

Assessment of fuelwood diversity and utilization patterns in a Himalayan protected area: implications for conservation and management

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Abstract

Background

Protected areas, besides their principal role in biodiversity conservation, provide life-supporting ecosystem services to local communities. This study was aimed to assess the diversity and utilization patterns of fuelwood – an important provisioning ecosystem service – collected by local communities from the Overa-Aru wildlife sanctuary in Kashmir Himalaya.

Methods

A regular field survey was carried out in all the selected villages during summer and winter seasons of the year 2020 and 2021. Data were collected from five villages viz., Overa, Vir Siran, Mamal, Mandlan and Aru, located in or at the fringes of the sanctuary. These villages rely mainly on the sanctuary for fuelwood to meet their day-to-day needs. Using a multistage random sampling approach, we conducted semi-structured face-to-face interviews with 100 respondents in the sanctuary.

Results

The results revealed that 35 plant species occurring in the sanctuary have been historically used by the locals as fuelwood, while only 22 species are currently utilized. The results also showed the burning quality and fuelwood characteristics of the fuelwood species. The mean annual fuelwood utilization was 5911 ± 313.01 kg/household, but a striking seasonal variation was found with a mean of 9.50 ± 0.95 during summer and 29.25 ± 0.95 kg/household/day during winter. The fuelwood was mainly collected by women (95%), and the percentage of collectors of total village population varied significantly across the sanctuary ($p < 0.01$). There was a significant positive correlation between the age of the respondents and the number of citations of fuelwood species ($p < 0.05$), but the education status of the respondents and the number of citations showed a negative correlation ($p < 0.05$).

Conclusions

The study gathered precious information on fuelwood utilization patterns that could be useful for sanctuary management plans, especially while raising plantations of preferred fuelwood species, which in turn will alleviate the detrimental impacts on biodiversity and help in sustaining ecosystem services. Moreover, results showed that local residents who collect fuelwood from the sanctuary to sustain their wellbeing and livelihood embody a traditional knowledge base on the fuelwood species. This traditional sociocultural knowledge depends on the fuelwood users' age and educational status. We recommend evolving appropriate guidelines and policy interventions for the sustainable utilization of fuelwood resources in this Himalayan protected area, with lessons for environmental management of such natural areas elsewhere in the world.

Background

The humanity is currently facing a great challenge of maintaining the global biodiversity and at the same time ensuring the sustainability of life-supporting ecosystem goods and services [1]. Globally, protected areas (PAs) are considered to have huge potential to mitigate the biodiversity crisis [2, 3]. Successful conservation and management strategies of PAs need empirical assessment of the biodiversity resource base and its utilization by local communities [4]. The forests in PAs are a treasure trove of goods and services that sustain human wellbeing and livelihood [5]. The lower socio-economic conditions of the people living inside or near the PAs lead to their total dependence on forest resources which are available free of cost. [6]. Forests provide fuelwood—a source of energy for industrial, commercial, or domestic use [7]. Fuelwood constitute plant species used by humans for combustion to generate energy especially in rural areas [8]. However, in recent times, unsustainable fuelwood extraction is posing threats to forest biodiversity and creating hurdles for the local communities to meet their energy needs [9]. Furthermore, due to high demand for fuelwood, the heavy lopping of trees, coppicing shrubs and commercial felling in many regions have affected the long-term sustainability of fuelwood availability [10].

In India, fuelwood accounts for 54% of the total biofuels for household and industrial purposes [11]. Worldwide, approximately 2 billion people in rural areas rely on forest products to meet their livelihood demands, of which fuelwood is a preferred product [12]. It is estimated that one in every three people uses wood for burning purposes [11]. In developing nations, it is often the major source of energy [13] and contributes 50 to 90% to total household energy, especially in rural areas [14, 15]. The countries that rely on fuelwood are emerging economies where the socioeconomic conditions of the people lead to greater dependency on wood as fuel [16]. For instance, the consumption of fuelwood in India is $\sim 85,290,000$ tonnes per annum, thus indicating its huge demand [17]. Further, biomass meets $\sim 80\%$ of total primary energy demand in the country [11], and $\sim 70\%$ of the rural households fulfill their energy requirements by consuming fuelwood as a source of energy [18]. Recent studies have highlighted an intricate relationship between biomass-based fuel and climate change [19, 20, 21]. While biomass is considered carbon-neutral in theory, it is increasingly recognized that the net carbon balance depends on various factors, including land-use changes, forest management, and the efficiency of combustion technologies [22, 23]. Inefficient or unregulated biomass burning can release substantial amounts of black carbon, which can accelerate global warming [24]. Additionally, the health implications of indoor air pollution from biomass combustion have gained more attention, especially with evidence of negative long-term respiratory and cardiovascular health effects [25, 26]. On the socioeconomic front, overreliance on fuelwood resources in many developing regions still perpetuates a cycle of poverty, as households, particularly women, spend significant time collecting biomass and face health risks [27, 28]. To address these challenges, recent initiatives emphasize sustainable forestry practices, improved stoves, and transitioning to cleaner energy alternatives, recognizing the multifaceted impacts of biomass fuels on both the environment and human well-being.

The Himalaya, occupying a special place in the world's mountain systems, has a dominant role in determining the climate and hydrology of the Indian subcontinent and harbors a rich treasure of diverse flora and fauna [29]. However, the current practices exacerbate fuelwood extraction rates and pose an immense threat to the regional flora and fauna [30, 31]. Excessive and non-judicious harvesting of fuelwood can lead to deforestation, and thereby disrupt natural habitats [32, 33], which in turn can alter local microclimates, accelerate soil erosion, and impact water availability, and hence affect flora and faunal species dependent on these ecosystems [34, 35, 36]. Overall, the current fuelwood extraction rates and practices can have profound negative consequences on regional ecosystems and the delicate ecosystem balance. In the Himalayan regions, the harsh winters, erratic supply of electricity and low availability of commercial fuels increase human dependence on fuelwood, which is mostly collected from the forests [37, 38]. Although a considerable quantity of fuelwood is used for making charcoal for commercial purpose, a substantial quantity is also prioritized for heating and cooking purposes [11, 39]. This results in the utilization of different types of fuelwood species along with their residues especially the preferred ones [40]. There is a broad choice among fuelwood species with different availability and fuelwood properties. In this line, various studies have focused on estimating the burning quality and fuelwood characteristics of various fuelwood species [11, 41].

Socioeconomic or demographic variables significantly determine the degree of traditional knowledge associated with the collection and utilization of fuelwood resources [42, 43]. However inconsistent family size, geographical location, and socioeconomic status lead to uncertainty in the characterization and utilization of fuelwood species within a particular region [42]. The urbanization gradient and advent of modernization not only have changed the rural peoples' standard of living but also dwindled the traditional knowledge [44, 45]. Therefore, the documentation and evaluation of traditional knowledge, especially from far-flung and fragile areas of the Himalaya is a need of the hour [29, 46]. However, the available information on resource utilization patterns, especially on fuelwood resources is insufficient. Although few studies have been undertaken on fuelwood utilization patterns from some of the Himalayan regions [47, 48, 49, 50, 51, 52, 53, 54], no such information is available from the Kashmir Himalaya, India.

In this study, we aimed to address the following objectives: a) to document the fuelwood species usually collected from the Overa-Aru wildlife sanctuary in Kashmir Himalaya and their associated traditional knowledge, b) to investigate the burning qualities and characteristics of the fuelwood species, c) to analyze the fuelwood collection and utilization patterns, and d) to find whether the fuelwood collection and utilization pattern differ according to the demographic variables of the respondents.

The findings from this study may help in guiding sustainable management of fuelwood resources from this Kashmir Himalayan protected area through the active participation of the local communities to achieve twin goals of conservation of biodiversity and sustenance of local livelihood.

Methods

Study site

The study was carried out in the Overa-Aru wildlife sanctuary — a protected area located in the Kashmir Himalaya — a region falling in the northwestern side of the Himalaya biodiversity hotspot in India [29, 55]. Lying between Zaskar and Pir Panjal mountain ranges, the sanctuary is situated between latitudes 33°55'43.86"–34°15'20.50" North and longitudes 75°15'44.15"–75°16'29.37" East, with elevation ranging from 2000–5425 m a.s.l. [56] (Fig. 1). The area of the sanctuary is 425 km² and it is demarcated into 38 Forest Compartments. The study area experiences four well defined seasons: the spring which is cool and wet lasts from March–May; the summer which is warmer and relatively dry lasts from June–August; the autumn which is moderately cool and dry lasts from September–November; and winter which is extremely cold and brings heavy snowfall lasts from December–February [57, 58]. The area receives precipitation mostly in the form of snow during winter and intermittent rainfall in other seasons with an average of 1300 mm annually. During the last decade, the average minimum and maximum temperature recorded in the region was 3.5 and 16.8 °C, respectively [59].

The vegetation in the sanctuary comprises of two major forest types: (i) Himalayan dry temperate forest and (ii) Subalpine forest [60]. The sanctuary harbors several fuelwood species which are widely distributed from lower to higher altitudes. The species such as *Abies pindrow*, *Aesculus indica*, *Acer caesium*, *Fraxinus hookeri*, *Celtis australis*, *Picea smithiana*, *Pinus wallichiana*, *Juglans regia*, *Ulmus wallichiana*, *U. villosa*, *Populus deltoides*, *P. ciliata*, *P. nigra*, *Prunus cornuta*, *P. persica*, *Salix alba*, *S. disperma*, *Sorbaria tomentosa* and *Viburnum grandiflorum* are found at lower elevations while species such as *Betula utilis*, *Abies pindrow*, *Prunus cornuta*, *Acer caesium*, *Juniperus squamata*, *Rhododendron campanulatum* are distributed at higher elevations. The sanctuary also provides a critical habitat for several faunal species such as *Cervus hanglu*, *Moschus cupreus*, *Capra sibirica* and *Panthera pardus* [61, 62, 63, 64].

Field survey

Regular field surveys were carried out in all the selected villages during the summer and winter seasons of the years 2020 and 2021. The summer is the peak season for fuelwood collection from the sanctuary and the winter is the main season of its utilization. Several villages such as Overa, Laddi, Dahwato, Khelan, Vir Siran, Mamal, Mandlan and Aru are located in or around the fringes of the sanctuary. However, after preliminary field surveys, we selected five villages: Overa, Vir Siran, Mamal, Mandlan and Aru, which mainly rely on the sanctuary for fuelwood resource to sustain their wellbeing and livelihood. The residents of these villages practice farming, rear livestock, and are associated with tourism-related activities. Based on revenue records and the information obtained from the village heads (*sarpanchs*), the number of households in each village was estimated (Table 1). The sanctuary holds two major ethnic groups: *Gujjars* and *Kashmiris*; and comprise of different castes/linguistic groups such as *Ganie*, *Khandey*, *Gujjar*, *Malik*, *Gege*, *Khatana*, *Gorsi*, *Sheikh*, *Mir* and *Laway*. The households residing in the villages of Mamal, Mandlan, and Aru have tourism as a source of income, while the most households residing in the villages of Overa and Vir Siran rely primarily on agriculture [61, 64, 65].

Table 1
Sampling framework, sample size and sampling intensity in the Overa-Aru wildlife sanctuary, Kashmir Himalaya.

Name of the village	Elevation	Geo-coordinates	Sampling frame		Sample size		Sampling intensity	
			Gujjars	Kashmiris	Gujjars	Kashmiris	Gujjars	Kashmiris
Overa	2050	75.26087° E, 33.94912° N	281	100	20	0	7.18	0
Vir Siran	2000	75.27891° E, 33.93440° N	265	180	3	17	1.13	9.44
Mamal	2150	75.31202° E, 34.02148° N	13	140	0	20	0	14.29
Mandlan	2250	75.29367° E, 34.04992° N	4	80	0	20	0	25
Aru	2450	75.26397° E, 34.09314° N	12	71	5	15	41.67	21.13
Total			575	571	28	72	4.87	12.61

Data collection

Using a multistage random sampling approach, we conducted semi-structured face-to-face interviews of the respondents or data collection. We interviewed only the heads of each family, preferably the elderly, which in most families were males. Before data collection, the head or elderly member of each household was briefed about the purpose of the work. After receiving their consent, the selected individuals were interviewed [66]. The data was collected in their native language with the help of a resident who acted as an interpreter. Based on the availability and willingness of the family heads, data were collected from a total of 100 households. The respondents were both male ($n = 94$) and female ($n = 6$), and belonged to different age groups (< 30 , $30-40$, $41-50$, $51-60$, and > 60 years old) and were with different educational status (illiterate, primary, middle, secondary and above secondary level) (Table 2). Further, the respondents had different occupations such as pastoralists, shepherds, agriculturalists, pony riders, shopkeepers, and service classes (Table 3). Apart from demographic data of respondents, details regarding the fuelwood resources, their collection and utilization patterns, and other related information were collected. The responses include both categorical and numerical ones. The species mentioned by the respondents during the interview were collected from the forests accompanied by residents. The collected data on fuelwood resources was supplemented with information gathered through extensive field observations across the study area. The data generated were arranged in spreadsheets for further analysis. Fuelwood characteristics of plant species were retrieved from available literature [11, 52, 67, 68, 69, 70, 71, 72, 73, 74]. Standard taxonomic procedures were followed for the collection, drying, and further processing of the herbarium specimens [75]. We identified the collected specimens using the taxonomic literature, online floras, and databases [76, 77, 78], and a plant inventory was prepared (Table 4), which included the family, local name, and growth form of plants. The botanical nomenclature of each plant species was updated using the POWO [79].

Table 2
Demographic data of the respondents in the Overa-Aru wildlife sanctuary,
Kashmir Himalaya.

Variable	Category	No. of respondents (%)
Gender	Male	94
	Female	6
Age (in years)	Below 30	6
	30–40	22
	41–50	38
	51–60	25
	Above 60	9
Education qualification	Illiterate	48
	Primary (upto 5th)	36
	Middle (upto 8th)	3
	Secondary (upto 10th)	11
	Above Secondary	2

Table 3
General characteristics of respondents' households ($n = 100$).

Household size	Number of households (%)	Occupation									
		Agriculturist/pony rider	Agriculturist/labour	Carpenter	Driver	Service class	Hotel owner	House wives	Pastoralist	Pony rider	Pony rider
Small	6	0	1	0	0	0	0	1	1	2	0
Medium	57	1	9	1	1	11	1	2	9	12	4
Large	37	1	6	0	1	1	0	1	9	10	4

Table 4
Inventory of fuelwood species from the Overa-Aru wildlife sanctuary with their characteristics regarding burning qualities based on different literature.
(S=Shrub; T=Tree).

S. No.	Plant species	Family	Local name	Growth form	Calorific value (kJ/gdry wt.)	Wood density (g/cm ³)	Ash (%)	Moisture content (%)	Fuel value index	Reference(s)
1.	<i>Abies pindrow</i> Royle	Pinaceae	Budhul	T	21.2	0.81	1.9	45.6	903.8	[11, 68, 70]
2.	<i>Acer caesium</i> Wall.ex Brandis	Sapindaceae	Kanzul	T	17.07	0.43	0.8	45.04	2037	[67]
3.	<i>Aesculus indica</i> (Wall. ex Cambess.) Hook.	Sapindaceae	Haandoon	T	16.02	0.72	2.7	49.69	859	[11, 67, 70]
4.	<i>Ailanthus altissima</i> (Mill.) Swingle	Simaroubaceae	Buhed	T	NA	NA	NA	NA	NA	NA
5.	<i>Betula utilis</i> D. Don	Betulaceae	Burzeh	T	22.3	0.84	2	34.2	936.6	[68]
6.	<i>Cedrus deodara</i> G. Don	Pinaceae	Deodar	T	18.9	0.85	1.6	51.2	1004.1	[11, 68, 70]
7.	<i>Celtis australis</i> L.	Cannabaceae	Brimji Kul	T	16.22	0.89	2.4	44.67	1346	[67]
8.	<i>Euonymus hamiltonianus</i> Wall.	Celastraceae	Cheer Kul	T	NA	NA	NA	NA	NA	NA
9.	<i>Fraxinus hookeri</i> Wenz.	Oleaceae	NA	T	NA	NA	NA	NA	NA	NA
10.	<i>Indigofera hebeptala</i> Benth. ex Baker	Fabaceae	Pakhur	S	20.5	0.73	1.9	49.2	787.6	[68]
11.	<i>Indigofera heterantha</i> Brandis	Fabaceae	Kecz	S	19.1	0.89	1.5	45.6	1133.26	[11, 70]
12.	<i>Juglans regia</i> L.	Juglandaceae	Doon Kul	T	15.89	0.6	2.4	57.05	397.25	[11, 70]
13.	<i>Juniperus squamata</i> Buch.–Ham. ex D.Don	Cupressaceae	NA	S	NA	NA	NA	NA	NA	NA
14.	<i>Malus domestica</i> Borkh	Rosaceae	Cxoont Kul	T	16.54	0.81	1.55	42.09	864.34	[11, 74]
15.	<i>Morus alba</i> L.	Moraceae	Tul Kul	T	16.34	0.75	4.2	50	583	[67]
16.	<i>Morus nigra</i> L.	Moraceae	Tul Kul	T	NA	NA	NA	NA	NA	NA
17.	<i>Parrotiopsis jacquemontian</i> (Decne.) Rehder	Hamamelidaceae	Poosh/Poh	S	NA	NA	NA	NA	NA	NA
18.	<i>Picea smithiana</i> (Wall.) Boiss.	Pinaceae	Kechul	T	17.38	NA	NA	NA	NA	[11, 52]
19.	<i>Pinus wallichiana</i> A. B. Jackson	Pinaceae	Kayur	T	19.03	0.49	1.8	55.29	937	[11, 71]
20.	<i>Populus ciliata</i> Wall. ex Royle	Salicaceae	Virin	T	18.56	NA	NA	NA	NA	[11, 52]
21.	<i>Populus deltoides</i> W.Bartram ex Marshall	Salicaceae	Roose Fres	T	18.53	0.41	1.48	64.63	513.33	[74]
22.	<i>Populus nigra</i> L.	Salicaceae	Kashur Fres	T	18.55	0.42	1.48	63.02	526.41	[74]
23.	<i>Prunus armeniaca</i> L.	Rosaceae	Tchereh Kul	T	NA	0.48	NA	NA	NA	[11, 73]
24.	<i>Prunus cornuta</i> (Wall. ex Royle) Steud.	Rosaceae	Zameh	T	16.39	1.08	2.33	31.68	759.7	[11, 70]
25.	<i>Pyrus communis</i> L.	Rosaceae	Tang Kul	T	15.54	0.67	1.98	47.4	525.84	[74]
26.	<i>Rhododendron campanulatum</i> D.Don	Ericaceae	Yengeh	S	19	0.70	1.50	33.10	886.70	[68]
27.	<i>Robinia pseudoacacia</i> L.	Fabaceae	Kikar Kul	T	22.22	0.64	1.5	59.07	948.05	[74]
28.	<i>Salix alba</i> L.	Salicaceae	Vir	T	19.38	0.46	1.45	63.34	614.81	[11, 74]

S. No.	Plant species	Family	Local name	Growth form	Calorific value (kJ/gdry wt.)	Wood density (g/cm ³)	Ash (%)	Moisture content (%)	Fuel value index	Reference(s)
1.	<i>Abies pindrow</i> Royle	Pinaceae	Budhul	T	21.2	0.81	1.9	45.6	903.8	[11, 68, 70]
29.	<i>Salix disperma</i> Roxb. ex D.Don	Salicaceae	Vir	T	17.4	0.63	2.49	65.4	673	[69]
30.	<i>Sorbaria tomentosa</i> (Lindl.) Rehder	Rosaceae	NA	S	15.72	NA	NA	NA	NA	[11, 52]
31.	<i>Spiraea canescens</i> D.Don	Rosaceae	Tabre Gool	S	NA	NA	NA	NA	NA	NA
32.	<i>Taxus contorta</i> Griff.	Taxaceae	Pustul	T	NA	NA	NA	NA	NA	NA
33.	<i>Ulmus villosa</i> Brandis ex Gamble	Ulmaceae	Bren	T	NA	NA	NA	NA	NA	NA
34.	<i>Ulmus wallichiana</i> Planch.	Ulmaceae	Bren	T	23.2 S	0.95	0.9	41.33	2448.89	[11, 70, 72]
35.	<i>Viburnum grandiflorum</i> Wall. ex DC	Viburnaceae	Kul Maench	S	22.1	0.81	1.2	49.7	1491.8	[68]

Estimation of fuelwood collected and utilized

To cross-check the data collected from the interviews, a random sampling across the different seasons was carried out to weigh the headloads of fuelwood collectors while returning from the sanctuary. The household size in the study area ranges from 3 to 10 individuals with an average of 6.07 individuals per household. So, the households were grouped into three categories; small (3 family members), medium (4–6 family members), and large (7–10 family members) to estimate the fuelwood collection and utilization. For this, a sample of fuelwood lot was initially weighed and left in the kitchen to be burnt and the actual fuelwood utilization was measured after 24 hours. The fuelwood utilization in these households was evaluated by deducing the weight of the remaining load after 24 hours of use from the initial weight of the wood load by using a portable digital hanging weighing scale [48]. The remaining load was utilized later on or used for making charcoals. The estimated daily fuelwood collection and utilization was then converted into mean annual fuelwood collection and utilization by each household. To estimate the total annual quantity of fuelwood utilization in the sanctuary, we multiplied the estimated mean annual fuelwood collection and utilization by each household by the total number of households in the selected villages.

Statistical analyses

We employed Pearson's correlation to investigate the relationship between age and educational status with the number of known fuelwood species using Origin Pro software (version 9.9) (OriginLab) [80]. The age of respondents was categorized into four groups while education was considered as a continuous variable (Table 2). During analysis, these variables were considered independent variables, while the categorical variables were coded. We used Chi-square test to investigate whether there are significant differences in the observed percentage of fuelwood collectors. Further, we performed one-way ANOVA to investigate whether there are significant differences in the annual fuelwood utilization patterns across the surveyed villages. Both the tests were employed in R version 4.1.2 (R Core Team) [81]. The data was also analyzed to perform Pearson's correlation matrix to determine the relationship between surveyed villages based on the annual fuelwood utilization patterns. The data visualization was performed using Origin Pro software (version 9.9) (OriginLab) [80].

Results

Demographic and socioeconomic profile

In the villages surveyed, the number of households ranged from 83 to 445 with a mean of 229 households per village. The family size decided the quantity of collection and utility of fuelwood. In households surveyed, the family size ranged from 3 to 10 members with a mean of 6.07 members per household. The land owned by each family ranged from 0.06 to 1 acre with a mean of 0.38 acre, including arable and residential lands (**Appendix-I**). Among the respondents residing in the surveyed villages, 24% were pony-riders who solely relied on tourism, 19% were pastoralists who depended upon livestock as their sole source of income, 18% were dependent on agriculture, 12% belonged to the service class, 9% were shopkeepers, 4% were housewives, while the remaining were occupied as drivers, carpenters, shepherds and hotel- and tea-stall owners (Table 3). Fuelwood was collected and carried in bags or packs (wrapped by ropes) as headloads depending upon the quantum of the material collected.

Traditional knowledge and utilization of fuelwood species

A total of 35 fuelwood species belonging to 28 genera in 18 families were known to the respondents and of these 22 species were utilized by them (Table 4 and **Appendix-I**). The most frequent collections were species of the family Rosaceae (n = 6) followed by Salicaceae (n = 5) and Pinaceae (n = 4). Sapindaceae and Ulmaceae were represented by two species each while the rest of the species were represented by a single species. Trees were the most

commonly used plants for fuelwood purpose (n = 18, 81.82%) followed by shrubs (n = 4, 18.18%) (Table 4). The respondents' preference for fuelwood species varied considerably. For instance, *Pinus wallichiana* was a highly preferred species, followed by *Abies pindrow* and *Prunus cornuta* while the least preferred species was *Ulmus wallichiana*, followed by *Fraxinus hookeri*, *Juglans regia*, *Ailanthus altissima*, and *Robinia pseudoacacia*.

Burning qualities and characteristics of the fuelwood species

As described in the methods, we consulted the existing literature to understand the fuelwood characteristics of each fuelwood species that occur in the sanctuary (Table 4). Of the fuelwood species utilized by the households, the calorific value (kJ/g dry wt.) was highest for *Ulmus wallichiana* (23.20), followed by *Betula utilis* (22.30) and *Robinia pseudoacacia* (22.22). Conversely, *Pyrus communis* has the lowest calorific value (15.54 kJ/g dry wt.), followed by *Sorbaria tomentosa* (15.72) and *Juglans regia* (15.89). The wood density (g/cm³) was highest for *Prunus cornuta* (1.08), followed by *U. wallichiana* (0.95) and *Celtis australis* and *Indigofera heterantha* (0.89 each) while the lowest was for *Populus deltoides* (0.41), followed by *Populus nigra* (0.42) and *Acer caesium* (0.43). Further, *Morus alba* has the highest ash content (4.20%), followed by *Aesculus indica* (2.70%) and *Salix disperma* (2.49%) while the lowest was for *A. caesium* (0.80%), followed by *U. wallichiana* (0.90%) and *Viburnum grandiflorum* (1.20%). The highest moisture content was in *S. disperma* (65.49%) followed by *P. deltoides* (64.63%) and *Salix alba* (64.34%) and the lowest was in *P. cornuta* (31.68%), followed by *Rhododendron campanulatum* (33.10%) and *B. utilis* (34.20%). As per Fuel Value Index (FVI), *U. wallichiana* has the maximum reported FVI (2448.89), followed by *A. caesium* (2037) and *V. grandiflorum* (1491.8), while the lowest FVI was for *J. regia* (397.25), followed by *P. deltoides* (513.33) and *P. communis* (525.84) (Table 4).

Patterns of fuelwood collection and utilization

Of the villages surveyed, Overa and Aru were located inside the sanctuary while Vir Siran and Mamal were partially covered by the sanctuary and the village Mandlan was located at the fringe of the sanctuary. The collectors trekked from their respective villages for fuelwood collection. The fuelwood collection and utilization varied from household to household, village to village and community to community. Among the two communities residing in the selected villages, the *Gujjars* collected fuelwood throughout the year while *Kashmiris* collected fuelwood in some months of the summer season, and few months before the advent of winter. For instance, the *Kashmiri* community residing in the village Overa collected fuelwood during April–December while the *Gujjar* community collected fuelwood throughout the year. Gender-wise, males collected fuelwood during the snowy season and females during the rest of the year. The households in the villages of Vir Siran, Mamal and Mandlan collected fuelwood during May and June in summer while in winter it was carried out during October–December and September–December respectively. Likewise, the households of village Aru collected fuelwood during the months of April and May in summer, and during winter, it was carried out during September–December (**Appendix-I**). The *Kashmiri* community skips the hot months of summer season for the collection of fuelwood and also during the holy month of Ramadan as they observe fasting. However, both the communities prioritize to store the fuelwood for peak winters, when the outdoor movement is severely hampered due to a well-known 40-day long chilling period (*Chillai Kalan*) and plenty of snowfall. The mud *chulhas* are used by villagers for cooking purposes (Fig. 2). Furthermore, the villagers are also using fuelwood-based fire pits and kerosene stoves.

The number of individuals collecting fuelwood/household/day ranged from 1–3 with a mean of 1.42 ± 0.05. The total days of fuelwood collection was highest for the households of village Overa with an average of 245/year while it was the lowest for the households of village Vir Siran with an average of 153/year (Table 5). Our study revealed that the collectors trekked on an average of 2–4 km/day/collection (to-and-fro) to collect fuelwood from the sanctuary, and during the collection children accompanied them occasionally. Concerning fuelwood collectors, 77% of the respondents stated that fuelwood collection was carried out by females, while only 5% of the respondents stated that it was related to males only. However, 18% of the respondents responded that fuelwood collection was appertained to both males and females. Also, the results of Chi-square test clearly showed that the percentage of fuelwood collectors varied significantly across the study area ($\chi^2 = 88.34$, $df = 2$, $p < 0.01$). Concerning family size classes, 6% belonged to the small family category, 57% to the medium family category, and 37% to the large family category. A small family collected a mean of 33.33 ± 4.22 kg of fuelwood per household, a medium family 33.95 ± 1.70 kg, and a large family 38.78 ± 2.35 kg (Table 6). The annual collection per household was 6113.33 ± 914.14 kg for a small family, 6455.88 ± 405.96 kg for a medium family and 8657.43 ± 785.19 kg for a large family. (Table 6).

Table 5
Village wise collection and utilization of fuelwood (Mean ± SE). (kg=Kilogram; HH=Household; Yr=Year) (Note: *Gujjar* community collected fuelwood throughout the year).

Name of the village	Collection (kg/HH/Day)	Collection (kg/HH/Yr)	Utilization (kg/HH/Yr)	Total collection days/Yr
Overa	49 ± 0.69	12305 ± 355.20	9397.50 ± 298.02	245
Vir Siran	46 ± 2.61	8204 ± 985.87	7452.50 ± 657.41	153
Mamal	33.50 ± 1.96	6130.50 ± 358.09	5422.50 ± 382.80	183
Mandlan	23 ± 1.64	4209 ± 299.82	2890 ± 272.47	183
Aru	27 ± 2.28	5401 ± 691.12	4392.50 ± 657.05	183

Table 6
Fuelwood collection and utilization by respondents' household size (Mean $\pm$ SE). (kg=Kilogram; HH=Household; Yr=Year).

Household size	Number of households	Collection (kg/HH/day)	Collection (kg/HH/Yr)	Utilization (kg/HH/Yr)
Small (≤ 3 family members)	6	33.33 $\pm$ 4.22	6113.33 $\pm$ 914.14	4941.67 $\pm$ 746.68
Medium (≤ 6 family members)	57	33.95 $\pm$ 1.70	6455.88 $\pm$ 405.96	5380.70 $\pm$ 339.63
Large (≤ 10 family members)	37	38.78 $\pm$ 2.35	8657.43 $\pm$ 785.19	6885.14 $\pm$ 629.77

Village-wise annual fuelwood collection depicts that the maximum fuelwood was collected by the households of village Overa with a mean of 12305 $\pm$ 355.20 kg/household, followed by Vir Siran (8204 $\pm$ 985.87 kg/household) while it was minimum for the households of Mandlan with a mean of 4209 $\pm$ 299.82 kg/household/year. Further, regarding annual fuelwood utilization, a similar pattern was followed like the annual fuelwood collection with the households of village Overa utilizing maximum fuelwood with a mean of 9397.50 $\pm$ 298.02 kg/household/year, followed by Vir Siran (7452.50 $\pm$ 657.41 kg) while it was minimum for the households of Mandlan with a mean of 2890 $\pm$ 272.47 kg (Table 5). Also, the results of ANOVA showed significant differences in the annual fuelwood utilization patterns across the surveyed villages ($F = 27.91$, $df = 4$, $p < 0.01$). Pearson's correlation test revealed a weak relationship between the villages on annual fuelwood utilization patterns (Fig. 3). Our study showed a seasonal variation in the fuelwood utilization. For instance, during the summer season, a small family utilized fuelwood with a mean of 8.33 $\pm$ 2.79 kg per household/day, a medium family utilized 8.77 $\pm$ 1.09 kg, while a large family utilized 11.62 $\pm$ 1.84 kg. On the other hand, during the winter season, a small family utilized 24.17 $\pm$ 2.01 kg/household/day, while a medium and large families utilized 26.93 $\pm$ 0.88 and 33.65 $\pm$ 1.96 kg, respectively (**Appendix-I**). The quantity of fuelwood utilization during the summer season ranged from 0–40 kg/household/day with a mean of 9.50 $\pm$ 0.95 kg/household/day while during the winter season it ranged from 20–60 kg/household/day with mean of 29.25 $\pm$ 0.95 kg/household/day (**Appendix-I**).

To summarize, the total annual fuelwood collection ranged from 3660–20075 kg/household with a mean of 7249.90 $\pm$ 387.86 kg/household, of which a small family collected 6113.33 $\pm$ 914.14 kg/household, a medium family collected 6455.88 $\pm$ 405.96 kg and a large family collected 8657.43 $\pm$ 785.19 kg. The total annual household fuelwood utilization ranged from 2400–17000 kg/household with a mean of 5911 $\pm$ 313.01 kg/household, out of which a smaller family utilized with a mean of 4941.67 $\pm$ 746.68 kg/household, a medium family utilized 5380.7 $\pm$ 339.63 kg and a larger family utilized 6885.14 $\pm$ 629.17 kg/household (Table 6). The total annual fuelwood utilization by all households of the selected villages located in or at the fringes of the sanctuary was 67,74,006 kg, out of which 27,51,546 kg were utilized during summer months and 40,22,460 kg during winter months.

Relationship between various variables studied

We recorded a significantly strong positive relationship between the age of respondents and the number of citations of fuelwood species ($r = 0.84$, $p < 0.05$) (Fig. 4a), which indicates that the elder persons have more knowledge on the number of well-known and widely used fuelwood species. The significant negative relationship between education status and the number of citations ($r = -0.78$, $p < 0.05$) (Fig. 4b), revealed that educated persons have lesser knowledge about fuelwood species than non-educated persons.

Discussion

Utilization of fuelwood species

The locals residing in the villages located in or at the fringes of the sanctuary utilize wood as a main source of fuel for room- and water-heating and cooking purposes. They utilize diverse plant species as fuelwood. Our results revealed that the utilization of fuelwood species highly depends on the easy availability and good fuelwood characteristics. Though trees have much higher potential as fuelwood sources compared to shrubs, the significance of the latter cannot be underrated and can prove useful in reducing the pressure on tree species which in turn facilitate tree cover in the sanctuary [11, 82, 83, 84]. The results showed that the fuelwood utilization was maximum by *Gujjar* families as compared to *Kashmiri* families (**Appendix-I**). However, there is not much variation in fuelwood collection between households, because the headloads carried by fuelwood collectors are more or less equal in weight. Forest rules implemented by the Jammu and Kashmir government and dwindled forest resources have constrained the fuelwood collection. On the other hand, easy accessibility and availability of fuelwood, low socioeconomic status, skyrocketing price of commercial fuel, and lack of employment opportunities among the locals increase the unsustainable use of fuelwood. Further, the daily demands and intense cold conditions in the region were not mitigated by electricity and commercial fuels. As revealed by the high-frequency citation values and respondents' preference for each fuelwood species, *Pinus wallichiana* and *Abies pindrow* were frequently used fuelwood species by the locals. The highest preference for these fuelwood species has also been reported from other areas in western Himalaya [85] and Kullu and Manali region of Himachal Pradesh [49, 52]. The plausible reason behind this could be the abundance of these species in this area [11].

The collection and utilization of fuelwood from temperate forests have been attributed to species composition and distribution [86]. Various studies divulge that the presence of forests in the surroundings enhances the inhabitants' traditional knowledge of the accessible species and their utilization [47, 87, 88]. The easy accessibility and abundance of fuelwood could change the preference of utilization [49, 89, 90]. Hence, only those species which possess better fuelwood characteristics and are easy to collect were preferred for utilization [11, 83, 91]. This can be depicted by the intensive looping of preferred fuelwood species in the western Himalaya [11, 92]. The respondents revealed that the fuelwood collectors mainly collect fallen logs, branches, and twigs for fuelwood. Since the government has implemented a blanket ban on chopping forest trees in the present study area, similar laws were promulgated in the other regions of the Himalaya [11, 93, 94, 95]. Besides use as fuelwood, the locals utilize trees for other purposes such as for making agricultural implements, poles for fencing, rachis for baskets, and firepots which in turn put immense pressure on forests [11]. The sustainability of traditional fuelwood selection, collection, and combustion practices calls for urgent modernization to enhance both efficiency and conservation efforts [96, 97]. Traditional methods often contribute

to deforestation and environmental degradation, threatening long-term viability [98, 99]. The adoption of modern approaches, including use of efficient cooking stoves and sustainable wood harvesting, is imperative for preserving ecosystems, reducing emissions, and ensuring a more sustainable energy future [100]. This shift towards modernization aligns with the broader goals of resource conservation, environmental protection, and improving the overall well-being of communities dependent on fuelwood, offering a promising path toward a more sustainable and eco-friendlier landscapes [101].

Characteristics of the fuelwood species

Our results revealed that the fuelwood characteristics, easy accessibility, and availability of fuelwood species are the prime indices of fuelwood utilization, and these observations were shared by the local communities residing in or at the fringes of the sanctuary. Fine chips of *Pinus wallichiana*, locally known as “Lesh” are often preferred by the *Gujjar* communities for igniting fire because they easily catch fire. The wood of *Pinus wallichiana*, *Abies pindrow* and *Prunus cornuta* was preferred because of their good burning quality, high calorific value, low ash content, and coal-forming properties. Similarly, the *Bhangalis* community residing in the *Chhota Bhangal* region of Himachal Pradesh utilizes the same fuelwood species as above [11]. This indicates the high preference for the above-mentioned fuelwood species by the respondents. People prefer wood that dries rapidly, burns gradually, and generates good heat and flames, simultaneously produces less smoke and low ash content [11]. These characteristics depict the role of recognizing people's perception of preferred fuelwood species. The locals revealed that the wood of *Pinus wallichiana* and *P. cornuta* provides maximum energy while the wood of *Picea smithiana* generates smokeless fire. Further, species with low moisture content such as *P. cornuta* are mostly preferred as fuel because of easy looping, higher energy content per unit volume, and slow burning rate. Based on the burning qualities and characteristics of documented fuelwood species, the local communities residing in the villages located in or at the fringes of the sanctuary frequently utilize those species that furnish good quality fuelwood.

Patterns of fuelwood collection and utilization

Results of this study indicate that family size plays an important role in guiding the collection and utilization of fuelwood [11, 102]. The reason behind the maximum fuelwood collection by large families could be due to the huge demand for fuelwood because of the higher family size. A similar pattern has been reported in *Chhota Bhangal* of Himachal Pradesh, where fuelwood collection was a mean of 52.17 ± 9.97 kg/household/day for a small family, 62.86 ± 11.74 kg/ for a medium family and 69.93 ± 13.01 kg for a large family [11]. Likewise, the daily fuelwood collection and utilization by the semi-nomadic pastoralist community “*Van Gujjars*” of Corbett Tiger Reserve has been estimated as a mean of 20.09 ± 0.7 kg/household/day [50]. Similarly, fuelwood collection and utilization in rural villages of southern Africa was recorded as 5.75 ± 0.47 kg/household/day [103]. Our results also showed the low percentage of males as fuelwood collectors and may be due to their other engagements. Similar studies carried out elsewhere also showed that fuelwood collection mainly relies on females [104, 105]. Further, males carry wood logs on their back while females carry fuelwood as headloads to their respective villages (Fig. 2) [106, 107]. The respondents also informed that fuelwood collectors besides collecting fallen branches, also undertake lopping of trees which was mainly done by males, as it is difficult for females to climb trees. Similarly, in Sierra Leone of west Africa and *Bhangalis* community of western Himalaya, females were mainly engaged in fuelwood collection [11, 108]. Since, there is a well-demarcated winter in the study area, a seasonal variation in the quantity of fuelwood collection and utilization was noted (**Appendix-I**).

This study also revealed that the magnitude of fuelwood resource utilization varied across the villages. The maximum fuelwood collection and utilization by the village Overa could be due to the greater number of households in that village. The inhabitation of *Gujjar* community in the village who collect and utilize the fuelwood throughout the year could be another reason. The relatively lower fuelwood collection by the households of the village Mandlan could be due to the increased availability of alternative sources of energy (i.e., regular supply of electricity, LPG and kerosene oil). Concerning fuelwood utilization per capita, the study showed that the mean per capita fuelwood utilization for each household of the selected villages was 4.51 kg/day for smaller families, 2.78 kg/day for medium families and was 2.10 kg/day for larger families which is higher than the per capita fuelwood consumption for households of Sirmaur District of Himachal Pradesh in the western Himalaya where it was recorded as a mean of 1.96 kg/capita/day [109]. Similarly, per capita fuelwood consumption by semi-nomadic pastoralist community “*Van Gujjars*” of Corbett Tiger Reserve is a mean of 2.77 kg/day [50]. However, in Alaknanda valley, mean fuelwood consumption was a mean of 2.05 kg/capita/day [91]. In Lahaul valley of north-western Himalaya, the daily fuelwood utilization ranged from 0.91 kg/capita among larger families to 2.74 kg/capita among smaller families [86]. A similar pattern of seasonal fuelwood utilization has been reported from *Chhota Bhangal* of Himachal Pradesh where during the winter season mean fuelwood utilization for a small family was 20.24 ± 2.2 kg/household/day, and medium and large families utilized 23.93 ± 2.3 and 25.55 ± 2.5 kg respectively, while during the summer season it was 13.00 ± 1.75 kg/household/day for a small family, the rate was 17.07 ± 2.09 kg for a medium family and 17.23 ± 1.69 kg for large families. [11]. Likewise, the fuelwood utilization by *Van Gujjars* of Corbett Tiger Reserve was a mean of 16.12 ± 3.29 kg/household/day for small families and for larger families it was 26.11 ± 7.00 kg. All these results indicate a seasonal variation in both fuelwood collection and utilization among the local communities of selected villages located in or at the fringes of the sanctuary; a significant difference ($p < 0.05$) was observed for both the variables during the summer and winter seasons. Similar patterns were also observed from Lahaul valley of Himachal Pradesh [86] and Garhwal and Alaknanda valley of Uttarakhand Himalaya [91, 102], Dolakha district of Nepal [110] and *Bhangalis* community of western Himalaya, India [11]. Understandably, during winters the required quantity of fuelwood is comparatively high to fill the flames in firepots (*Kangris*) and also to keep the rooms warm. Another reason is that the chilling cold during winter hampers the outdoor movement of people, so indoor gatherings are common during this season ultimately leading to the utilization of a maximum quantity of fuelwood, which is comparatively higher than the reports of other studies in the Himalayan region. For instance, the annual fuelwood utilization by the villagers residing in the periphery of Adwani forest range, Uttarakhand ranged from 5504.88–6720.48 kg with a mean of 5960.40 ± 468.72 kg. Similarly, in Hat-Kalika, Pithoragarh, of western Himalaya, the total annual household fuelwood collection ranged from 1256.6–2916.4 kg/household/year. Likewise, the total annual fuelwood collection ranged from 5124 to 7992 kg/household in Himachal Pradesh [12]. Also, total annual fuelwood collection varied between 6237 and 6498 kg/household in the Manali wildlife sanctuary in Himachal Pradesh [49]. This difference in fuelwood collection in different Himalayan regions can be ascribed to the increase in the severity of cold from eastern Himalaya to the western Himalaya [83].

Relationship between fuelwood collection and demographic variables

We observed a strong affiliation of aged people with forests and forest resources. Also, elderly people mostly stay at home engaged in traditional work including the utilization of fuelwood [11]. However, there is limited dissemination of traditional knowledge to the younger generation which can dwindle the traditional knowledge of forest and forest products among future generations. Such patterns in age-determined possession of traditional knowledge have been also reported from elsewhere [8, 11]. It is also clear from the results of the study that the households with higher educational status and employment opportunities were less dependent on forest resources since they have other livelihood options [111, 112]. These results agree with other studies which reported that the lower the education status of people, the higher their dependency on forest resources and they thus inherit useful traditional knowledge [11, 50]. The present findings can guide the demand and supply of fuelwood that could be beneficial for sanctuary management plans, especially in the plantation of preferred fuelwood species. Integrating the cultivation of preferred fuelwood species into plantation drives can ease pressure on forests and also bridge the gap between the demand and supply of fuelwood resources. In short, this study would help to guide the sustainable management of fuelwood resources in this Himalayan protected area, and the lessons learnt can be translated elsewhere.

Limitations of the study

The study revealed the diversity and utilization patterns of fuelwood species in Kashmir Himalaya. The fuelwood is a crucial energy source for mountainous communities, especially in the Himalayan region, contributing to household livelihoods and meeting energy needs. Nevertheless, the present study used relatively smaller sample size, which may preclude the findings from being extrapolated to other mountainous ecosystems across the world. Also, the utilization patterns of each fuelwood species individually, estimation of utilization patterns among different communities or the remaining load which was used for making charcoals was beyond the scope of present study, which need to be considered in future studies. Furthermore, role of the recently launched centrally-sponsored schemes such as Ujjwala Yojana on fuelwood utilization pattern merit attention of future researchers.

Conclusions

In India, fuelwood collected from forests constitutes the prime source of household energy for sustaining human wellbeing and livelihood in remote rural areas, especially in the Himalayan region. In particular, the study area of this work experiences harsh and prolonged winters that compels the locals to store and utilize ample fuelwood, and the per capita fuelwood utilization was highest during the winter months usually for cooking and keeping houses warm during the cold winter. Likewise, the rate of fuelwood utilization is also important for local communities in the region. The harsh and prolonged winters and the deprived socioeconomic status of people are prominent driving forces behind the total dependence on forest resources. The local community which extracts fuelwood from the sanctuary also holds precious traditional knowledge regarding the quality of different fuelwood species. And, the traditional knowledge is sociocultural dependent, related to age and education status. The duration, quantity and utilization of fuelwood varied considerably among communities and households. The species with a high frequency of citation values have good burning qualities and fuelwood characteristics. The demand and frequent utilization of the fuelwood species can put immense pressure on the community assemblages. It is thus necessary to educate the public with the consequences of unsustainable fuelwood utilization and the current rate of depletion of the resources. The unavailability of preferred fuelwood species in the vicinity of villages would compel the locals to access relatively undisturbed forest belts. In this context, the availability of fuelwood from agro-ecosystems offers direct benefits to the local communities.

To the best of our knowledge, this is the first-ever study on fuelwood diversity and utilization from Kashmir Himalayan protected areas. The information generated by this study would be useful while developing the sanctuary management plans, especially in the plantation of preferred fuelwood species, and alleviate the detrimental impacts on biodiversity and also sustain the supply of ecosystem services provided by the sanctuary.

Recommendations and policy interventions

Based on the insights gained from the present study, we suggest the following recommendations and the need of policy interventions:

- Identification of barren lands at the lower elevations in the sanctuary and afforesting them with preferred fuelwood species will reduce the dependance for fuelwood from forests. Integrating preferred fuelwood species such as *Abies pindrow*, *Pinus wallichiana* and *Prunus cornuta* into scientifically managed plantations can also ease pressure on forests and bridge the gap between the demand and supply of fuelwood resources.
- Promoting fuelwood species in agro-ecosystems can reduce the current pressure on fuelwood resources from forests.
- The burning qualities of fuelwood species in the sanctuary should be validated scientifically. This will aid in the preference of fuelwood species for plantation purposes.
- To mitigate the emission of greenhouse gases from the combustion of fuelwood, government and non-government organizations should provide alternative sources of energy (regular supply of electricity, LPG and kerosene oil).
- Awareness programs on the importance of forest resources should be conducted regularly in villages adjacent to the sanctuary. This will help in the management and proper utilization of fuelwood species based on their different qualities as fuel.
- Unrestricted and uncontrolled extraction of fuelwood from forests needs to be curtailed through implementation of efficient policy measures. To help with this, the concerned Government departments may also notify the criteria for fuelwood collections from forests by the local communities.

Declarations

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CRediT authorship contribution statement Authorship contributions statement

Tajamul Islam: Conceptualization; Methodology; Data collection; Curation and analysis; Software; Visualization; Writing-Original draft; Revision. **Anzar Ahmad Khuroo:** Conceptualization; Methodology; Supervision; Investigation; Validation; Writing-Original draft; Revision. **Irshad A. Nawchoo:** Conceptualization; Supervision; Investigation; Validation.

Declaration of competing interest

The authors declare that they have no financial or non-financial competing interests.

Data availability

The data will be made available on request.

Clinical trial number: Not applicable.

Ethics statement: All procedures performed in studies involving human participants were in accordance with the ethical standards and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The ethical approval is provided by University of Kashmir.

Human and Animal Ethics: The present study does not involve any human or animal usage.

Consent to Participate statement: Informed consent was obtained verbally before each interview in order to clearly state the objectives of present study and to obtain their consent to participate. Each of the interviewees was informed beforehand of the confidentiality of this study, and of his/her right to withdraw its participation at any time, and of the objective of a publication under the form of a scientific publication.

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Figures

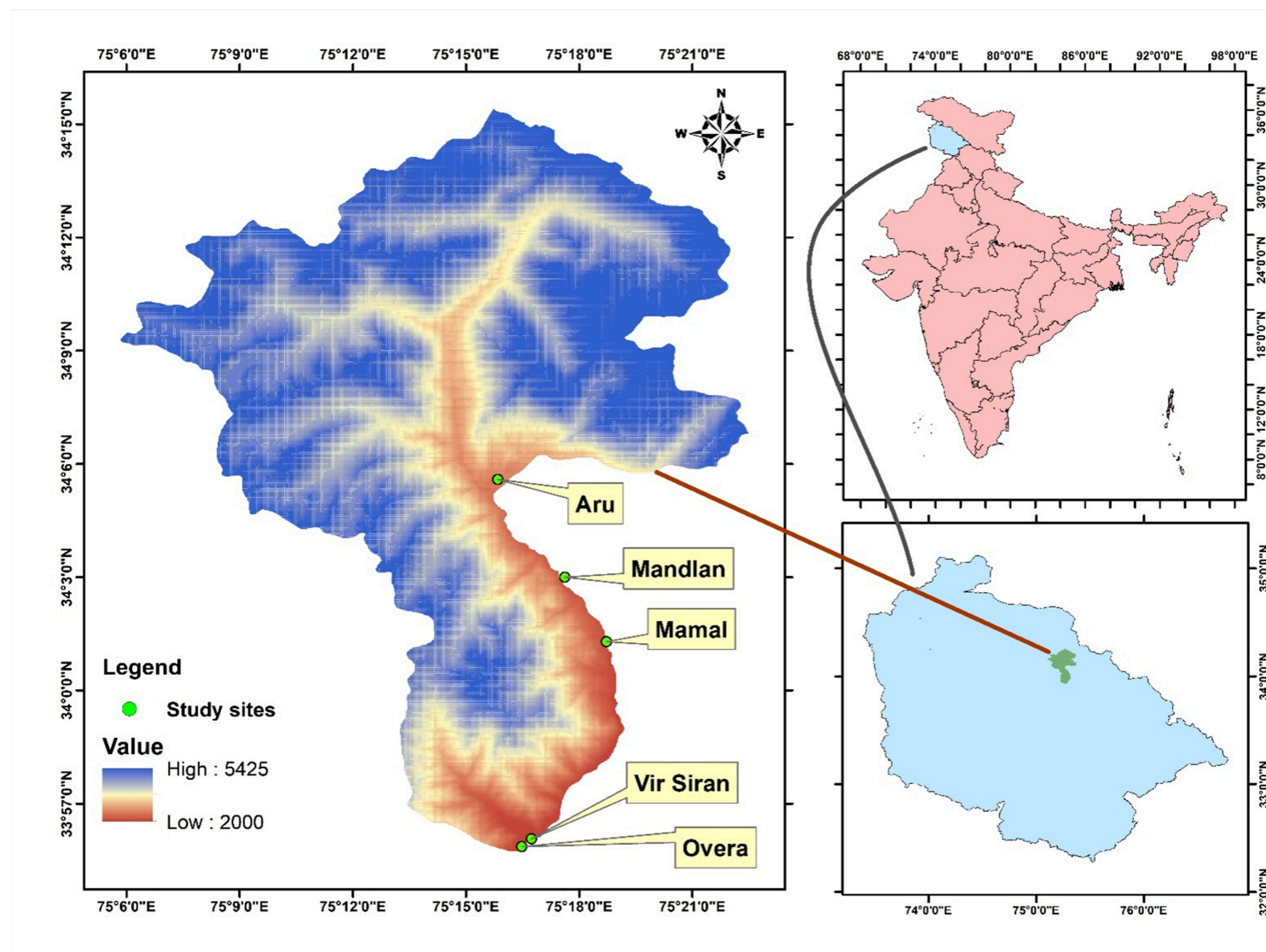


Figure 1

Map showing the villages located in or at the fringes of Overa-Aru wildlife sanctuary.

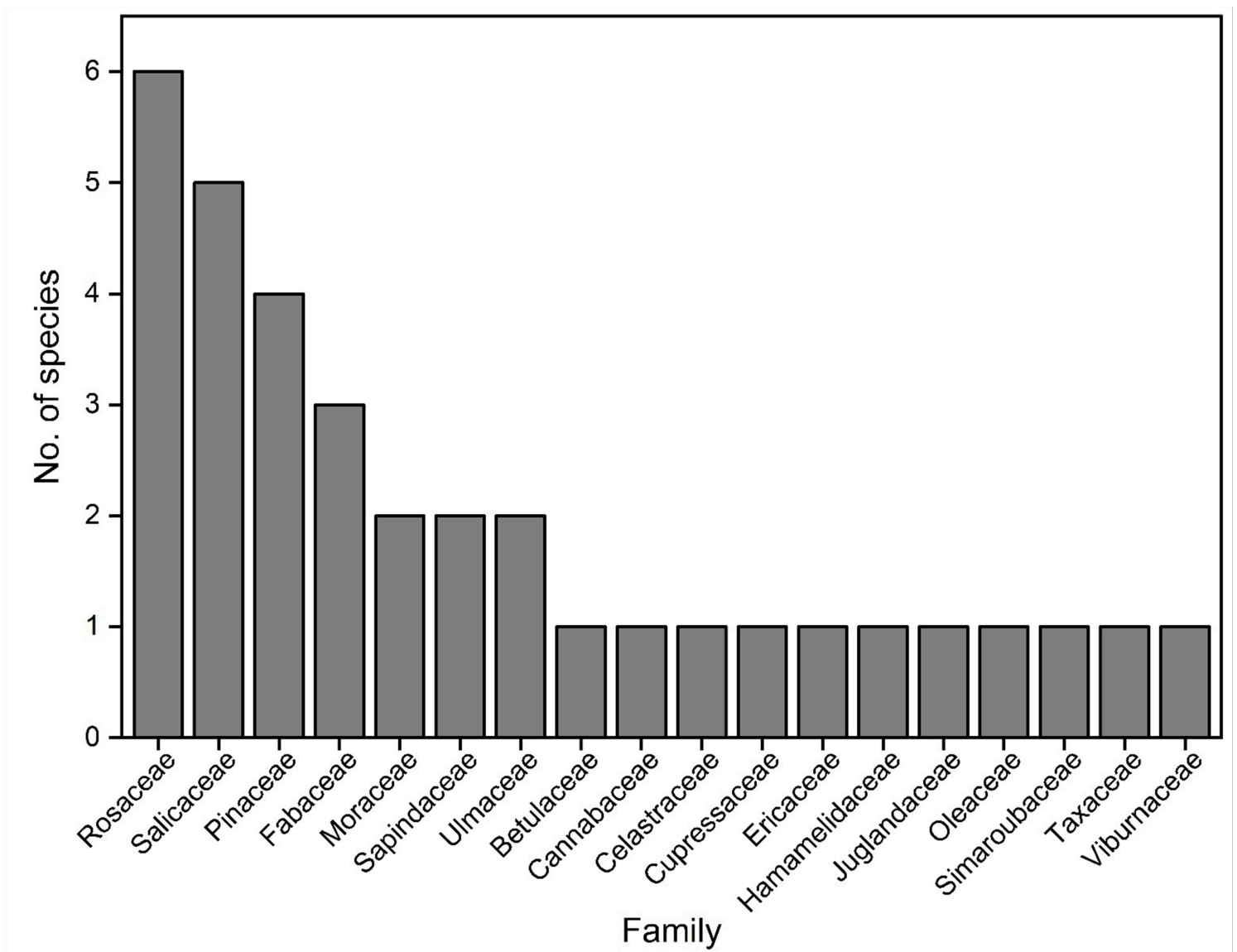


Figure 2

Dominant families with their species number recorded as fuelwood species in Overa-Aru wildlife sanctuary.

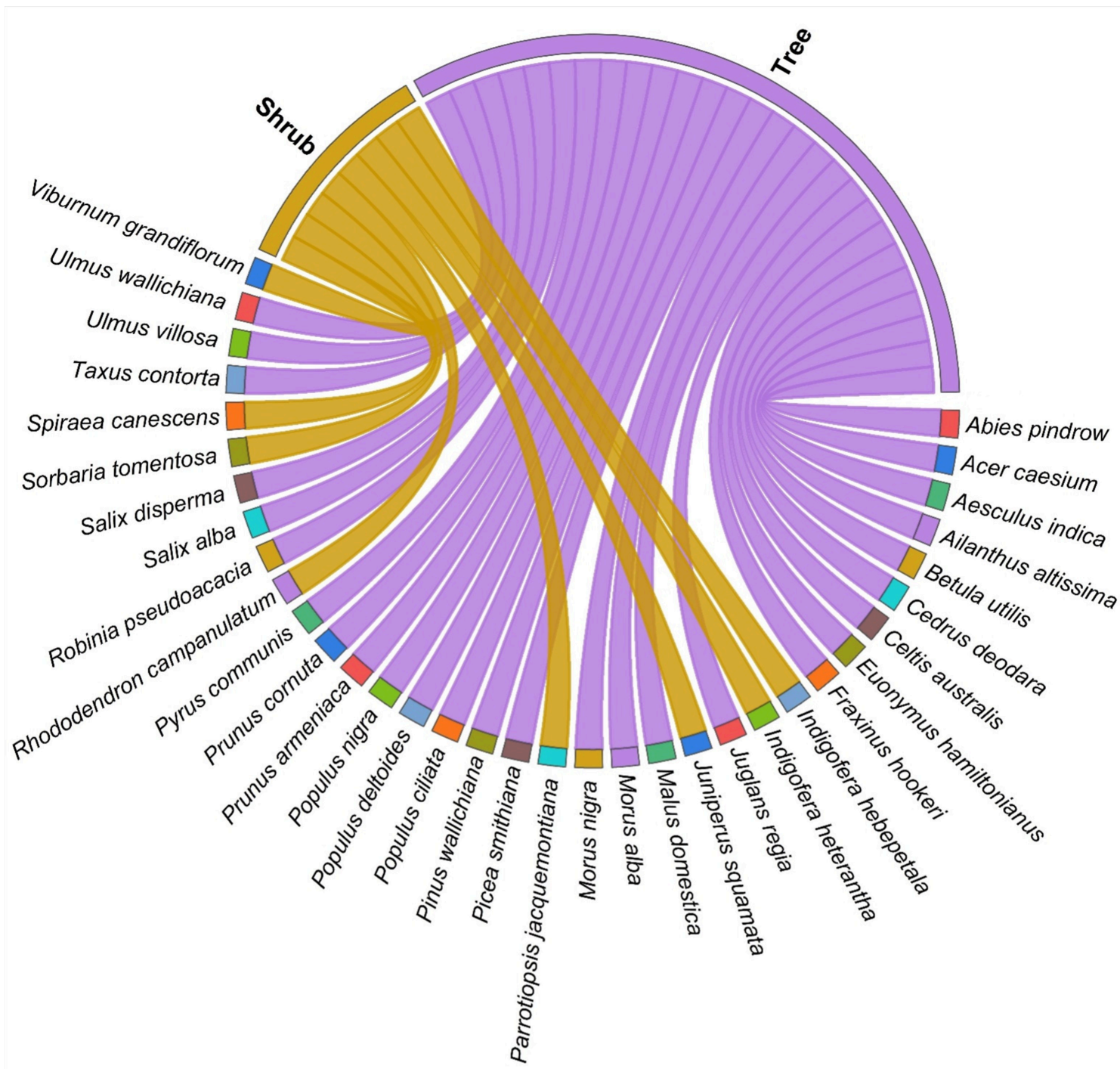


Figure 3

Life-form wise category of known fuelwood plant species in Overa-Aru wildlife sanctuary.



Figure 4

a&b – Females with a headload of fuelwood; **c&d** – Fuelwood stored for winter season; **e&f**– Fuelwood with flames in mud *chulha* used for cooking purpose.

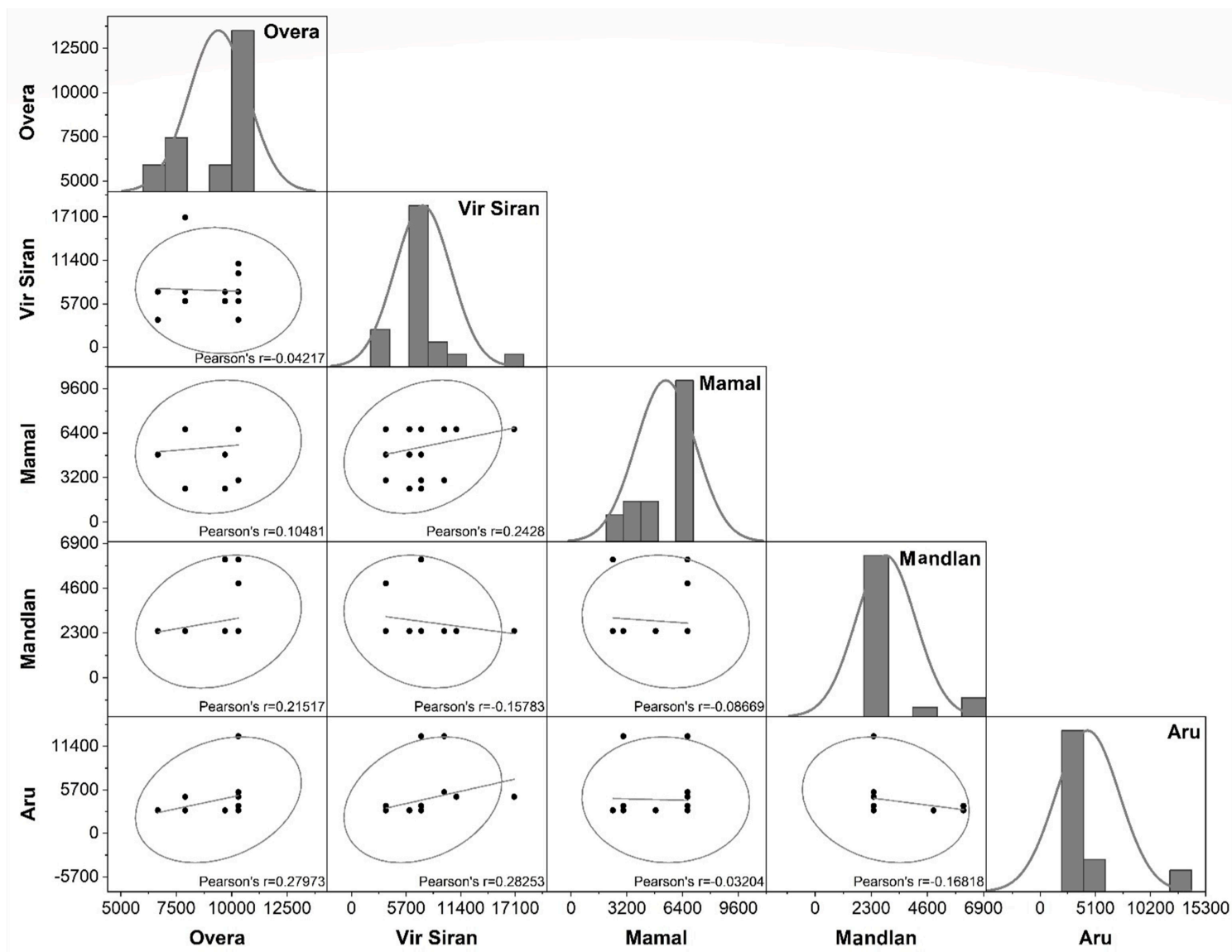


Figure 5

Correlation matrix showing the relationship between surveyed villages based on based on the annual fuelwood utilization patterns in Overa-Aru wildlife sanctuary.

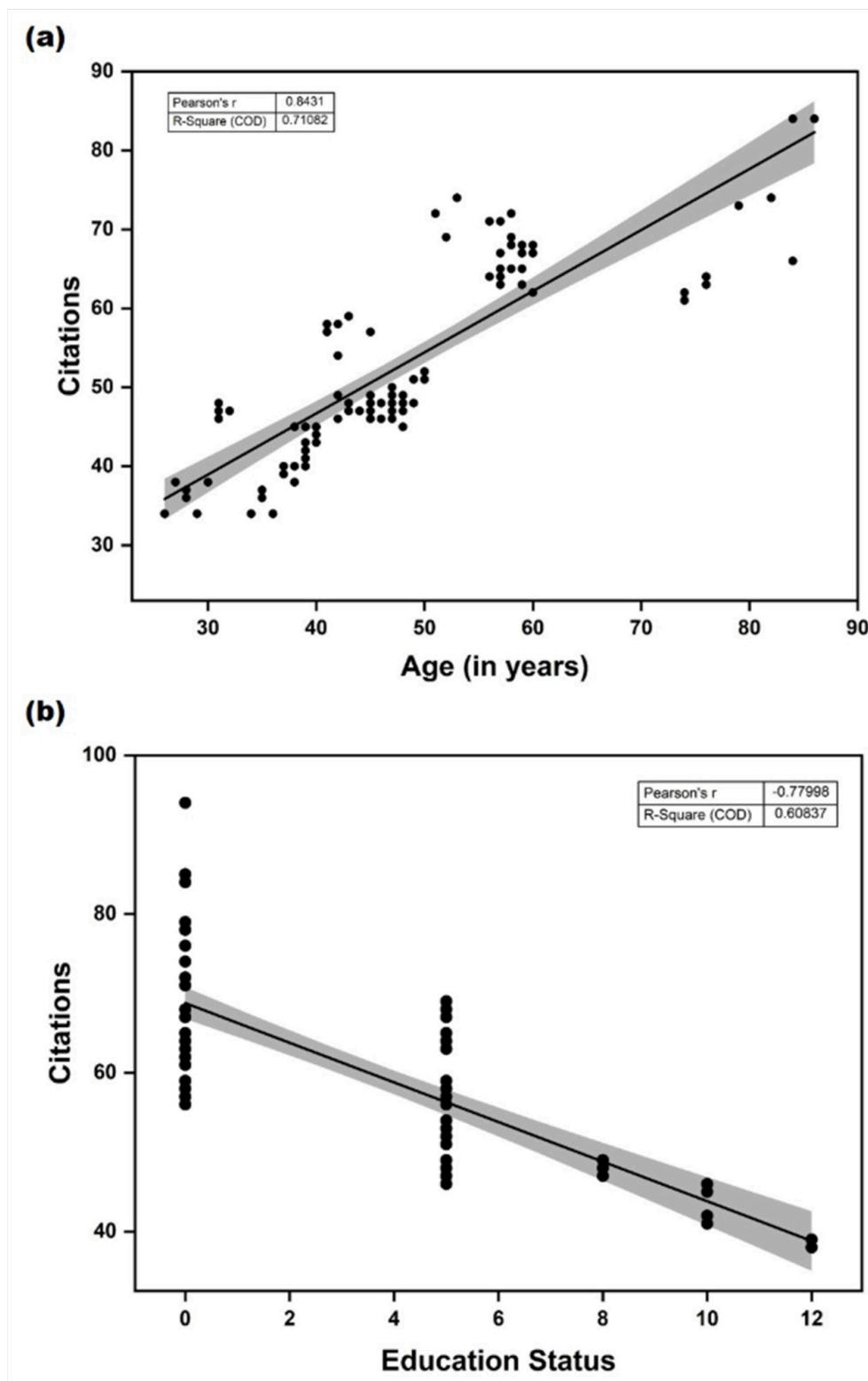


Figure 6

(a). Correlation plot representing relationship between age (in years) of respondents interviewed in Overa-Aru wildlife sanctuary and number of citations ($r = 0.84$). Each black dot in the plot represents the number of citations and the grey areas represent a 95% confidence interval, (b). Correlation plot representing relationship between education status of respondents interviewed in Overa-Aru wildlife sanctuary and number of citations ($r = -0.78$). Each black dot in the plot represents the number of citations and the grey areas represent a 95% confidence interval: 0-Illiterate; 5-Primary; 8-Middle; 10-Secondary; 12-Above secondary.