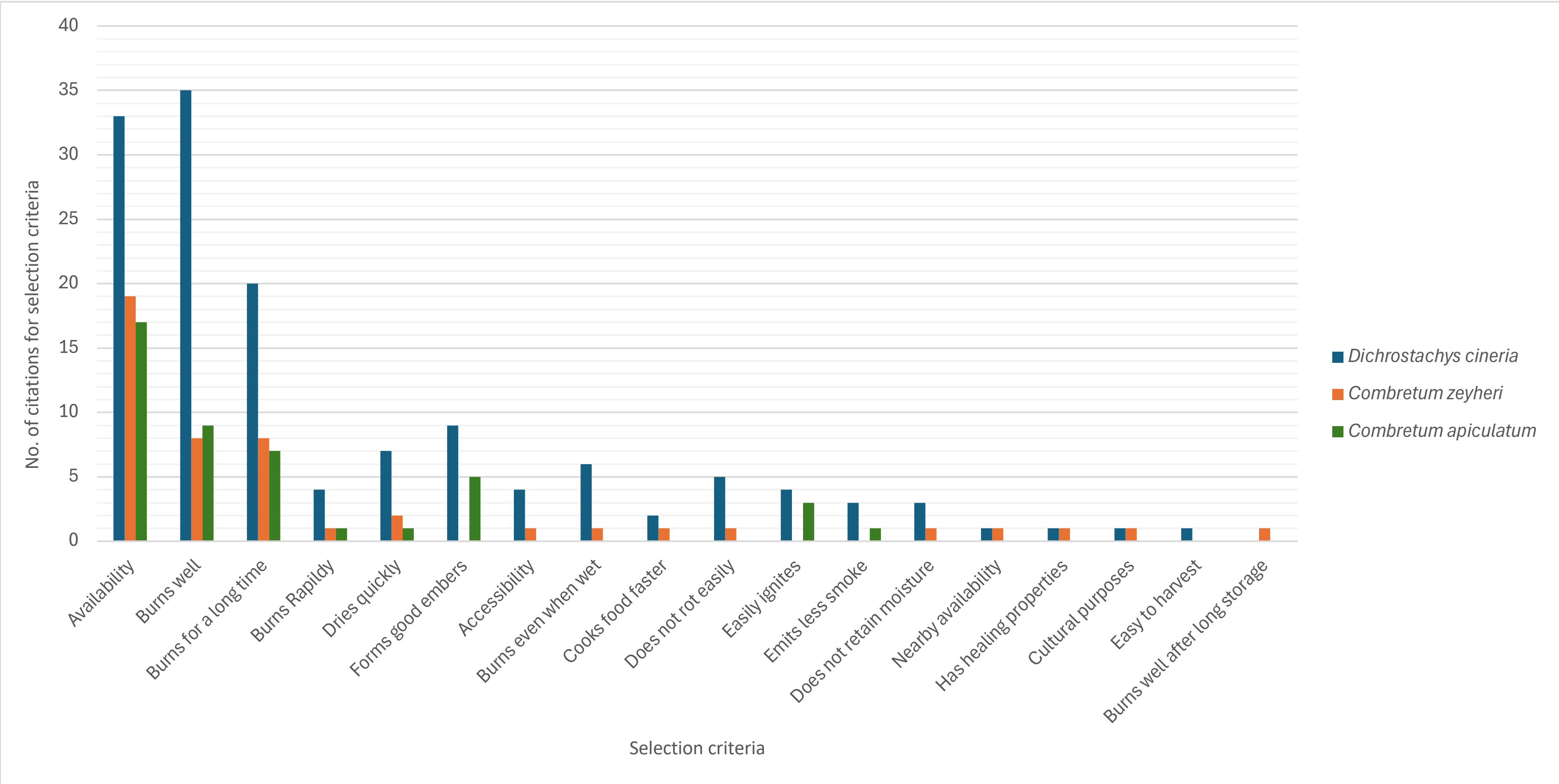

Figure 3. The selection criteria of the 3 most salient firewood species in Nyakelang households

Conclusion

This study assessed and documented culturally salient firewood species and the criteria influencing their selection in the Nyakelang section community of the Lemondokop Village in the Limpopo Province, South Africa. It addresses the limited documentation of firewood species importance and the degree of shared knowledge on the criteria of selection within South African communities by integrating Smith's S, UC, and the ICF to understand how traditional ecological knowledge and socio-economic factors shape firewood use. Thirty-eight firewood species were reported by the community, and the core firewood species were identified as *D. cinerea, C. zeyheri,* and *C. apiculatum.* These species also reflected a strong UC further highlighting their significance as an energy source in the study area. The ICF results revealed a strong consensus within the community on firewood that: 1) burns well, 2) is available, and 3) burns for a long time. This highlights the significance of quality criteria such as combustion efficiency and availability in household energy sources.

The demographics reveal that firewood use is to a lesser extent about deep-rooted cultural significance but more about necessity within a context of economic vulnerability and shifting social structures. The dominance of female perspectives in salience rankings emphasises the gendered nature of domestic energy knowledge, while the observed generational differences point to a shift in cultural knowledge transmission potentially eroding cultural continuity. Therefore, poverty or economic hardships, force households to use firewood, even if it means violating conservation laws. This reveals a mismatch between top-down conservation policies and bottom-up realities of poverty. Additionally, relying on indigenous knowledge alone without the integration of scientific guidance particularly on the health and environmental risks (using protected species) may compromise public health and resource sustainability in rural areas.

Overall, these findings indicate a system that is optimised for survival under poverty, and largely blind to health and conservation outcomes. Future research should look into providing a roadmap for intervention, considering the socio-demographics of households, legal constraints of resources use and health education on the implications of firewood use. The opportunity in these recommendations lies in designing interventions that respect the lived realities of households, while simultaneously promoting sustainable energy planning or transition policies that work on reducing dependence on firewood, support gendered energy needs and cleaner energy alternatives.

Declarations

List of abbreviations: CDA - Cultural Domain Analysis, Eskom - Electricity Supply Commission, FBE - Free Basic Electricity, kWh - Kilowatt hour, i.e. - That is, IUCN - International Union for Conservation of Nature, ICF – Informant Consensus Use, Smith's S – Smith's Salience, UC – Use Consensus, , SANBI - South African National Biodiversity Institute.

Ethics approval and consent to participate: Verbal and written consent was sought and obtained from all participants. The ethical clearance route is detailed in the ethical considerations section of the manuscript.

Consent for publication: Not applicable

Availability of data and materials: Data for this study is available from the corresponding author upon request.

Competing interests: The authors declare that they have no conflicts of interest.

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Author contributions: M.E.M: Conceived the idea, collected data, carried out the data analysis and conducted the write up of the manuscript. S.K: Supervision. L.M.S-D: Supervision.

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