Evaluation of Indigenous Knowledge and Fuel Value Index of Some Selected Sudano-Sahelian Fuelwood Species in Damaturu, Yobe State of Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author AMD design the work and wrote the protocol as well wrote the first draft of the manuscript. Author OAS performed the statistical analysis. Authors AMD and OAS managed the analysis and presented the results and discussion of the study. However, author AMD managed the literature searches. Both authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Fuelwood utilization in the sudano- sahelian region requires massive felling of tree species which in turn resulted to deforestation and sand dunce couple with scarce vegetation in the region. Moreover, fuelwood is not only used for domestic and commercial purposes but for livelihood sustenance. This increases the demand and intensity for fuelwood through indiscriminate felling of trees species for energy use, with a trend that does not appear to have the possibility of meeting the increasing demand in the future. The study aimed to evaluate the indigenous knowledge and fuel value index (FVI) of ten selected sudano-sahelian fuelwood species and the results revealed a significant relationship between the indigenous knowledge and Fuel value index (FVI) of the ten selected fuelwood species. Higher FVI of $13.56 MJ/m^3 \%^2$ was obtained in A. leiocarpus followed by $6.61 MJ/m^3 \%^2$ and $6.53 MJ/m^3 \%^2$ obtained in B. aegyptiaca and C. arereh meanwhile, lower

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energy fuelwood ranged from 0.11MJ/m^3% ^{2} obtained in C. lamprocarpum. to 0 85MJ/m^3% ^{2}, in S. birrea respectively. Meanwhile, A. leiocarpus, C. arereh, C. molle, and B. aegyptiaca were the most preferred and possessed good fuel quality. The indigenous knowledge might not be solely based on their fuel properties but availability and other possible reasons. Therefore, those fuelwood species identified with higher energy value can be incorporated in to fuelwood plantation establishment programs and those with lower energy value fuelwood should be allowed for environmental restoration and amelioration.

1. INTRODUCTION

The use of wood as a source of energy for cooking and heating is still very much relevant in the developing countries, most especially those of sub-Saharan Africa. It is not only used for domestic and commercial purposes but also for livelihood sustenance. The demand for fuelwood is increasing rapidly with a trend that does not appear to have the possibility of meeting the demand in the future FAO [1,2], Erakhrumen [3,4,5]. Moreover, fuelwood is the cheapest, the most suitable and accessible energy source in many rural areas, Abbiw [6], Cotton [7]. The use of fuelwood as a source of energy for cooking and heating had drawn a lot of interest due to it easy access and cheaper cost compare to other source of energy (Kerosene, LPG's and electric devices) and as such influenced deforestation, sand dunce and desertification. Meanwhile, majority of woody plants species can be used as a source of fuel for indigenous peoples, many species are recognized for particular burning qualities, Cotton [7].

Charcoal is a valuable and a chief domestic fuel in most developing countries compared to other source of energy such as liquefied petroleum gas (LPG), kerosene and electric stove. Due to this reason, it is a common source of fuel wood in urban centers. In the absence of fossil fuel, charcoal is more advantageous and must prefer fuelwood were used for the production of charcoal due to their inherent energy qualities Abbiw, [6]. It is more efficient and produces a constant heat with little or no smoke Abbiw [6], Cotton [7], Kochhar [8]. Conversely, the long distance transportation makes increases the cost as compared to fuelwood. During charcoal production, about half of the wood's energy is wastefully burned away Abbiw, [6]. Consequently, massive felling of fuelwood species is requires the high charcoal demand. Moreover, charcoal production causes a lot of accidental forest fires. Thus, both charcoal harvesting and accidental fire contribute to deforestation and land degradation, Silayo et al. [9]. The study aimed to evaluate the indigenous knowledge and fuel value index (FVI) of ten selected sudano-sahelian fuelwood species.

2. MATERIALS AND METHODS

2.1 Study Area (Geographical Location)

Damaturu lies between latitudes *11.44*^{0} to *11.75*^{0} N and longitudes *11.57* ^{0} E to *11.96* ^{0} E with an elevation of *456*m with an annual temperature of *25.2*ºC and rainfall of *649* mm. The dry month is January with *0* mm rain and the higher amount of moisture content occurs in August with a mean of *223* mm (Fig. 1). The warmest month of the year is May with a temperature of *29.7*ºC, Hess et al.*,* [10]. Total land area of *2,366* km^2 and population of *87,706* people out of which *48,361* are males and *39,345* are females. Age groups of the people ranged from *0-14 to 15-64* and *65* years and above and population of *39,010*, *47,080* and *1,616* respectively NPC, [11]. Meanwhile, Damaturu is surrounded in the north and south by Tarmuwa, Geidam, Bade (north) and Gujba, Gulani (South) Local Government Areas and east and west by Maisandari, Kukareta (East) and Fune, Potiskum (West) Local Government Areas (Fig. 1). The experimental materials (fuelwood species information) were obtained at the three major fuel corridors namely Damaturu-Gashu'a road, Damaturu- Maiduguri and Damaturu- Gujba roads (Fig. 1).

Information on the fuelwood species used for the study was sourced from reconnaissance survey using sixty (60) structured questionnaires and were administered to the people selling fuelwood at the three major fuelwood corridors in Damaturu. The fuel corridors are Damaturu – Gashu'a road, Damaturu - Gujba road and Damaturu – Maiduguri road (Fig. 1). However, the questionnaires were drawn in such a way that the respondent listed all the fuelwood species known and used in the study area and out of that, ten (10) preferred fuelwood species were listed and prioritized them based on their energy value in ranking order 1 to 10, with

position number 10 being the most preferred and position number 1 being the least preferred fuelwood species. The fuelwood species in order of 1 to 10 listed by the respondent were sum and divided by the total number of fuelwood species recorded from each fuelwood corridor and ranked them according to their respective total values and this was used as the indigenous knowledge. However, the most common fuelwood species from the list of ranking by the respondent in each of the three fuelwood corridors, ten fuelwood species were selected for the study (*Piliostigma reticulatum, Tamarindus indica, Acacia sieberana, Sclerocarya birrea, Combretum lamprocarpum, Terminalia mollis, Balanites aegyptiaca, Anogeisus leiocarpus, Caccia arereh* and *Combretum molle).*

2.2 Sampling Method

Ten fuelwood species were measured for their height, bole height and diameter at breast height (Dbh). Thereafter, a stem disc of *25* cm long was cut at above and below diameter at breast height, thereby making a total stem disc of *50* cm long and wrapped with a black polythene bag to prevent loss of moisture and transported to laboratory for investigation. In the laboratory, each billet was reduced to chip sizes of 10 to *30*

mm with the aid of axe. On each chips (wood and bark), the following samples were created using Nosek et al. [12]:

W_A = Wood sample without bark (Zero Bark)
W_{B5} = Wood samples with 5% bark
W_{B10} = Wood samples with 10% bark
W_B = Samples with 100 % bark
The breakdown of the samples was as follow:

Number of tree species	10
Number of replicates per tree species	3
Number of wood chips	4
Total	10 x 3 x 4 = 120 samples

Samples with 5 and 10% bark chips were created by mixing wood sample without bark with the bark sample. The proportion of 5 and 10% were employed due to high numbers of fuelwood with bark contents in the range of 5 to 10%. The chips were separately put in a container and carefully labeled and air dried at room temperature to a constant moisture content and grinded to fraction size of less than 1mm based on American Standard for Testing and Material (ASTM) standard designation D*2013-86* and thereafter subjected to various investigations which includes; physical properties (density, moisture content) and proximate analysis (Volatile matter, ash content and heating value).
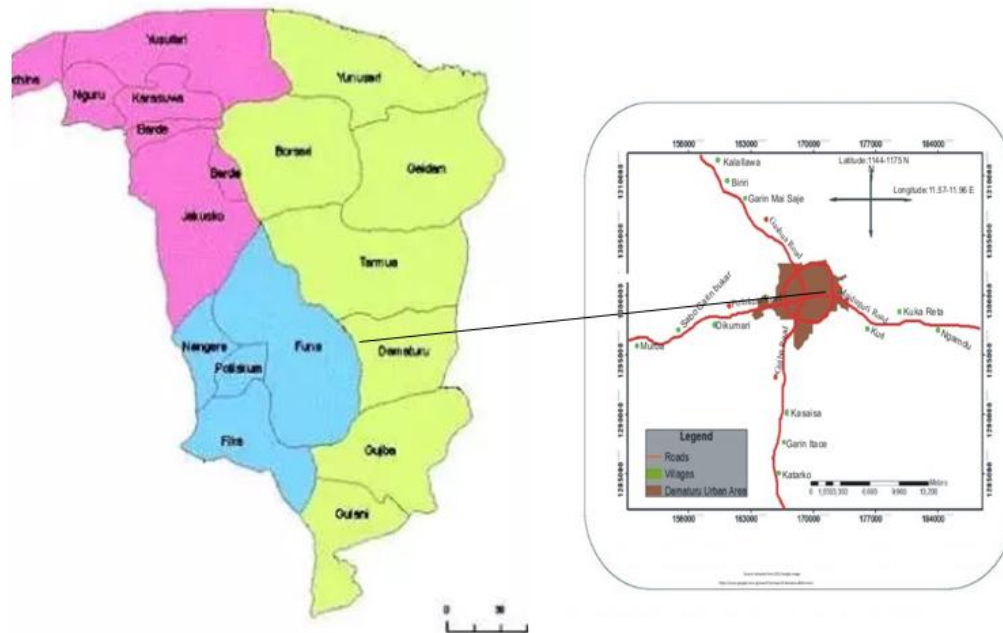

Fig. 1. Map showing the study area and the four major roads supplying fuelwood into Damaturu, Yobe state
Source: The world Gazetteer, (2007)

2.3 Determination of Density

The density of the fuelwood species was determined by using Archimides principle adopted from Wilson, (2012). One gram of wood chip was weighed and put in a measuring cylinder and placed in a beaker with full of water inside a bowl. The water displaced was measured and recorded as the volume of the wood sample and the following equation was used to determine the density.

$$D \ = \frac{M}{V} \ kg/m3 \ (1)$$

Where; D is the density, M is the mass of the sample and V is the volume of the wood sample

2.4 Determination of Moisture Content

Moisture content of the wood chip was determined by using ASTM, [13,14,15]. One gram of the freshly prepared wood chip was weighed in an empty platinum crucible of known weight and oven dried at 105±2ºC to a constant weight. The sample was cooled in a desiccator and the final weight was determined. The oven dry moisture content was calculated using equation below:

$$MC = \frac{W_o - W_1}{W_0} \times \ 100\% \ \ (2)$$

Where, MC is the Moisture content in %, W_o is the initial weight of the freshly prepared wood fraction, W_1 is final weight of the wood fraction after drying to a constant weight at 105±2ºC

2.5 Proximate Analysis

This is a standard test for determining the relative proportions of volatile matter, ash content and fixed carbon of a biomass material. The percentage of volatile matter, fixed carbon and ash of the wood fractions were determined based on ASTM Standard.

2.5.1 Volatile Matter

Percentage volatile matter was determined by using one gram of oven dried wood sample was placed in a platinum crucible of known weight and heated at a temperature *600*ºC for *10* minutes in a furnace. At the end of this duration, the samples are allowed to cool and then the final weights were measured and recorded. The volatile matter was estimated using the equation below as stated in ASTM, [13,14,15].

$$PVM = \frac{B - C}{B} \times 100\% \ (3)$$

where: *PVM* is the percentage volatile matter, *B* is the weight of oven dried wood fraction (g) and *C* is the weight (g) of the wood fraction after heating in the furnace for ten minutes.

2.5.2 Ash content

The ash content determination followed the same procedure as volatile matter but in this case the sample were heated in the furnace for three hours and obtained as expressed in the equation below using ASTM, [13,14,15].

$$PAC = \frac{D}{B} \times 100\% \ (4)$$

Where, PAC is the percentage of ash content, *D* is the weight of ash in gram and *B* is the oven dried weight of wood sample in gram.

2.5.3 Fixed carbon

The percentage fixed carbon was determined by using equation below in accordance with ASTM, [16].

$$FC = \ 100\% \ - \ (PVM + PAC) \ ... (5)$$

Where: *FC* is the percentage of fixed carbon, *PVM* is the percentage of volatile matter, and *PAC* is the percentage of ash content in the wood fraction.

2.5.4 Heating value

The heating value was calculated using this Gouthal formula in accordance with Bailey and Blankehorn, [17].

$$HV = \ 2.326 \ (147.6FC + 144PVM) \ .... (6)$$

Where, *HV* is the heating value in MJ·kg^{-1}, *FC* is the percentage of fixed carbon, and

PVM is the percentage of volatile matter [17].

2.5.5 Fuel value index (FVI)

FVI was determined as the product of calorific value (heating value) and density divided by the product of ash content and moisture content adopted from Bhatt and Tomar, (2002).

$$FVI = \frac{HV \times P}{PAC \times MC} \ MJ/cm^3 \%^2 \ (8)$$

Where; *HV* is the heating value on dry basis (MJ·kg^{-1}), *P* is the oven dry density of the wood sample, *PAC* is the percentage ash content of the sample and *MC* is the oven dry moisture content of the samples.

3. RESULTS AND DISCUSSION

3.1 Density and Moisture Content

The results presented in Table 1 shows that variation among the fuelwood studied, *A. leocarpus* has the highest density, *0.664* g/cm^3 followed by *0.639, 0.631* and *0.567* g/cm^3 obtained in *C. arereh, B. eagyptiaca* and *C. mole*, respectively while the lower values of *0.353, 0.352, 0.306* and *0.259* g/cm^3 were obtained in *S. birrea, C. lamprocarpum, P. reticulatum* and *A. sieberana*. Therefore, apart from *S. birrea, C. lamprocarpum, P. reticulatum* and *A. sieberana* with low density range between *0.259* and *0.353* g/cm^3, the remaining six species had density value ranged between *0.419* and *0.664* g/cm^3 comparable to those reported for some selected sudano-sahelian trees and shrubs by Montes et al. [18], selected fuelwood species from Masindi and Nebbi districts in Uganda [19], wild grown *Acacia* species reported by Nasser and Aref [20] and commonly used fuelwood species in Mizoram, north-east India [21]. Meanwhile, moisture content (MC) ranged from *27.66%* in *A. leiocarpus* to *40.44%* in *A. sieberana* (Table 1). This means that as the MC increases, affect the combustion rate and similarly in many studies have demonstrated the influence of MC on the combustion properties of fuelwood materials by Kataki and Konwer, [22], Ojelel et al. [19], Nosek et al. [12], Álvarez-Álvarez et al. [23] and concluded that moisture has negative effect on fuel value.

3.2 Proximate Properties

3.2.1 Volatile Matter (VM)

The results of this study reveals that volatile matter (VM) ranged from *61.38%* in *P. reticulatum* to *75.11%* in *A. leiocarpus* followed by *C. arereh.* The high values obtained were similar to those recorded for some indigenous tree species in north-east India by Deka et al. [24] but a bit lower than the range of *74.7%* and *87.1%* in some woods by Telmo and Lousada, [25]. Meanwhile, ash content (AC) ranged from *0.52%* in *A. leiocarpus* to *2.42%* in *P. reticulatum* (Table 1). These values are within the range reported by Chettri and Sharma, [26]; Telmo and

Lousada, [25], Senelwa and Sims, [27]. But lower than the ash recorded in some indigenous fuelwood species in north-east India by Deka et al. [24]. The low ash contents reported for the trees under study is desirable, because it implied that a considerable portion of the wood volume can be converted into energy.

3.2.2 Fixed carbon (FC)

The average fixed carbon content ranges from *24.19%* in *C. arereh* to *36.20%* in *P. reticulatum* (Table 1). The values obtained in this study were similar to those recorded for some indigenous tree species reported by Deka et al., [24] but higher than the range of *13.50%* to *23.02%* obtained in some tree species by Álvarez-Álvarez et al. [23] and *5.1%* to *7.6%* obtained in the stump of some trees from short rotation forest by Senelwa and Sims, [27]. The fixed carbon content recorded for the fuelwood species under study is a reflection of their high volatile matter content which according to Senelwa and Sims, [27] is an indication that the bulk of the fuelwood material is consumed in the gaseous state during combustion.

3.2.3 Heating Value (HV)

The average heating value obtained for all the selected trees was quite high. The value ranged from *32.99* MJ.kg^{-1} in *P. reticulatum* to *33.53* MJ.kg^{-1} in *A. leiocarpus* (Table 1). The values obtained were similar to *32.94* to *33.68* MJ.kg^{-1} reported for some fuelwood tree species by Chavan et al. [28] but higher than a range of *19.6* to *20.2* MJ.kg^{-1} recorded for some short rotation forest biomass by Senelwa and Sims, [27], *13.78* to *22.22* MJ.kg^{-1} higher heating values of some ash free and extractive free biomass reported by Demirbas and Arin, [29] and *18.00* to *20.45* MJ.kg^{-1} for some *Acacia* species by Nasser and Aref [20].

3.2.4 Fuel Value Index (FVI)

Among the selected trees, higher FVI was found to be *13.56* MJ/cm^3 %^{2} in *A. leiocarpus* followed by *6.53* to *6.61* MJ/cm^3 %^{2} in *C. arereh and B. aegyptiaca* respectively (Table 1). Meanwhile, lower values of *0.83* and *0.85* MJ/cm^3 %^{2} were obtained in *S. birrea* and *A. sieberana,* respectively The values recorded for the trees under study were conversely to those reported for some woody tree species of Mamlay watershed by Rai et al., [30] for some Aravally mountain tree and shrub species of Western India by Kumar et al. [31] and fuelwood tree

species of Bundelkhand region Chavan et al., [28] but higher than those reported by Sahoo et al. [21].

3.3 Fuelwood Species and their Ranking Order

The results of this study shows that ranking of fuelwood species based on their properties ranged from *1.14* in *A. leiocarpus* followed by *2.14* in *C. arereh* to *9.00* and *9.14* in *A. sieberana* and *P. reticulatum* (Table 2). Similar view was reported by Chettri and Sharma, [26] for some wood constituent properties from trekking corridor, India. Meanwhile, Table 3 shows the ranking order of fuelwood species by respondents at the three major fuelwood corridors. The ranking order ranged from *1.00* in *A. leiocarpus* to *9.33* in *G. senegalensis* (Table

3). Similarly, Chettri and Sharma, [26] reported that *Quercus lamellosa* was the most preferred fuelwood species followed by *Schima wallichii* and least preferred was found in *Symplocos ramosissima*. However, Bahru et al., [32] reported that *Acacia seyal* was ranked the highest for some woody species in and around semi arid Awash National park, Ethiopia.

Comparison between indigenous knowledge and fuel value index (FVI), *A. leoicarpus, C. arereh, B. aegyptiaca* and *C. molle* are the most preferred fuelwood species while the least preferred fuelwood species are *A. sieberana , G. senegalensis* and *P. reticulatum* (Tables 1 and 2). Meanwhile, *C. arereh* was ranked averagely but possessed higher FVI. In addition, *P. Africana* and *P. erinaceus* were also preferred but their FVI was not captured in this study

Table 1. Physical, proximate properties and fuel value index of some selected fuelwood species

Tree species	D(kg/m³)	MC (%)	VM (%)	AC(%)	FC (%)	HV(MJ/kg)	FVI(MJ/cm³%²)
Anogeisus leiocarpus	0.664ᵃ	27.66ᵈ	75.11ᵃ	0.52ᵈ	24.37ᶜ	33.53ᵃ	13.56ᵃ
Caccia arereh	0.639ᵃᵇ	30.87ᵇᶜᵈ	75.10ᵃ	0.71ᶜᵈ	24.19ᶜ	33.46ᵃ	6.53ᵃᵇ
Balanites aegyptiaca	0.631ᵃᵇ	29.43ᶜᵈ	71.64ᵇ	1.42ᵇᶜ	26.94ᵇ	33.25ᵃᵇ	6.61ᵃᵇ
Combretum molle	0.567ᵇ	31.53ᵇᶜᵈ	71.62ᵇ	1.29ᵇᶜᵈ	27.09ᵇ	33.29ᵃᵇ	5.64ᵃᵇ
Terminalia Mollis	0.486ᶜ	31.71ᵇᶜᵈ	71.38ᵇ	1.83ᵃᵇ	26.79ᵇ	33.11ᵇ	1.85ᵇᶜ
Tarmarindus indica	0.419ᶜᵈ	31.90ᵇᶜᵈ	67.48ᶜ	1.96ᵃᵇ	30.56ᵃᵇ	33.09ᵇ	1.23ᵇᶜ
Sclerocarya birrea	0.353ᵈᵉ	33.47ᵇᶜᵈ	70.14ᵇᶜ	1.92ᵃᵇ	27.94ᵇ	33.08ᵇ	0.83ᶜ
C. lamprocarpum	0.352ᵈᵉ	34.17ᵇᶜ	70.44ᵇᶜ	1.85ᵃᵇ	27.72ᵇ	33.11ᵇ	1.09ᶜ
P. reticulatum	0.306ᵉᶠ	35.61ᵃᵇ	61.38ᵈ	2.42ᵃ	36.20ᵃ	32.99ᵇ	2.62ᵇ
Acacia sieberana	0.259ᶠ	40.44ᵃ	69.75ᶜ	2.13ᵃᵇ	28.12ᵇ	33.02ᵇ	0.85ᶜ

D: Density, MC: Moisture content, VM: Volatile matter, AC: Ash content, FC: Fixed carbon, HV: Heating value and FVI: Fuel Value Index

Table 2. Fuelwood properties and their ranking order

	Al	*Ca*	*Ba*	*Cm*	*Tm*	*Ti*	*Sb*	*Cl*	*Pr*	*As*
Physical										
Density (g/cm³)	1	2	3	4	5	6	7	8	9	10
Moisture content (%)	1	3	2	4	5	6	7	8	9	10
Proximate properties										
Volatile matter (%)	1	2	3	4	5	6	8	7	10	9
Ash content (%)	1	2	4	3	5	8	7	6	10	9
Fixed carbon (%)	2	1	4	5	3	9	7	6	10	8
Heating value (MJ/kg)	1	2	4	3	5	6	8	5	10	9
Fuel value index	1	3	2	4	6	7	10	8	5	9
Rank	1.14	2.14	3.14	3.86	4.86	6.86	7.71	6.86	9.00	9.14

1 = good quality, 10 = poor quality. The ranking was done by adding the values for each fuel properties in the same column and divided by the number of fuel properties. Meanwhile, Al (Anogeisus leiocarpus), Ca (Cassia arereh), Ba (Balanites aegyptiaca), Cm (Combretum molle), Tm (Terminalia mollis), Tm (Tamarindus indica), Sb (Sclerocarya birrea), Cl (Combretum lamprocarpum), Pr (Piliosigma reticulatum) and As (Acacia sieberana)

Table 3. Respondents ranking of fuelwood species at the three fuelwood corridors

Fuelwood species	Dtr - Gujba	Dtr – Gashua	Dtr- maiduguri	Total Ranking	Rank
A. leiocarpus	1	1	1	3	1.00
P. Africana	-	6	-	6	2.00
C .molle	2	3	3	8	2.67
P. erinaceus	4	5	-	9	3.00
P. reticulatum	-	9	-	9	3.00
B. aegyptiaca	3	4	2	9	3.00
T. mollis	3	-	6	9	3.00
C. lamprocarpum	5	2	5	12	4.00
T. indica	-	7	7	14	4.60
A. chevalieri	7	-	9	16	5.33
V. paradoxa	9	-	8	17	5.67
C. arereh	6	8	4	18	6.00
G. senegalensis	8	10	10	28	9.33

Rank was obtained by dividing the sum of scores of the respondents by the number of fuelwood corridors. Dtr means Damaturu

(Table 3). It was observed that almost all the FVI of fuelwood species were similar to the indigenous knowledge. Meanwhile, the present study revealed that indigenous knowledge on fuelwood species tallied with the FVI and this shows that indigenous knowledge can be considered in selecting fuel wood species for good combustion quality. However, apart from FVI, fuel properties such as ash, volatile matter and moisture contents were observed and found that there are significant relationship between them and indigenous knowledge.

4. CONCLUSION

The fuelwood species investigated had significant relationship between indigenous knowledge on fuel quality and fuel value index (FVI). Majority of the fuel wood species with higher FVI were the most preferred by the people in the study area. Although, there were few fuelwood species that possessed better energy value and were less preferred by the people in the study area. This signifies that indigenous knowledge for fuelwood species is not actually based on their energy value but might be due to their availability and easy access. Meanwhile, those fuelwood species that have significant relationship with FVI and preferred by people in the study area can be incorporated in fuelwood plantation establishment program and those with low energy value should be allow restore and maintain the ecosystem services and to ameliorate the environment from deforestation and desertification. This will go a long way to reduce the indiscriminate felling of fuelwood species for energy uses in the region.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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