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Original Research

Assessment of Ecosystem Services and Regeneration Patterns of Subalpine *Betula utilis* Forests in Western Himalaya

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Abstract

Betula utilis is an indicator species of subalpine forest in the western Himalayan region, performing dynamic ecological functions and providing significant ecosystem services to rural mountainous communities that support livelihoods in harsh environmental conditions. The current study was designed to investigate the ecosystem services and regeneration patterns of *Betula utilis* forest in the subalpine zone of Kashmir, western Himalayas. The questionnaire method was used for collecting ethnobotanical and fuelwood data. The systematic quadrat method was used for assessing the regeneration patterns of *B. utilis* forest at 15 sites. *B. utilis* is a versatile plant with significant religious and cultural values, as well as being used for the treatment of various diseases in humans and animals. Results of fuelwood consumption revealed that mountainous rural communities consumed an average of 7.18 kg/capita/day. The linear regression analysis showed that fuelwood consumption values increase along the altitude of the investigated area. As altitude increases, the rural population uses more fuelwood for heating purposes to sustain their lives in harsh environmental conditions. The average seedling density was calculated at 1351.47/ha in the study area. Significant regeneration was observed in some sites, while others showed a lower regeneration rate due to immense anthropogenic pressure. The seedlings and saplings showed a higher number, ranging from 1429/ha to 911/ha, 1915/ha to 495/ha, 1054/ha to 623/ha, and 1493/ha to 436/ha on the south and north aspects, respectively. The north-facing aspect depicts more seedling and sapling numbers due to favorable conditions, whereas

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the south-facing aspect showed fewer numbers as compared to the north-facing aspect. Climate change and anthropogenic pressure significantly affect the long-term viability of *Betula* forests in subalpine zones because of their restricted ecological niches. Immediate management strategies are required to minimize these threats and implement effective conservation strategies and a sustainable forest management policy for the preservation of the subalpine forest in Kashmir.

Keywords: fuelwood consumption, subalpine forest, seedlings, north aspect, Kashmir

Introduction

Ecosystem services are the benefits that humans derive from their forest ecosystems, which promote their well-being through ecological characteristics, functions, and products and help them understand the relationship between rural populations and ecosystems in accordance with the regenerative sustainability approach [1-4]. Numerous ecosystem services produced by forest ecosystems support over 1.6 billion people's livelihoods directly or indirectly around the globe and improve the quality of life on the planet [5]. The forest provides a wide range of products for millions of households, particularly in the rural areas of developing nations [6-9]. Forest products are broadly classified into carbon and non-carbon products. Carbon products include fuel wood, timber, and medicinal plants [10], whereas non-carbon products include carbon storage, soil water conservation, ecotourism, and climate regulation [11, 12]. Forest products play a crucial role in the economic development of rural populations [13-15].

B. utilis D. Don is an important tree species of the *Betula* genus in the family Betulaceae [16]. The genus *Betula* is commonly known as birches, which are only angiosperm broadleaved species present at high altitudes and latitudes. This genus is widely distributed in the Northern Hemisphere, polar boreal forests, and alpine tree lines [17]. The World Checklist of the selected plant families recognizes 62 species of the genus *Betula*, all of which are essential ecological components of northern temperate and boreal forests across the world [18]. *B. utilis* is the only angiosperm broadleaved species present in the Himalayas and dominates most of the area at subalpine altitude. It is a moderate-sized tree that grows up to 20m in height [19]. *B. utilis* tree line vegetation helps to maintain the fragile ecosystem of the Himalayas, which controls soil erosion and creates a bioshield for the rest of the forest and Alpine meadows [20].

Fuelwood consumption is the main energy source for cooking, heating rooms, etc. for rural populations in the western Himalayan region [21, 22]. Due to the limited availability of energy sources, poor socioeconomic status, bad road connectivity, and the high cost of other commercially available energy sources, people continue to depend on the forest ecosystem to sustain their lives in harsh environmental conditions [23, 24]. Globally, 2.8 billion people, the world's poorest and most marginalized rural populations, use biomass to cover their daily home energy needs [25]. Biomass extraction may additionally threaten forests' potential to provide a healthy environment for people by contributing to global forest deforestation, degradation, and climate change [26, 27]. The Western Himalayan region has high fuelwood demand, which has resulted in the significant degradation of forest resources near settlements [22]. Fuel, forage, lumber, and other natural resources are becoming increasingly scarce in the region as the population grows [23]. In order to meet future demand, fuelwood production and use in a sustainable manner have drawn a lot of attention. For fuelwood utilization to be sustainable, it is critical to comprehend the factors influencing the patterns of fuelwood consumption. These factors include activities involving fuelwood [28], fuelwood prices [29], household size [30], and elevation [31]. Fuelwood was roughly 42 million m^3 in 2011, and by 2030, it is predicted to reach 55 million m^3 [32].

Lack of adequate regeneration in the *B. utilis* stands could be a major threat to its survival in the Himalayan forests [19, 33]. Natural regeneration is the process of reproducing or re-growing, which plays an important role in maintaining the stable structure of a species in a community [34]. Undisturbed old-growth forests have poor seedling recruitment in understories, according to most studies on *B. utilis* in the subalpine forests [35]. Due to regional geographical and metrological peculiarities as well as socioeconomic household variables like size and wealth, data on fuelwood consumption is insufficient [36]. Fuelwood collection, especially in the western Himalayas, is unsustainable, which has drastically reduced the population of woody species and prevented the production of biomass for bioenergy in a sustainable manner [37]. The main objectives of the current study are to investigate: 1) traditional ethnobotanical knowledge of *B. utilis* among local communities; 2) the fuelwood consumption pattern of *B. utilis* across various elevations in the subalpine zone; and 3) the regeneration patterns of *B. utilis* in the subalpine of Kashmir, western Himalayas.

Materials and Methods

Study Area

The study area is located in the western Himalayan region of Kashmir, spread between longitudes 73° and 74° north and 33° and 36° east. The landscape

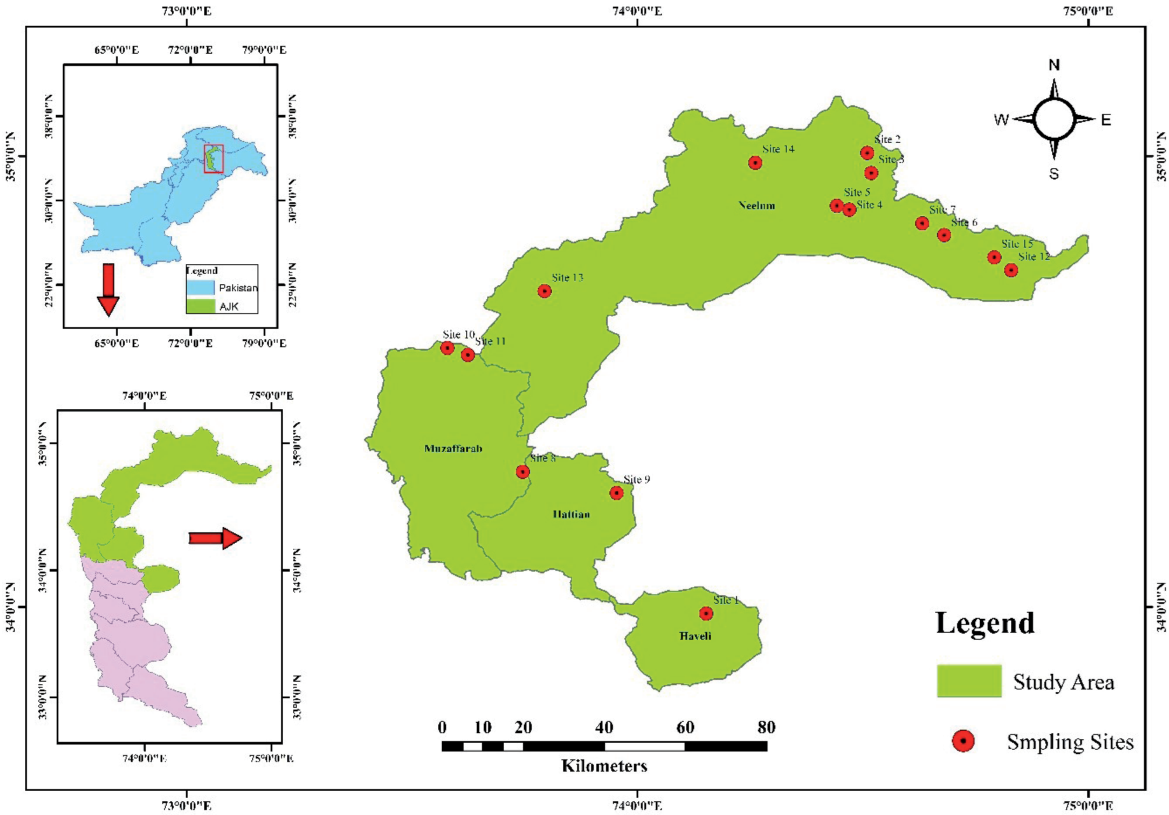

Fig. 1. Map of the study area in the western Himalayan region of Kashmir and location of sampling sites.

of the study area is hilly and rugged, with deep valleys carved out by numerous streams and rivers and mountainous slopes covered with forests. Kashmir is a hotspot for regional biodiversity that supports a wide range of climatic conditions and ecosystems because of its enamored elevational gradient [38, 39]. The current field investigation was carried out in the subalpine zone of Kashmir in four districts named Neelum, Jhelum, Farwad Kahuta, and Muzaffarabad along an altitudinal range of 2900-4000 m (Fig. 1). The climate of the subalpine zone is characterized by extreme cold during the winter season, with heavy snowfall and freezing temperatures down to -10ºC from November to April. The average temperature is around 10ºC during the summer from June to August, while the summer season is cold and short. The area receives about 1000 mm of precipitation annually, most of which falls as snow in the winter [40].

Ecosystem Services Assessment

Fuelwood collection and consumption patterns are influenced by the climatic conditions, availability of resources, and cooking techniques and are thus likely to differ among valleys. A total of 15 sites were selected from four districts for the assessment of subalpine forest ecosystem services (Table 1). Each household's head member was chosen for an interview, during which they were questioned about the size of the family, the resources available for fuelwood, how fuelwood is collected and used, and other pertinent topics by following the method of Rawat et al. [41]. In accordance with Negi and Maikhuri [42], data on fuelwood consumption and collection were gathered based on family size and subsequently converted into per capita fuelwood usage. A well-designed questionnaire was used for individual interviews regarding fuelwood collection and consumption patterns. A weight survey approach was used to measure the amount of fuel wood consumed during a 24-hour period [14]. The rural populations residing in the high-altitude settlement collected fuelwood at all of the sites from June to September. The ethnobotanical data for *B. utilis* was collected using the questionnaire method. A semi-structured questionnaire was used to collect the data from the rural populations of Kashmir by following the method of Mirzaman et al. [43].

Regeneration Patterns

The sampling was carried out at each of the 15 subalpine forest sites, and 15 quadrats were taken at each site. The regeneration status of subalpine *B. utilis* forests was determined by counting the number of seedlings and saplings at each individual 900 m^2 (30 m × 30 m) quadrat. The proportionate distribution of individual densities in each seedling, sapling, and adult tree species within the forest stand was used to evaluate the regeneration status of dominant trees. The regeneration status of species was classified into different categories:

‘‘good’’ when seedling density>sapling density>adult tree density; ‘‘fair’’ when seedling density>sapling density≤adult tree density; ‘‘poor’’ when species only in sapling stage and absence of seedling stage in stands; ‘‘none’’ no seedling and sapling but only adult trees; ‘‘new’’ when sapling and seedlings were present and adult trees were absent [44]. The recorded primary data were used to compute the stump-to-tree value/ha. Visual indicators such as browsed vegetation, cattle dung, hoof markings, and trampling tracks were used to determine the amount of grazing pressure at the study locations and classify them into low, moderate, and highly grazed groups [45].

Results

Ecosystem Services of B. Utilis Forest

Demographic Information

A total of 103 informants, including 67 males (65.05%) and 36 females (34.95%), were surveyed during the field investigation. The interviews and group discussions were carried out in the local language to facilitate communication with the informants.

Religious and Cultural Values of B. Utilis

The papery bark of *B. utilis* was used for writing purposes. According to respondents, the bark of *B. utilis* has a great religious value. Because the bark contains lines, local people told us that these lines, Alif (the first letter of the Urdu alphabet), represent the name of Allah. The bark of *B. utilis* was also used for the writing of the Holy Quran and the Mascot (Taweez) in ancient times. Nowadays, bark is used for writing the mascot (Taweez) and is hung around the neck for the protection of misfortunes, evil, and disease. Local people collect the papery bark of *B. utilis* to make a large sheet by combining small pieces of bark. A large sheet of the bark is also used during the wedding ceremony. Before the wedding ceremony, 4-6 women put rice on the papery bark sheets to check for dirt and small pebbles in the rice. After this process, the rice is ready for cooking.

Ethnobotanical Uses of B. Utilis Bark

The bark of *B. utilis* is used for the treatment of wounds in humans and animals. It’s also used for the cleaning of wounds. Brunt bark ash paste is used for the treatment of wounds in animals. The decoction of *B. utilis* bark is used for the treatment of kidney, bladder, and urinary tract disorders and jaundice. A paste of bark is used for the treatment of swellings and bone fractures. It is frequently used for writing purposes, the packing of butter (locally known as ghee) for long-term preservation and keeping butter fresh, food plates, and as a source of light during the night.

Ethnobotanical Uses of B. Utilis Wood

B. utilis wood is used for the construction of huts and making bridges on the streams in the subalpine zone. Wood is used for making utensils such as wooden plates, spoons, bowls, sitting stools, agricultural implements, homogenizers (Madhani), small tables and chairs, and making a spinning wheel (locally known as charkha) for the spinning of cotton. The wooden triangle is wrapped around the necks of animals used for the treatment of haematuria (blood in urine).

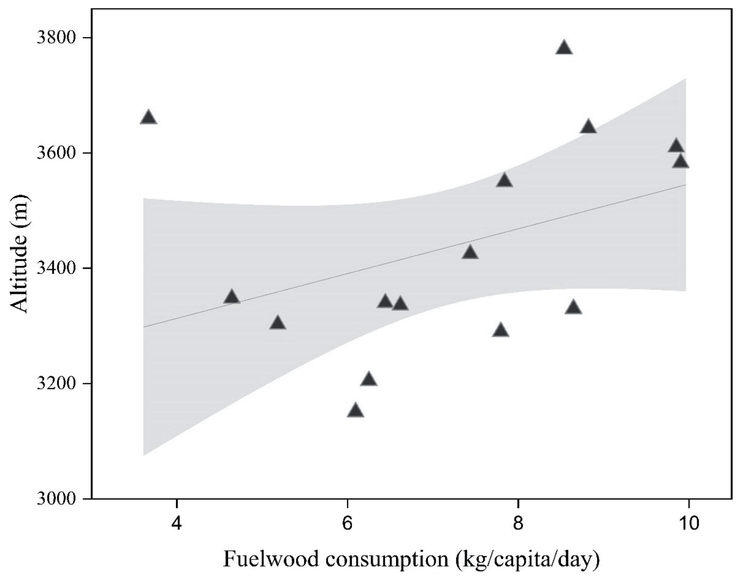

Fig. 2. Linear regression analysis between altitude and fuelwood consumption patterns in the western Himalayan region of Kashmir.

Other Uses

The branches of *B. utilis* are used as a source of fuelwood. Young branches are harvested in the summer season, dried, and then used as fodder in the winter season and as a rope (locally known as Sobbii) to wrap the bundle of sticks and grass. Fresh leaves of *B. utilis* are used as a source of fodder. Leaves are also used to make soft beds in the form of carpet.

Fuelwood Consumption

The average fuel wood consumption by the local population was calculated at 7.18 kg/capita/day. The highest value of daily fuel wood consumption per capita was 9.90 kg at Hari Perbat, whereas the lowest value of daily fuel wood consumption per capita was 3.67 kg at Leswa (Table 1). Rural communities mostly rely on *B. utilis* wood as a source of fuelwood for cooking and heating their homes because subalpine zones are dominated by *B. utilis* forests, and other tree species like *Taxus wallichiana*, *Pinus wallichiana*, *Abies pindrow*, and *Acer caesium* were recorded in fewer numbers. The linear regression analysis revealed that fuelwood consumption values increase along the altitude of the study area (Fig. 2). This relationship showed the dependency level of the rural population on *B. utilis* as fuelwood due to harsh environmental conditions.

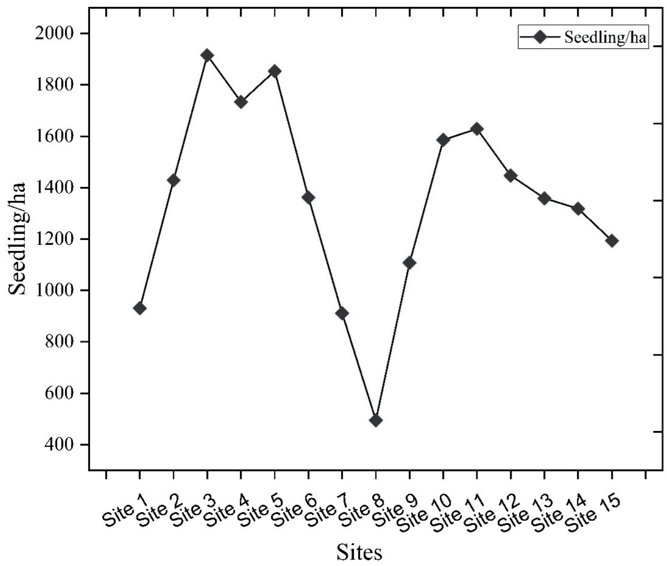

Fig. 3. Graph representing the seedling density/ha in the subalpine *Betula* forests.

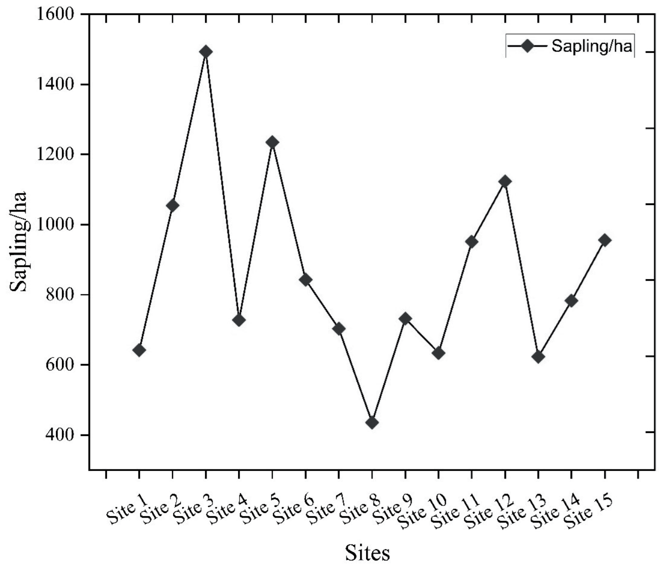

Fig. 4. Graph representing the sapling density/ha in the subalpine *Betula* forests.

As altitude increased, the rural population used more fuelwood for heating purposes to sustain their lives in harsh environmental conditions.

Regeneration Patterns

The regeneration patterns of *B. utilis* forests were recorded by counting the number of seedlings and saplings from each quadrat. The 12 sites were recorded on the north aspect, and 3 sites were recorded on the south aspect. The majority of sampling sites were observed as pure *Betula* forests, but some sites showed mixed *Betula* forests with associations of *Taxus wallichiana, Pinus wallichiana, Abies pindrow*, and *Acer caesium*. The average seedling density was calculated as 1351.47/ha from the study area (Table 1). The highest seedling density was calculated as 1915/ha at site 3 (Hari Perbat), whereas the lowest seedling density was calculated as 495/ha at site 8 (Sari Top) (Fig. 3). The average sapling density was calculated as 862.41/ha from the study area. The highest sapling density was calculated at 1493/ha at site 3 (Hari Perbat), whereas the lowest seedling density was calculated at 436/ha at site 8 (Sari Top) (Fig. 4). The seedling stratum showed a higher number of seedlings and ranged from 1429/ha to 911/ha and 1915/ha to 495/ha on the south and north aspects, respectively. The sapling stratum showed comparatively low values and ranged from 1054/ha to 623/ha and 1493/ha to 436/ha on the south and north aspects, respectively. The lower values of seedling and sapling are due to anthropogenic pressure such as grazing intensity, as 7 sites (46.66%) were observed as highly grazed, 5 sites (33.33%) were moderately grazed, and 3 sites (20%) were less grazed (Table 1).

Discussion

The current study highlights the ecosystem services, including ethnobotanical uses, fuelwood utilization, and regeneration patterns, of *B. utilis* forests in the western Himalayan region of Kashmir. *B. utilis* is an indicator species of the subalpine zone and regulates various ecological functions.

B. utilis is a versatile plant with many uses. The word "utilis" means many uses of trees [16]. *B. utilis* is an ethnobotanically important plant used for various healthcare purposes in the region. The bark of *B. utilis* is extensively utilized by the local populations of Kashmir. The bark is used for various purposes, like packaging material, writing, wound healing, and as a source of light. The research on *B. utilis* indicates that this species is used for the treatment of various diseases such as colds, coughs, anemia, obesity, cough, urinogenital diseases, and skin problems [46, 47]. From a religious point of view, bark was used for the writing of mascots to avenge misfortune, etc., and was also used for writing the holy Quran in ancient times [48, 49]. Decoction and paste of bark are used for the cure of a variety of diseases because *B. utilis* bark contains significant biological compounds such as betulic acid, methyl betulate, triterpenoid karachic acid, sitosterol, oleanolic acid, betulin, lupenone, methyl betulonate, and lupeol [50, 51]. The wood of this plant is used for fuel wood, the construction of huts, and the making of agricultural tools and utensils. Leaves are used as fodder. A similar pattern of usage was also reported by several workers [46, 52-57].

The detailed interviews with the respondenst showed that *B. utilis* is shifting in the range of higher elevations. The shifting of *B. utilis* towards higher elevations is possibly due to climate change. The *B. utilis* shift in the upper subalpine zone has also been reported by Bobrowski et al. [58]. Anthropogenic pressure and climate warming play a key role in shifting the *B. utilis* forest to the upper belt [59]. Overexploitation is a major threat to *B. utilis* due to the high domestic medicinal value of this plant [60]. The reduction in the population size of the *B. utilis* forest is due to overgrazing, deforestation, excessive medicinal use, and soil erosion [61].

The depletion of forest resources in the Himalayan region has been mostly attributed to the exploitation of forests for the harvest of fuel wood. The fuelwood consumption results revealed an average fuelwood consumption by rural populations calculated at 7.18 kg/capita/day. All investigated sites are in remote areas due to hilly terrain, resulting in the unavailability of LPG and light, which support livelihoods in the subalpine zone [62, 63]. *B. utilis* is the only tree present in the subalpine zone of Kashmir and the only source of fuelwood and light. So, local populations use this plant as a source of fuel wood for cooking and heating their rooms. High elevations are characterized by severe environmental conditions, including longer winters and lower temperatures, leading to increased fuelwood usage [22]. Linear regression analysis revealed that fuelwood utilization patterns increase along the elevational gradient due to the severity of environmental conditions. According to Singh et al. [64], fuelwood consumption level is also significantly influenced by altitude. Extensive fuelwood extraction, overgrazing, and deforestation are significant factors that impact the size, shape, and structure of forests. Fuel wood consumption has a great impact on the *Betula* forest, which is reflected by the higher number of stumps in the study area. The current study results are well in line with the following results: fuel wood consumption of 4-9 kg/capita/day in the Western Himalayas [33]. Results show that fuel wood consumption in the area is greater than other studies from the Himalayan region [5, 14, 22, 23, 65, 66].

The average seedling density was calculated at 1351.47/ha in the study area. Significant regeneration of *B. utilis* was observed, which indicates successful regeneration in the pure as well as in the mixed at some sites of *Betula* forest. In mixed *Betula* forests, a higher number of seedlings were observed as compared to pure *Betula* forests. The mixed *Betula* forest with

Table 1. Study sites, demographic profile, fuelwood consumption (Kg/capita/day), seedling/ha, sapling/ha, and grazing intensity in *Betula* forests.

Site No.	Site Names	Altitude	Latitude	Longitude	Stay duration (months)	Number of households	Population	Family size	Fuelwood consumption (kg/capita/day)	Seedling/ha	Sapling/ha	Grazing intensity
Site 1	Bhurjan Behak kahuta	3205	33°59'07.31"N	74°9'07.96"E	3.5	15	36	2.4	6.25	931	642	3
Site 2	Shounthar Bhurjan	3610	35°0'25.56"N	74°30'34.65"E	3.5	27	74	2.7	9.85	1429	1054	2
Site 3	Hari Perbat	3583	34°57'45.45"N	74°31'6.38"E	3.5	31	72	2.3	9.90	1915	1493	1
Site 4	Dak Wali Behak	3643	34°52'52.95"N	74°28'10.80"E	3.5	18	51	2.8	8.82	1734	728	1
Site 5	Baboon	3425	34°53'24.55"N	74°26'31.66"E	3.5	28	64	2.3	7.44	1854	1235	1
Site 6	Bach top	3780	34°49'29.94"N	74°40'48.20"E	3.5	22	67	3.0	8.54	1362	843	2
Site 7	Domailan	3330	34°51'3.24"N	74°37'53.46"E	4	47	125	2.7	8.65	911	703	3
Site 8	Sari top	3303	34°17'59.92"N	73°44'44.10"E	4	9	33	3.7	5.18	495	436	3
Site 9	Bara Hazari	3290	34°15'10.64"N	73°57'14.69"E	4	16	39	2.4	7.79	1108	732	3
Site 10	Makra 1	3336	34°34'28.40"N	73°34'42.46"E	4	25	68	2.7	6.62	1586	634	3
Site 11	Machiyara 1	3550	34°33'33.01"N	73°37'25.89"E	4	27	62	2.3	7.84	1629	951	2
Site 12	Narr	3340	34°44'49.62"N	74°49'43.22"E	3.5	36	95	2.6	6.44	1447	1123	2
Site 13	Leswa	3659	34°42'2.17"N	73°47'37.90"E	4	23	69	3.0	3.67	1359	623	3
Site 14	Samgam Valley	3151	34°59'7.96"N	74°15'40.61"E	3.5	17	53	3.1	6.09	1318	783	3
Site 15	Nikron Nar	3348	34°46'31.91"N	74°47'28.10"E	4	19	45	2.4	4.64	1194	956	2

open canopy has great potential for regeneration, and these forests ensure a higher number of saplings and seedlings in the open canopy forest [44]. In the closed canopy, *Betula* forest has a low potential for regeneration due to the low light intensity on the ground surface. The lower light intensity constrains the establishment of seedlings in the mature forest. So, in the adult stage, trees are well represented, but seedlings require high light intensity [19, 45, 61, 67].

The seedling and sapling density varies on the south and north aspects. Higher numbers of seedlings and saplings were observed on the north-facing aspect as compared to the south-facing aspect. Aspect also affects the establishment of seedlings, preventing successful regeneration on south-facing slopes exposed to intense solar radiation, etc. [19, 44, 61]. Higher seedling accumulation at high altitudes in some of the study sites would suggest that climatic variations may be crucial in synchronizing these patterns [68]. Extensive grazing in the subalpine forest poses significant threats to the viability of *Betula* Forest. Due to overgrazing, the *B. utilis* did not survive at the seedling and sapling stages. Besides grazing, other factors, such as fuelwood extraction, also decrease tree density and regeneration rates in the region. Due to the abovementioned problems, the *B. utilis* regeneration rate was not good as compared to the regeneration status of *B. utilis* across the globe [61].

Conclusions

B. utilis is an indicator species of subalpine forest in the western Himalayan region, performing dynamic ecological functions and providing significant ecosystem services to local communities. The current study provides valuable insights into the ecosystem services of the *B. utilis* forest and the regeneration patterns of subalpine forests. Ethnobotanically, *B. utilis* is a very important plant with various religious, cultural, and medicinal uses. Results of fuel wood consumption revealed an average value of 7.18 kg/capita/day, which indicates the dependency of the rural population on *B. utilis* for the subsistence of their lives at high elevations with harsh environmental conditions. Regeneration patterns showed that the north aspect had more seedling and sapling density as compared to the south-facing aspect. Fuelwood extraction, overgrazing, deforestation, and climate change are the main threats to the long-term viability of *Betula* forests. We suggest immediate conservation measures, long-term forest monitoring, and sustainable harvesting for the conservation of *Betula* forests in the western Himalayan region of Kashmir.

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Ethical Approval and Consent to Participate

All the experiments were performed in accordance with relevant guidelines and regulations.

Author Contributions

Muhammad Manzoor: Field Collection, Writing-Original draft preparation, Hamayun Shaheen: Supervision and Review Editing, Javeed Hussain, Tariq Saiff Ullah: Interpretation of Results, Analysis and Visualization, Syed Waseem Gillani: Field Collection, Methodology and Data analysis, Investigation, Syed Waseem Gillani, Muhammad Manzoor: Interpretation of Results, Abdullah Ahmed Al-Ghamdi, Mohamed S Elshikh, Mohamed Ragab AbdelGawwad: Data Curation, Funding.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

All the data has been presented in this article.

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