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RESEARCH PAPER

Population ecology and habitat suitability modelling of *Betula utilis* D. Don in the sub-alpine ecosystem of Great Himalayan National Park, North-Western Indian Himalaya: a UNESCO World Heritage site

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Abstract

Betula utilis is a native tree and important tree line species in the Indian Himalayan Region (IHR). Due to various natural and anthropogenic factors, the population of the species has become dwindling. Therefore, study was conducted to; assess population, regeneration, habitat suitability model, size class distribution and physico-chemical properties of the soil in sub-alpine ecosystem of Great Himalayan National Park. Total 64 populations assessed to determine the density, Total Basal Area, Species diversity index, Concentration of dominance and regeneration pattern of seedlings and saplings. Amongst the identified populations, total trees density ranged from 10–730 Ind ha^{-1}; total basal area 0.00–43.32 m^2 ha^{-1}; total shrubs density 340–3490 Ind ha^{-1}; total herbs density 8.54–152.77 Ind m^{-2}; total saplings density 9–3050 Ind ha^{-1} and total seedlings density 10–1840 Ind ha^{-1}. Species diversity of trees was ranged from 0.00 to 0.37; Concentration of dominance ranged from 0.00 to 1.00. Size class distribution revealed that maximum number of individuals was fallen in the range of 52.6–73.5 cm whereas lowest numbers of individuals were fallen in the range of 136.6–157.5 cm and ≥ 220.6 cm. The model calibration test for *B.utilis* yielded satisfactory results (AUC $_{\text{Mean}} = 0.91 \pm 0.02$) indicated that MaxEnt could be used to predict the potentially suitable habitats for *in-situ* or *ex-situ* conservation. The model predicted 268 km^2 area suitable for reintroduction. Frequent monitoring of populations for understanding the dynamics and identifying natural habitats for the *in-situ* conservation of the species are suggested.

Keywords *Betula utilis* · Population ecology · Habitat suitability modeling · Sub-alpine ecosystem · Physico-chemical properties · Great Himalayan National Park

Introduction

The typical topographical gradients and climatic conditions of the Himalaya supports tropical, sub-tropical, temperate, sub-alpine, alpine and tundra ecosystems/biomes. In these diverse ecosystems, broadleaved evergreen and deciduous forests and evergreen coniferous forests predominate, with a wide range of species. The Indian Himalayan Region (IHR) is home to the world's highest and most diversified sub-alpine environment, which forms the transition between temperate and alpine ecosystems (Samant et al. 1998; Singh and Samant 2010; Devi et al. 2019; Lal and Samant 2019). Among the sub-alpine forest, *Betula utilis* D.Don (Himalayan birch or Bhojpatra), a climax species that contribute ecological and ecosystem services and forms tree line vegetation across the IHR, and extensive stands of this species are found in northern shaded moist slopes and riverine areas and widely dominated in the sub-alpine ecosystem throughout

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the Himalaya (Zobel and Singh 1997). However, the population distribution is very narrow throughout the IHR due to various anthropogenic activities and severe climatic conditions. Generally, it grows as a pure forest, but it can also grow in close proximity with *Abies pindrow*, *A. spectabilis*, *Quercus semecarpifolia*, *Salix daphnoides*, *Taxus wallichiana*, *Acer acuminatum* and *Prunus cornuta* (Dhar et al. 1997; Joshi and Samant 2014; Rana and Samant 2009; Devi et al. 2019; Lal and Samant 2019).

Betula utilis D. Don, family Betulaceae is a moderate-sized broad leaved deciduous tree that grows upto 20 m in height. It also have medicinal properties, the bark and resin is used as antiseptic, fever, cuts, ear complaints, hysteria, jaundice and wounds (Samant et al. 2007). In the GHNP the main use of bark of *B. utilis* is for religious purposes and also used for making mats and agricultural tools. Parts of the plant, including the fungal parasite (Bhujra-granthi or Bhujra) have used in local traditional medicine and ash of Bhujra-granthi given to women during pregnancy pain. Bhojpatra is well-known for the use of its bark for writing in ancient India, the leaves used as fodder, wood for fuel and for making agricultural tools.

The alpine tree line, which contains unique ecosystems and species diversity, have attracted the attention of scientists for decades. However, the timberline of IHR has not been so much studied due to its unique physiographical composition, divergent elevations, highly rugged terrains and remoteness of the mountains. In general, a large number of studies have been carried out on the qualitative assessment of the vegetation (Chowdhery and Wadhwa 1984; Aswal and Mehrotra 1994; Singh and Rawat 2000; Naithani 1984, 1988; Gaur 1999 etc.). These studies states the status of species based on observations (Rana and Samant 2010). However, in sub-alpine ecosystem a very few studies are available on composition, structure and function of vegetation (Kalakoti et al. 1986; Bankoti et al. 1992; Rawal et al. 1994; Dhar et al. 1997; Rawat et al. 1999; Johnsing et al. 1998; Joshi and Samant 2004, 2014; Samant and Joshi 2004; Shrestha et al. 2007; Pant and Samant 2012; Ghimire and Lekhak 2007; Rana and Samant 2009; Singh and Samant 2010; Rana et al. 2011; Rai et al. 2012; Bharti et al. 2012; Sharma and Samant 2013; Rai et al. 2013; Rawat et al. 2015; Gairola et al. 2015; Lal and Samant 2019; Maletha et al. 2020; etc.).

Regeneration is the prominent feature of the forest composition and species diversity. It depends on seedlings, saplings, mature trees and associated tree species (Austin 1977). It is significant to note that the presence of seedlings, saplings, and mature species in adequate estimates shows successful forest regeneration (Samant and Joshi 2004; Joshi and Samant 2014). The arrangement of population structure by size class distribution has been used to figure out regeneration, distribution and future stability of tree species population in forest communities (Schmelz and Lindsey 1965). Calculations based on seedlings, saplings and mature individuals and analysis of size class distribution are methods for the regeneration analysis (Dhar et al. 1997).

Rapidly changing climate, habitat fragmentation, species invasion, overexploitation and unsustainable use are the most important factors responsible for ecosystem degradation (Adhikari et al. 2012). Land use activities can lead to changes in habitat area, structure and intensity of stress. With the increasing availability of high-resolution climate data for global land areas, ecological statistical modeling, geographic information systems, remote sensing, and species distribution models have emerged as important tools in ecological research for species conservation and prioritization (Barik and Adhikari 2012; Franklin 2009; Peterson 2012; Yang et al. 2013). Habitat Suitability Modeling or Ecological Niche Modeling (ENM) helps to predict the suitability of habitats across a landscape, and are routinely used in conservation planning and appropriate management of biodiversity (Kreman et al. 2008). Presently, there are a very few studies on the distribution of tree line ecotone species in the Himalaya. Information of the potential distribution of the tree line species in Indian Himalayan Regions is important to understand and conservation of these fragile ecosystems (Singh et al. 2013). With the above facts it is utmost important to evaluate performance of such models and develop the Ecological Niche Models for the ecologically and economically important species (Lal and Samant 2017; Lal et al. 2020).

At national and international levels, studies on habitat suitability modeling or Ecological Niche Modeling of the species are available, and have been carried out by various workers across the Himalayan region (Rey et al. 2011; Adhikari et al. 2018; Barik and Adhikari 2012; Yang et al. 2013; Jaryan et al. 2013; Linshan et al. 2017; Mohpatra et al. 2019; Luitel et al. 2020). Attempts have been also made by various workers in different regions of Himachal Pradesh (Paul et al. 2018, 2019a, 2019b; Singh et al. 2021). The ENM helps in identifying the suitable habitats (*i.e.*, highly suitable, suitable, moderately suitable and least suitable). Due to severe climatic conditions and anthropogenic pressures, *B. utilis* is facing severe threats. Therefore, ecological niche modeling is essentially required to identify suitable habitats for re-introduction and *in-situ* conservation of the species. This necessitates the evaluation of sensitive habitats supporting ecologically and economically important species (Rana and Samant 2009). In view of the above, the present attempt has been made to; (i) assess the status and regeneration pattern of *B. utilis* in Great Himalayan National Park, (ii) Develop the habitat distribution model to predict the potential habitats, and (iii) suggest management options.

Material and methods

Study area

The present study was conducted in sub-alpine ecosystem of the Great Himalayan National Park (GHNP), located in the Kullu district in Himachal Pradesh, India (Fig. 1). It covers 1171 km^2 area, which lies between 31°38′28″ N to 31°51′58″ N latitudes and 77°20′11″ E to 77°45′52″ E longitudes and 1344–6248 m amsl altitudinal range. The GHNP, a natural site notified in 1994, was inscribed into the UNESCO World Heritage list during the session of the 38th World Heritage Committee in Doha (Qatar) on 23rd June 2014. It is surrounded from all directions by wildlife sanctuaries. Administratively, the area has Eco-development Zone in the south-west, Tirthan Wildlife Sanctuary in the south, GHNP in the north and Sainj Wildlife Sanctuary lying between west to east directions. The GHNP is bordered by Rupi Bhava Wildlife Sanctuary in the east, Khirganga National Park in north, Pin Valley National Park in the north east, Kanawar Wildlife Sanctuary in the north–west and south eastern part of park bounded by Baga sarahan forest area. The altitudinal range of GHNP supports representative, natural, unique and socio-economically important biodiversity. According to biogeographical classification, GHNP falls under north-western Himalayan biotic province (Rodgers and Panwar 1988). The temperature ranges between − 10° and 35 °C and rainfall between 1000 and 2000 mm, annually. The underlying rock found in GHNP is largely quartzite, schist, phyllite, dolomites, limestone, shale, slate, gneiss and granites (Anonymous 1987). The GHNP has a complex geography with sub-tropical, temperate, sub-alpine, and alpine vegetation. Mainly dominated by the broad-leaved evergreen, deciduous and mixed conifer forests.

Surveys, samplings, identification and data analysis

The sites representing *B. utilis* populations were selected along an altitudinal gradient between 2800 and 3700 m amsl. Information on habitat type, aspect, altitude, slope, latitudes and longitudes of sites was obtained with the help of Global Positioning System (Garmin GPSMAP 78s). Slope was determined by using clinometer. Habitats were classified based on their physical characteristics and vegetation dominance. Closed canopy sites with high humus and moisture content were considered moist habitat, sites having high

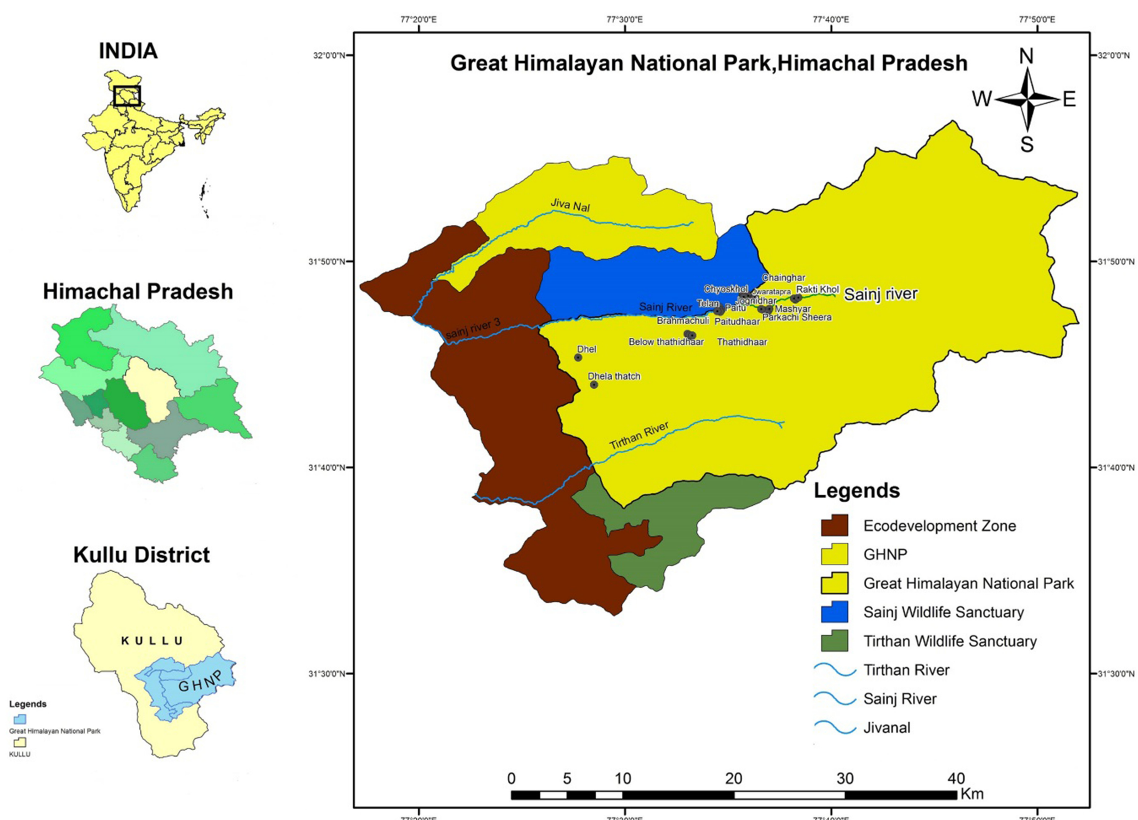


Fig. 1 Location map of Great Himalayan National Park

amount of moisture with slopes were considered as moist slope, the sites having > 50% boulders of the ground cover were considered as bouldary habitat, sites which falls in rock cliffs were considered as rocky habitat and sites along the nallah and river banks were considered as riverine habitat. The field surveys and samplings were conducted from June to August during 2015–2018.

For the quantitative assessment, a plot of 50 × 50 m was laid randomly. Within this plot for trees, saplings and seedlings, 10 quadrates of 10 × 10 m, for shrubs 20 quadrates of 5 × 5 m, and for herbs 20 quadrates of 1 × 1 m were placed randomly. The CBH (Circumference at Breast Height) of tree measured at 1.37 m with the help of measuring tape. For seedlings, the diameter was measured at 10 cm from the base. For the data collection, standard ecological methods were used (Curtis and McIntosh 1950; Greig-Smith 1957; Joshi and Samant 2004; Samant and Joshi 2004; Kershaw 1973; Mueller-Dombois and Ellenberge 1974). The size class categorization of *B. utilis* was recorded in all the 64 plots which is based on CBH. The individuals with CBH ≥ 30.5 cm were considered as trees; between 10.5 and 31.4 cm as saplings, and diameter < 10.5 cm as seedlings. For sites/populations, habitats and aspects, the values were pooled and analyzed for average values. The status of regeneration of species was determined based on the status of seedlings and saplings.

Soil sampling and analysis

During the population sampling in each site, soil was cored up to 20 cm depth, 5 soil samples one from the centre and 4 from the corners of each site/plot were collected and mixed together. A composite homoginized soil sample of 200 g was collected and kept in air tight polybags. Soil samples were bought to the laboratory for the analysis. The pH and mositure content of soil was measured. Soil is dried under open air, seived with 2 mm mess and used for the analysis of total nitrogen, organic carbon, organic matter, available phosphorus and available potassium (Olsen 1954; Jackson 1958; Allen 1974).

Habitat distribution modelling

MaxEnt, Version 3.4.1 dowloaded from the portal (https://biodiversityinformatics.amnh.org) (Phillips et al. 2006) was used for modelling. The output generated by MaxEnt predicted suitability of habitats of species on the scale of 0 to 1, with the lowest suitable areas represented by 0 and 1 representing the high suitable areas. Sixty-four primary distribution records of *B. utilis* were collected through field surveys. Environmental data of 19 bioclimatic parameters (Table 1), was downloaded from the WorldClim data and the Digital Elevation Model (DEM), Shuttle Radar Topography Mission (SRTM) 30 m resolution data was download from U.S Geological Survey (USGS) portal (https://earthexplorer.usgs.gov). Remotely sensed data on elevation and bioclimatic variables (Hijmans et al. 2005) in higest resolution (~ 1 km) were downloaded and all the predictive variables rescale to~ 250 m pixel dimension in ArcGIS 10.1 version. For the geographical distribution of species, MaxEnt was run using auto features, with output set to logistic, easier to interpret then raw or cumulative formats (Philips and Dudik 2008). The MaxEnt generates response curves for each predictor variable. For highlighting the relative influence of each predictor variable, Jackknife method was used (Fielding and Bell 1997).

Table 1 Codes and discription of 19 bioclimatic factors

Codes	Discription
*BIO1	Annual mean temperature
BIO2	Mean diurnal range (mean of monthly (max temp−min temp))
*BIO3	Isothermality (BIO2/BIO7)*(100)
*BIO4	Temperature seasonality (standard deviation*100)
BIO5	Maximum temperature of warmest Month
BIO6	Minimum temperature of coldest Month
*BIO7	Temperature annual range (BIO5-BIO6)
BIO8	Mean temperature of wettest quarter
BIO9	Mean Temperature of driest quarter
BIO10	Mean Temperature of warmest quarter
BIO11	Mean Temperature of coldest quarter
*BIO12	Annual precipitation
BIO13	Precipitation of wettest month
BIO14	Precipitation of driest month
BIO15	Precipitation seasonality (coefficient of variation)
BIO16	Precipitation of wettest quarter
BIO17	Precipitation of driest quarter
BIO18	Precipitation of warmest quarter
*BIO19	Precipitation of coldest quarter

Asterisks indicate variables use as model input

Before running model, correlations among the bioclimatic variables was checked for reduce biasness (Brown 2014) by using Ecological Niche Modelling (ENM) tools, version 1.4.3 (Warren et al. 2010). Based on correlation results (variables having correlation coefficient value > 0.70), a total of 6 variables were selected. These included BIO1 (annual mean temperature), BIO3 (isothermality), BIO4 (temperature seasonality), BIO7 (temperature annual range), BIO12 (annual precipitation), and BIO19 (precipitation in the coldest quarter) along with aspect and elevation, were selected as input variables for modeling; other variables were highly correlated (Pearson correlation coefficient > 0.70) were excluded.

To validate the model robustness, we performed 15 replicated runs for the species with a threshhold rule of 10 percentile training presence. In the replicated runs, cross validation technique was employed, where samples were divided into replicate folds and each fold was used for test data. Other parameters were set to default as the programme was already calibrated on a wide range of species datasets (Philips and Dudik 2008). Maxent estimates the importance of the variables with percent contribution and permutation importance values. Percent contribution represents how much the variable contributed to the model based on the path selected for the perticular run. Permutation importance is determined by changing the predictor values between presence and background points and observing how they affect the AUC. The permutation importance is upto the final performance of the model rather then path used in an individual run and therefore it is better for evaluating the importance of a perticular variable (Songer et al. 2012). The contributions of each variable to the habitat model of *B. utilis* were calculated using the Jackknife test which were used to determine the dominant bioclimatic factors responsible for the potential distribution of the species (Li et al. 2016). Based on the Area Under Curve (AUC) value, the quality of model was evaluated and graded following Thuiller et al. (2005) as poor (AUC < 0.8), fair (0.8–0.9), good (0.9–0.95) and very good (0.95–1.0). MaxEnt version 3.4.0 and ArcGIS version 10.1 were used to generate predictive maps of species distribution and potential areas of distribution and reintroduction.

Results and discussion

Distribution and spatial pattern of *B. utilis*

Total 64 populations of *B. utilis* representing five major habitats and 8 aspects in an altitudinal range from 2807 to 3715 m amsl and between 31°39′35.94″N to 31°51′48.3″N latitudes and 77°21′11.1″E to 77°39′40.38″E longitudes were selected and sampled from the GHNP. Maximum sites (36) were represented by shady moist habitat, followed by moist slope (13), bouldery (10), riverine (3) and rocky (2) habitats. Twenty-two (22) sites were represented in north aspect, 13 on northwest, 10 on northeast, 6 on west, 5 on southwest, 4 on east, 3 on south, and 1 on southeast aspects. The slope varied from 10° to 65°. The physical characteristics of *B. utilis* populations in the sub-alpine ecosystem are presented in Table 2.

Population ecology

Overall, site wise species richness, total basal area (TBA), Species diversity (H') and Concentration of dominance (Cd) of tree, shrub and herb layers have been presented in Table 3. Richness of trees was ranged from 1 (Dhel Thatch, Thathidhar 1, Raktikhol, Naina Thatch, Rahla, Indira, Bhujaradi, Gumtaraw, Ansurbagh and Rakhundi populations) to 6 (Chyoskhol and Dwada Thatch); shrubs richness ranged from 3 (Raktikhol 1, Raktikhol 2 and Raktikhol 3 populations) to 12 (Bhujaradi and Sartu Thatch populations); and herb richness ranged from 4 (Upper Kholi Poi 2) to 40 (Naina Thatch).

Total trees density ranged from 10 Ind ha^{-1} (Dhel Thatch and Indira populations) to 1830 Ind ha^{-1} (Upper Kholi Poi 1), and the density of *B. utilis* ranged between 10 Ind ha^{-1} (Dhel Thatch and Indira) to 730 Ind ha^{-1} (Parkachi Sheera 2). Total shrub density ranged between 340 Ind ha^{-1} (Chyoskhol) to 3490 Ind ha^{-1} (Thathidhaar 2) and total herbs density ranged from 13.2 Ind m^{-2} (Upper Kholi poi 2) to 187.3 Ind m^{-2} (Majhoni 2). TBA ranged from zero (Indira and Kukhad Gaad populations) to 43.3 m^2 ha^{-1} (Upper Parkachi). TBA of *B. utilis* ranged between zero (Indira and Kukhad Gaad populations) to 43.3 m^2 ha^{-1} (Upper Parkachi).

The concentration of dominance (Cd) for trees was ranged between 0.1 (Phupphu, Brahmachuli, Dhel) and 1.0 (Ansrubagh, Rahla, Bhujaradi, Shilla Berkeru, Shatholi 2, Rhakundi Top, Luthla pani, Naina thatch, Satholi 1, Jammu Nala 2, Rhakundi, Thathidhaar 1, Gumtaraw 4, Kukhdi thatch, Dhel thatch, Rakti Khol 2, Indira, Rakti Khol 1, Rakti Khol 3, Dwada thatch, and Kholi poi 5 populations). Cd for shrubs ranged from 0.13 (Thathidhaar 4, Parkachi Sheera, Ansrubagh) to 0.39 (Chyoskhol), and Cd for herbs, it was ranged from 0.04 (Shilla Berkeru and Majhoni 2 populations) to 0.45 (Upper Kholi poi 2).

Species diversity (H') for trees ranged from 0.02 to 0.37; the highest was found in the Telan, Chainghar 2 and Upper Kholi poi 1, and lowest was recorded in Parkachi ka Sheera, Paitu, and Jammu Nala populations. H' of shrubs ranged from 1.07 to 2.21; the highest was found in the Parkachi Sheera population, and the lowest was found in the Chyoskhol population. For herbs, H' ranged from 0.93 to 3.35; the highest was found in Naina thatch, and the lowest was found in Upper Kholi poi 2 population.

Regeneration pattern

Total seedlings density was ranged from 10 Ind ha^{-1} (Kukhad Gaad) to 1840 Ind ha^{-1} (Upper Kholi poi 3). Similarly, Seedling density of *B. utilis* was 10 Ind ha^{-1} (Kukhad Gaad), and it was highest in Upper Kholi Poi 3 (1840 Ind ha^{-1}) population. Total saplings density ranged between 20 Ind ha^{-1} (Kukhad Gaad) to 3050 Ind ha^{-1} (Rakti Khol 3). Sapling density for *B. utilis* was ranged from 9 Ind ha^{-1} (Majhoni 2) to 3050 Ind ha^{-1}(Rakti Khol 3) (Table 4). Seedling density and sapling density were significantly correlated ($p \le 0.01$, r = 0.80, n = 64) throughout the sites.

Table 2 Physical characteristics of *B. utilis* populations in the sub-alpine ecosystem of GHNP

Population	Habitat type	Aspect	Altitude (m)	Latitudes (N)	Longitudes (E)	Slope (◦)	Associated species
Dhel	MS	N	3525	31°45′20.93″	77°27′44.87″	40	*Abies pindrow*
Dhel Thatch	MS	NE	3692	31°44′6.421″	77°28′28.83″	50	*Rhododendron campanulatum*
Sartu Thatch	SM	NW	3300	31°48′24.67″	77°35′55.54″	35	*Abies spectabilis*
Chyoskhol	RI	NW	3021	31°48′24.12″	77°35′55.45″	25	*Salix daphnoides*
Jwaratapra	SM	SW	3239	31°48′20.56″	77°35′59.60″	25	*Abies pindrow*
Thathidhaar 1	SM	NE	3670	31°46 ′17.28"	77°33′11.27"	30	*Rhododendron campanulatum*
Brahmachuli	SM	SE	3370	31°48′23.4"	77°35′42.3"	40	*Abies pindrow*
Chainghar	SM	E	3329	31°48′21.96"	77°35′44.62"	20	*Abies pindrow*
Sartu Thatch	MS	E	3203	31°48 ′16.38"	77°35′45.52"	45	*Taxus wallichiana*
Chainghar 2	SM	N	3566	31°48 ′ 9.18"	77°38′16.04"	30	*Lonicera purpurascens*
Rakti Khol 1	BD	N	3593	31°48′11.73"	77°38′11.76"	30	*Lonicera obovata, L. rupicola*
Rakti Khol 2	BD	N	3535	31°48 ′14.58"	77°38′24.50"	10	*Lonicera obovata*
Rakti Khol 3	SM	NW	3124	31°47′36.99"	77°36′45.82"	15	*Abies pindrow*
Parkachi Sheera	RK	NW	3242	31°47′37.42"	77°36′57.96"	56	*Abies pindrow*
Parkachi Sheera 2	SM	N	3194	31°47 ′41.60"	77°37′0.048"	30	*Abies pindrow*
Parkachi Sheera 3	SM	SW	3147	31°47′29.25"	77°36′53.42"	30	*Abies pindrow*
Mashyar	BD	W	3109	31°47′40.95"	77°36′36.28"	15	*Abies pindrow*
Jognidhar	MS	W	3381	31°48′10.8"	77°36′11.08"	56	*Abies pindrow*
Parkachi Thatch	MS	NW	3515	31°48′12.92"	77°36′15.04"	65	*Abies pindrow*
Upper Parkachi	RK	N	3590	31°48′16.63"	77°36 ′18.43"	15	*Abies pindrow*
Thathidhaar 2	SM	N	3596	31°46′28.80"	77°33′ 1.73"	35	*Abies pindrow*
Parkachi ka Sheera	SM	N	2829	31°47′38.29"	77°34′40.8"	15	*Taxus wallichiana*
Telan	SM	N	2842	31°47′37.50"	77°34′35.4"	33	*Taxus wallichiana*
Paitu Dhaar 2	MS	NW	2924	31°47′32.85"	77°34′ 37.46"	40	*Abies pindrow*
Paitu Dhaar	RI	NW	2807	31°47′34.69"	77°34′28.59"	20	*Taxus wallichiana*
Naina Forest	SM	NE	3704	31°46′11.76″	77°37′56.77″	32	*Salix daphnoides*
Naina Thatch	BD	NE	3294	31°46′38.74″	77°37′20.10″	20	*Abies pindrow*
Paitu	SM	NE	3330	31°44′12.66″	77°30′28.18″	30	*Abies pindrow*
Jaula 2	SM	W	3529	31°46′19.32″	77°38′27.60″	40	*Lonicera angustifolia*
Rahla	MS	W	3689	31°46′2.70″	77°39′40.38″	50	*Juniperus communis*
Thathidhaar 4	SM	NE	3518	31°46′24.35"	77°33′15.77"	35	*Abies pindrow, Prunus cornuta*
Indira	BD	NE	3400	31°48′51.96″	77°30′41.52″	40	*Abies pindrow*
Neeliyali	SM	W	2984	31°51′48.3″	77°25′21.66″	20	*Acer acuminatum*
Dwada Thatch	SM	NW	3353	31°50′56.22″	77°21′11.1″	35	*Rhododendron campanulatum*
Bhujaradi	SM	N	3610	31°42′12.84″	77°29′31.02″	20	*Abies pindrow*
Rakhundi forest	SM	NE	3594	31°42′38.82″	77°29′40.02″	40	*Abies pindrow*
Gumtaraw 4	SM	SW	3490	31°43′16.68″	77°29′18.24″	30	*Betula utilis, Abies pindrow*
Kukhad Gaad	SM	E	3593	31°42′31.98	77°29′34.08″	35	*Abies pindrow*
Thathidhaar 3	SM	E	3605	31°46′25.61"	77°33′8.16"	25	*Abies pindrow, Acer caesium*
Jammu Nallah	MS	NW	3609	31°42′25.8″	77°29′33.6″	40	*Abies pindrow*
Jammu Nallah 2	MS	N	3646	31°42′3.84″	77°29′25.68″	40	*Rhododendron campanulatum*
Rhakundi Top	SM	N	3537	31°40′0.36″	77°29′19.2″	30	*Rhododendron campanulatum*
Rhakundi	BD	N	3105	31°39′42.42″	77°30′43.38'	30	*Prunus cornuta, Betula utilis*
Kholi Poi 1	BD	N	3107	31°39′43.26″	77°30′46′74″	35	*Abies pindrow*
Kholi Poi 2	BD	N	2979	31°39′50.4″	77°30′49.32″	20	*Abies pindrow*
Upper Kholi Poi 1	SM	NW	3347	31°39′37.92″	77°30′53.52″	30	*Quercus semecarpifolia*
Kholi Poi 4	SM	N	3600	31°39′35.94″	77°31′7.5″	33	*Abies spectabilis*
Upper Kholi Poi 2	SM	N	3036	31°39′48.36″	77°30′41′88″	25	*Taxus wallichiana*
Upper Kholi Poi 3	SM	N	2900	31°39′57.48″	77°30′53.58″	30	*Taxus wallichiana*
Kholi Poi 5	SM	NE	3624	31°42′25.97"	77°33′6.00"	20	*Abies pindrow, Acer caesium*

Table 2 (continued)

Population	Habitat type	Aspect	Altitude (m)	Latitudes (N)	Longitudes (E)	Slope (◦)	Associated species
Luthla Paani	BD	S	3128	31°42′18.66"	77°34′22.32"	20	*Salix denticulata*
Shankha Thatch	RI	S	3212	31°42′18.18"	77°31′8.4"	30	*Quercus semecarpifolia*
Majhoni 1	MS	NW	3360	31°42′33.18"	77°35′10.32"	50	*Abies spectabilis, A. pindrow*
Majhoni 2	SM	SW	3332	31°42′32.58"	77°34′59.88"	30	*Abies pindrow*
Thathidhaar 5	SM	W	2950	31°47′46.96"	77°34′35.22"	30	*Taxus wallichiana*
Kukhdi Thatch	MS	N	3715	31°42′10.02"	77°35′28.74"	48	*Rhododendron anthopogon*
Shilla Berkeru	BD	N	3667	31°42′13.98"	77°35′49.2"	38	*Rosa sericea*
Mandrach 2	SM	NW	3575	31°42′12.6"	77°32′58.8"	30	*Abies pindrow*
Satholi 1	MS	N	3545	31°41′9.42"	77°32′54.84"	45	*Rhododendron anthopogon*
Shatholi 2	SM	N	3468	31°41′2.7"	77°32′44.4"	28	*Rhododendroncampanulatum*
Phupphu	SM	S	3546	31°40′35.52"	77°32′53.88"	32	*Rhododendron campanulatum*
Ansrubagh	SM	NE	3492	31°40′4.26"	77°32′53.88"	30	*Rhododendron campanulatum*
Chandni Top	SM	NW	3382	31°40′10.8"	77°32′12.06"	30	*Rhododendron campanulatum*
Chandni	MS	N	3263	31°40′16.56"	77°31′48.84"	45	*Viburnum grandiflorum*

SM shady moist, *MS* moist slope, *RI* riverine, *BD* bouldery and *RK* rocky, *N* north, *NW* northwest, *SW* south west, *NE* north east, *S* south, *W* west

Size class distribution of B. utilis

Size class distribution of *B. utilis* is slightly deviated from reverse J-shaped structure that is considered to be indication of good regeneration status (Fig. 2). Individuals with small diameter class > 10.5 cm i.e., seedlings and 10.5 to 31.4 cm i.e., saplings were relatively very high, but those with diameter class between 31.6 to 52.5 cm were less in number. Further, individuals with medium girth class i.e., 52.6 to 73.5 cm have increased. In younger trees i.e., 52.6 to 73.5 cm were found maximum.

Physico-chemical properties of soil

Among the populations, pH was ranged from 5.13 (Chainghar) to 7.35 (Thathidhaar 2). Total nitrogen of soil was found to be the highest at Jwaratapra (0.79%) and the lowest at Chandni Top (0.04%). Soil organic matter ranged from 2.21% (Satholi 2) to 16.47% (Bhujaradi). Similarly, the total organic carbon of soil varied from 1.2% (Satholi 2) to 9.55% (Bhujaradi). Moisture content of soil to be the lowest at Parkachi Thatch (5.49%) and the highest at Chandni (57.9%). Available phosphorus ranged from 2.57 kg ha^{-1} (Kholipoi 4) to 438.8 kg ha^{-1} (Majhoni 2) and available potassium varied from 75.5 kg ha^{-1} (Kukhad Gaad) to 935 kg ha^{-1} (Satholi 1) (Fig. 3). Available phosphorus and pH were found to be significantly correlated ($p \leq 0.01$, r = 0.20, n = 64) and ($p \leq 0.01$, r = 0.20, n = 64) with tree density throughout the sites.

Habitat distribution modelling

The model calibration test for *B. utilis* yielded satisfactory results ($AUC_{Mean} = 0.91 \pm 0.02$) (Fig. 4A). The red line indicates the mean area and light blue line shows the omission on training samples (Fig. 4B). The omission rate was calculated both on the training presence records on the test records. Based on permutation importance of the input environment variables, precipitation of coldest quarter was the most influential and contributed 65.5%, followed by annual precipitation which contributed 16.9%, and aspect contributed 5.9% to the habitat model, while other variables contributed only 4.8%. The most important variable based on percent contribution was annual precipitation, which contributed 36% to the habitat model, followed by temperature seasonality, precipitation of coldest quarter, aspect, and other variables had percent contribution of 25%, 19.3, 13.8, and 5.8, respectively (Table 5).

The Jackknife test results, comparing the climatic variables in the model prediction depicted in Fig. 5A. The environmental variables which showed the highest gain were temperature seasonality (BIO4). The bioclimatic variable that attains the lowest gain was aspect, and isothermality (BIO3). During field surveys, it was observed that the *B. utilis* better survived only in extreme climatic conditions, also the species preferred seasonal precipitation and make pure stands between 2800 and 3700 m above mean sea level (amsl) which is validated from model output (Fig. 5B).

Potential habitat distribution area

In Great Himalayan National Park, habitats with high suitability thresholds were distributed in Raktikhol, Kholi Poi, Parkachi Sheera, Rakti Khol, Rakhundi, Bhujaradi, Satholi, Ansurubagh and Kukhdi Thatch in north-west part of GHNP. Primary field investigations indicated that the predicted potential habitats were mostly shady moist located at

Table 3 Site wise species richness, density, species diversity (H'), TBA and concentration of dominance (Cd) of tree, herb and shrub layers of *B. utilis* populations

	Trees					Shrubs				Herbs			
Populations	RC	Den	Cd	H'	TBA	RC	Den	Cd	H'	RC	Den*	Cd	H'
Dhel	3	30	0.01	0.21	0.01	7	640	0.17	1.85	25	41.00	0.08	2.80
Dhel Thatch	1	10	1.00	–	0.04	6	2520	0.28	1.46	22	36.30	0.16	2.37
Sartu Thatch	3	280	0.52	0.24	7.00	12	570	0.17	2.17	27	36.75	0.13	2.53
Chyoskhol	6	90	0.32	0.32	0.28	4	340	0.39	1.07	32	35.28	0.06	3.15
Jwaratapra	2	130	0.07	0.35	1.08	7	560	0.21	1.74	38	60.10	0.06	3.21
Thathidhaar 1	1	520	1.00	–	12.98	6	2540	0.23	1.58	21	60.85	0.11	2.54
Brahmachuli	5	40	0.01	0.20	0.07	7	1420	0.26	1.51	27	138.38	0.05	3.09
Chainghar	3	240	0.25	0.35	5.60	6	1680	0.18	1.76	29	122.23	0.08	2.79
Sartu Thatch	2	460	0.73	0.20	15.42	5	1540	0.27	1.46	25	94.95	0.08	2.82
Chainghar 2	3	220	0.13	0.37	6.77	7	1100	0.15	1.93	18	63.23	0.10	2.49
Rakti Khol 1	1	420	1.00	–	35.42	3	1370	0.34	1.09	15	80.23	0.09	2.56
Rakti Khol 2	1	660	1.00	–	18.28	4	2090	0.31	1.22	12	60.95	0.12	2.26
Thathidhaar 2	3	310	0.33	0.32	9.03	7	3490	0.22	1.64	20	78.00	0.13	3.16
Rakti Khol 3	1	290	1.00	–	5.03	4	2990	0.35	1.17	20	82.58	0.10	2.63
Parkachi Sheera	3	510	0.25	0.35	29.75	11	1960	0.13	2.21	21	79.43	0.09	2.67
Parkachi Sheera 2	4	730	0.58	0.21	35.58	5	1310	0.31	1.11	30	126.48	0.05	3.22
Parkachi Sheera 3	3	190	0.08	0.36	5.72	5	2090	0.33	1.28	16	80.33	0.08	2.61
Mashyar	4	420	0.42	0.28	12.00	4	840	0.28	1.33	28	122.65	0.06	3.07
Jognidhar	2	340	0.24	0.35	6.49	7	1080	0.17	1.83	18	67.70	0.09	2.65
Parkachi Thatch	2	400	0.18	0.36	24.65	7	1540	0.22	1.72	27	76.03	0.07	2.89
Upper Parkachi	2	480	0.50	0.25	43.32	6	1060	0.31	1.39	17	49.13	0.11	2.37
Parkachi ka Sheera	2	590	0.97	0.02	33.41	7	1020	0.24	1.51	17	83.13	0.10	2.52
Telan	3	290	0.11	0.37	22.39	7	1290	0.22	1.55	21	71.83	0.06	2.88
Paitu Dhaar 2	4	250	0.10	0.36	6.17	8	1480	0.15	1.99	17	65.00	0.07	2.56
Thathidhaar 3	2	270	0.17	0.36	10.96	7	1550	0.32	1.37	21	81.15	0.10	2.55
Thathidhaar 4	3	220	0.09	0.36	3.17	10	1640	0.13	2.15	29	95.03	0.17	2.58
Paitu Dhaar	5	150	0.05	0.34	2.75	8	2170	0.15	1.97	22	53.68	0.08	2.83
Naina Forest	4	310	0.18	0.36	19.49	7	1270	0.19	1.80	18	58.53	0.10	2.57
Naina Thatch	1	230	1.00	–	2.71	6	1320	0.18	1.75	40	95.95	0.05	3.35
Paitu	2	420	0.95	0.02	11.18	9	2010	0.15	2.02	26	70.90	0.06	3.02
Jaula 1	2	160	0.56	0.30	8.67	6	1740	0.24	1.53	19	69.25	0.09	2.68
Rahla	1	320	1.00	–	3.72	9	2130	0.14	2.09	25	105.90	0.09	2.83
Indira	1	10	1.00	–	0.00	4	750	0.31	1.27	22	99.80	0.09	2.71
Thathidhaar 5	3	370	0.41	0.35	19.97	7	2350	0.18	1.79	10	56.78	0.07	2.77
Neeliyali	2	680	0.89	0.05	18.83	10	2640	0.14	2.11	30	151.58	0.05	3.21
Dwada Thatch	6	40	–	0.15	0.01	8	1730	0.25	1.63	29	151.13	0.05	3.12
Bhujaradi	1	680	1.00	–	13.97	12	2190	0.14	2.19	33	120.53	0.05	3.24
Rakhundi Forest	2	520	0.90	0.05	19.30	9	3250	0.28	1.69	26	72.28	0.09	2.82
Gumtaraw 4	1	280	1.00	–	10.11	5	2500	0.24	1.51	16	53.88	0.08	2.60
Kukhad Gaad	2	20	0.47	0.26	0.00	8	2110	0.20	1.76	24	84.53	0.07	2.92
Jammu Nallah	2	350	0.95	0.02	11.04	6	1660	0.28	1.50	25	66.50	0.09	2.65
Jammu Nallah 2	1	400	1.00	–	7.39	6	1330	0.20	1.66	15	38.98	0.11	2.46
Rhakundi Top	1	300	1.00	–	5.93	7	1200	0.17	1.82	15	26.33	0.14	2.33
Rhakundi	1	140	1.00	–	0.46	6	1307	0.21	1.63	27	47.73	0.10	2.76
Kholi Poi 1	5	115	0.01	0.26	39.02	4	1960	0.31	1.26	11	43.35	0.12	2.28
Kholi Poi 2	5	630	0.66	0.17	25.84	5	1240	0.26	1.48	15	59.00	0.10	2.50
Upper Kholi Poi 1	4	290	0.12	0.37	27.48	7	1405	0.17	1.85	18	55.30	0.10	2.58
Kholi Poi 4	5	570	0.24	0.35	26.09	4	910	0.36	1.18	12	27.20	0.12	2.28
Upper Kholi Poi 2	3	440	0.52	0.25	10.92	5	1160	0.31	1.27	4	13.20	0.45	0.93

Table 3 (continued)

Populations	Trees					Shrubs				Herbs			
	RC	Den	Cd	H'	TBA	RC	Den	Cd	H'	RC	Den*	Cd	H'
Upper Kholi Poi 3	2	320	0.95	0.03	6.20	5	1260	0.24	1.51	5	16.00	0.22	1.57
Kholi Poi 5	5	43	–	0.15	0.01	5	900	0.35	1.37	14	28.73	0.08	2.57
Luthla paani	1	20	1.00	–	0.43	7	1570	0.17	1.82	30	129.40	0.08	2.98
Shankha Thatch	2	436	0.64	0.18	15.35	5	2050	0.23	1.54	23	88.70	0.06	2.98
Majhoni 1	3	209	0.10	0.36	2.88	8	1088	0.16	1.93	20	71.93	0.07	2.84
Majhoni 2	2	80	0.03	0.31	0.20	7	1060	0.16	1.88	31	187.33	0.04	3.23
Kukhdi Thatch	1	500	1.00	0.00	16.36	6	2465	0.27	1.19	22	77.80	0.06	2.88
Shilla Berkeru	1	470	1.00	0.00	8.40	4	2250	0.15	2.03	32	88.15	0.04	3.30
Mandrach 2	2	500	0.74	0.13	19.42	6	1366	0.18	1.75	14	54.73	0.10	2.46
Satholi 1	1	680	1.00	0.00	14.93	6	822	0.20	1.69	18	58.43	0.09	2.60
Shatholi 2	3	440	1.00	0.00	9.84	7	2220	0.16	1.87	23	61.50	0.09	2.67
Phupphu	2	45	0.01	0.20	0.01	5	580	0.21	1.59	27	71.95	0.06	3.05
Ansrubagh	1	680	1.00	0.00	14.50	9	1099	0.13	2.09	28	97.58	0.06	3.06
Chandni Top	2	45	0.01	0.22	1.99	7	1000	0.22	1.73	23	140.65	0.08	2.78
Chandni	4	263.6	0.10	0.36	6.31	6	1460	0.18	1.75	24	59.93	0.06	2.95

RC richness, *Den* density (Ind/hectare), *Den** density (Individual/meter^2), *TBA* total basal area, *Cd* concentration of dominance, *H'* species diversity

Parkachi Sheera, Bhujaradi, Satholi, Ansrubagh, Rakti khol, Majhoni and Kholipoi populations in GHNP. Of the total 1171 km^2 area, 304 km^2 was predicted to be suitable for *B. utilis* reintroduction in which, 17.06 km^2 area (1.45%) was highly suitable, 74.56 km^2 (6.36%) was suitable, 101.31 km^2 (8.65%) moderately suitable and 111.06 km^2 (9.48%) least suitable. The remaining area of 866 Km^2 (74.03%) was not suitable (Fig. 6).

Discussions

In Indian Himalayan Region (IHR), a large amount of research on the composition and structure of vegetation has been conducted (Dhar et al. 1997; Joshi and Samant 2004; Samant and Joshi 2004; Rana et al. 2011; Samant et al. 1998). However, a very few studies on population ecology and habitat distribution modeling are available (Adhikari et al. 2012, 2018; Barik and Adhikari 2012; Paul et al. 2018, 2019a). There are a number of ecologically and economically important species in the region; among them, *B. utilis* is one of the most ecologically and economically important multipurpose species of sub-alpine ecosystem of the Himalayas. However, the population is very narrow throughout the IHR due to severe climatic conditions and various anthropogenic pressures. These threats affect the regeneration and distribution of the Himalayan Birch. As a result, Ved et al. (2003) categorized this species as Critically Endangered. Therefore, the present study investigated 64 populations of *B. utilis* occurring in the sub-alpine ecosystem of GHNP for the population status, regeneration pattern, physico-chemical properties of soil, size class distribution and habitat suitability modeling.

The sub-alpine ecosystem of GHNP differentiated into two stands, the lower belt showed mixed *Betula* forest whereas upper belt showed the pure *Betula* forest. The study revealed that the maximum density of *B. utilis* was found between 3500 and 3600 m, northern aspect and shady moist habitat. Similar trends have been reported in other parts of the IHR (Dhar et al. 1997; Joshi and Samant 2004; Samant and Joshi 2004; Joshi and Samant 2014; Shreshta et al. 2007; Sujakhu et al. 2013; Gairola et al. 2015).

The seedlings and saplings were abundant in the forests (1750 Ind ha^{-1} seedlings and 1635 Ind ha^{-1} saplings). The density of seedlings was higher than density of saplings, which was a normal demographic development (West et al. 1981). Occurrence of highest saplings density recorded in pure Rakti Khol 3 (3050 Ind ha^{-1}) population and highest seedlings density in Upper Kholi Poi 3 (1840 Ind ha^{-1}) population indicated the high suitability of these sites for the germination and growth of *B. utilis*.

Pearson correlation showed significant positive relations between the density of trees with TBA ($p \le 0.01$, r = 0.30, n = 64), pH ($p \le 0.01$, r = 0.20, n = 64) and available phosphorus ($p \le 0.01$, r = 0.21, n = 64), significant positive relations between seedlings density with saplings density ($p \le 0.01$, r = 0.80, n = 64) and available potassium ($p \le 0.01$, r = 0.20, n = 64) and negative relation with carbon ($p \le 0.01$, r = − 0.20, n = 64) (Fig. 7). Most of the populations of *B. utilis* had soil have pH below 6.5, this may be due to high organic matter content and undisturbed nature of the soil in the study area (Gairola et al. 2012).

Table 4 Site wise seedlings, saplings and total trees density of *B. utilis* populations

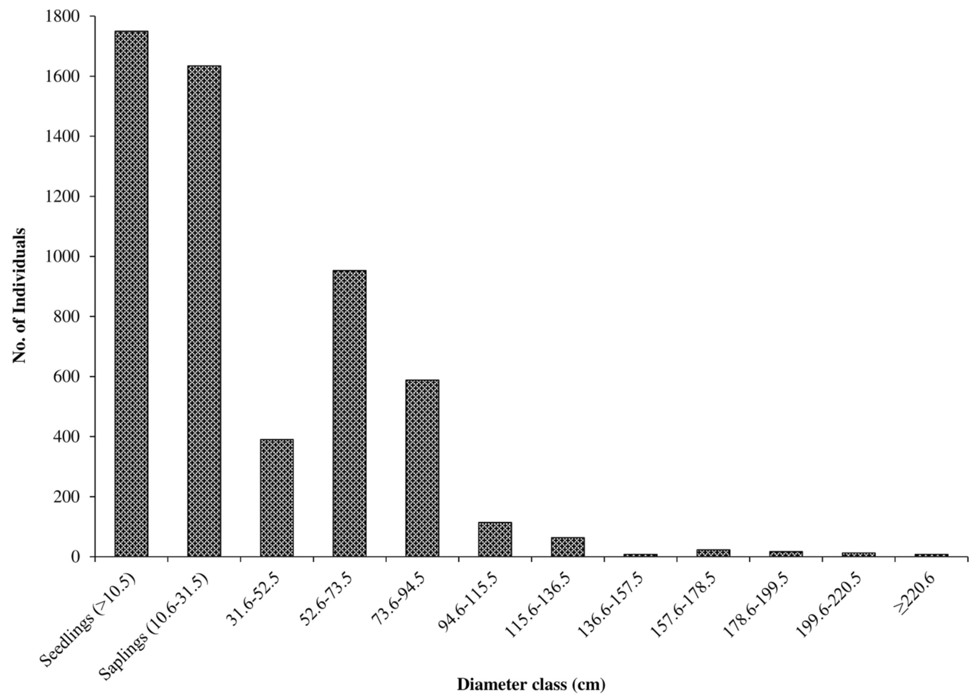
Density Ind/hectare							Density Ind/hectare						
Population	Tree		Sapling		Seedling		Population	Tree		Sapling		Seedling	
	1	2	1	2	1	2		1	2	1	2	1	2
Dhel	350	30	430	20	160	160	Rahla	320	320	820	820	400	400
Dhel Thatch	10	10	50	50	45	45	Indira	10	10	30	30	50	50
Sartu Thatch	390	280	110	50	30	30	Neeliyali	720	680	850	810	1270	1270
Chyoskhol	160	90	90	20	110	110	Dwada Thatch	810	40	140	–	200	200
Jwaratapra	480	130	210	10	–	–	Bhujaradi	680	680	610	610	650	650
Thathidhaar 1	520	520	160	160	30	30	Rakhundi Forest	547	520	960	960	500	500
Thathidhaar 2	536	310	170	90	–	–	Gumtaraw 4	280	280	180	180	310	310
Thathidhaar 3	650	270	130	70	230	230	Kukhad Gaad	29	20	20	20	10	10
Thathidhaar 4	708	220	50	50	–	-	Jammu Nallah	359	350	960	950	390	390
Thathidhaar 5	580	370	180	50	93	93	Jammu Nallah 2	400	400	540	540	850	850
Brahmachuli	490	40	–	–	–	–	Rhakundi Top	300	300	690	690	660	660
Chainghar	480	240	110	60	50	50	Rhakundi	140	140	380	380	240	240
Sartu Thatch	540	460	90	70	80	80	Kholi Poi 1	956	115	730	50	586	586
Chainghar 2	610	220	210	20	420	-	Kholi Poi 2	773	630	290	240	316	316
Rakti Khol 1	420	420	400	400	420	420	Upper Kholi Poi 1	1830	290	950	230	781	781
Rakti Khol 2	660	660	500	500	400	400	Kholi Poi 4	1157	570	628	340	760	760
Rakti Khol 3	290	290	3050	3050	1510	1510	Upper Kholi Poi 2	608	440	230	190	217	217
Parkachi Sheera	1010	510	810	90	810	810	Upper Kholi Poi 3	329	320	1410	1410	1840	1840
Parkachi Sheera 2	960	730	880	420	610	610	Kholi Poi 5	883	43	270	20	134	134
Parkachi Sheera 3	660	190	290	140	500	500	Luthla paani	–	20	100	100	50	50
Mashyar	650	420	240	160	460	460	Shankha Thatch	546	436	442	282	308	308
Jognidhar	700	340	330	140	400	400	Majhoni 1	652	209	219	109	153	153
Parkachi Thatch	940	400	350	130	300	300	Majhoni 2	440	80	169	9	119	119
Upper Parkachi	680	480	320	240	310	310	Kukhdi Thatch	500	500	820	820	690	690
Parkachi ka Sheera	600	590	530	530	220	220	Shilla Berkeru	470	470	400	400	510	510
Telan	880	290	390	70	150	150	Mandrach 2	580	500	270	230	330	330
Paitu dhaar 2	780	250	380	60	290	290	Satholi 1	680	680	380	380	720	720
Paithudhaar	670	150	790	320	300	300	Shatholi 2	493	440	270	270	320	320
Naina Forest	740	310	450	130	220	220	Phupphu	575	45	190	18	79	79
Naina Thatch	230	230	210	210	240	240	Ansrubagh	680	680	350	350	610	610
Paitu	430	420	270	270	250	250	Chandni Top	954	45	296	36	199	199
Jaula 2	640	480	120	60	300	300	Chandni	844	264	256	118	242	242

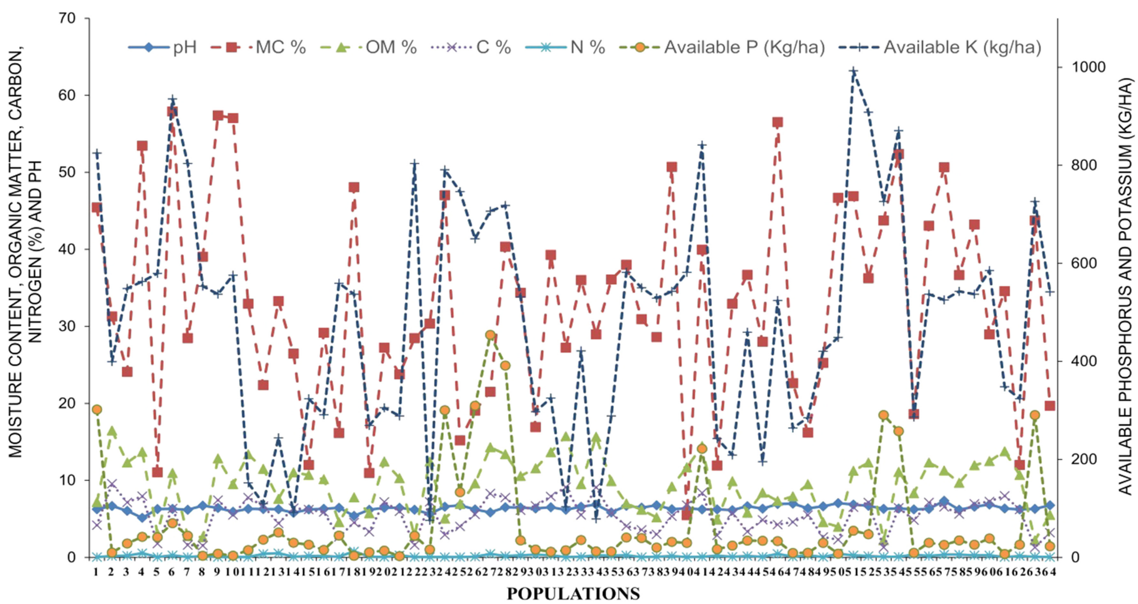
1 Total trees; *2 Betula utilis*

The status of regeneration of a tree species is determined by the presence of saplings and plants in the forest (Samant and Joshi 2004; Joshi and Samant 2014). The present study revealed the highest seedlings of *B. utilis* in Upper Kholi Poi 3, Rakti Khol 3, Neeliyali, Jammu Nallah 2, and Parkachi Sheera, respectively and saplings was highest in Rakti Khol 3, Upper Kholi poi 3, Rakhundi Forest, Jammu and Rahla, respectively, indicating their inaccessibility, remote access and high altitude location and less grazing pressures. However, lowest seedlings were recorded in Kukhad Gaad, Thathidhaar 1, Sartu Thatch, Dhel Thatch, Indira, Chainghar, Luthla Paani and Phupphu populations. These populations were located nearby villages (Shakti, Maraur, Lapah and Shumga) and villagers were largely dependent on these sites for fuel, fodder, grazing, etc. Also, seasonal forest fires severely damage to young seedlings and saplings.

The population assessment of *B. utilis* revealed that the number of seedlings and saplings were relatively very high compared to the trees in different size classes. This indicated that the seedlings are able to develop into saplings, but saplings did not develop into trees. This could be due to cutting and felling of saplings for various household needs. The mortality was due to heavy snow fall and heavy grazing pressure. The population was not encouraging

Fig. 2 Population profile of *B. utilis* in Great Himalayan National Park





1 = Ansrubagh, 2 = Bhujaradi, 3 = Brahmachuli, 4 = Chainghar, 5 = Chainghar 2, 6 = Chandni, 7 = Chandni Top, 8 = Chyoskhol, 9 = Dhel, 10 = Dhela Thatch, 11 = Dwada Thatch, 12 = Gumtaraw 4, 13 = Indira, 14 = Jammu Nallah, 15 = Jammu Nallah 2, 16 = Jaula 2, 17 = Jognidhaar, 18 = Jwaratapra, 19 = Kholi Poi 1, 20 = Kholi Poi 2, 21 = Kholi Poi 4, 22 = Kholi Poi 5, 23 = Kukhad Gaad, 24 = Kukhdi Thatch, 25 = Luthla Pani, 26 = Majhoni 1, 27 = Mjahoni 2, 28 = Mandrach 2, 29 = Mashyar, 30 = Naina Forest, 31 = Naina Thatch, 32 = Niliali, 33 = Paitudhaar, 34 = Paitu, 35 = Paitu 1, 36 = Parkachi ka Sheera, 37 = Parkachi Sheera, 38 = Parkachi Sheera 2, 39 = Parkachi Sheera 3, 40 = Parkachi Thatch, 41 = Phuppu, 42 = Rahla, 43 = Rakhundi Forest, 44 = Rakti Khol 1, 45 = Rakti Khol 2, 46 = Rakti Khol 3, 47 = Rakhundi, 48 = Rakhundi Top, 49 = Sartu Thatch, 50 = Sartu Thatch 1, 51 = Satholi, 52 = Shanka Thatch, 53 = Satholi 2, 54 = Shilla Berkeru, 55 = Telan, 56 = Thatidhaar 1, 57 = Thatidhaar 2, 58 = Thatidhaar 3, 59 = Thatidhaar 4, 60 = Thatidhaar 5, 61 = Upper Kholi Poi, 62 = Upper Kholi Poi 2, 63 = Upper Kholi Poi 3 and 64 = Upper Parkachi

Fig. 3 Physico-chemical profile of soil in different populations of *B. utilis*

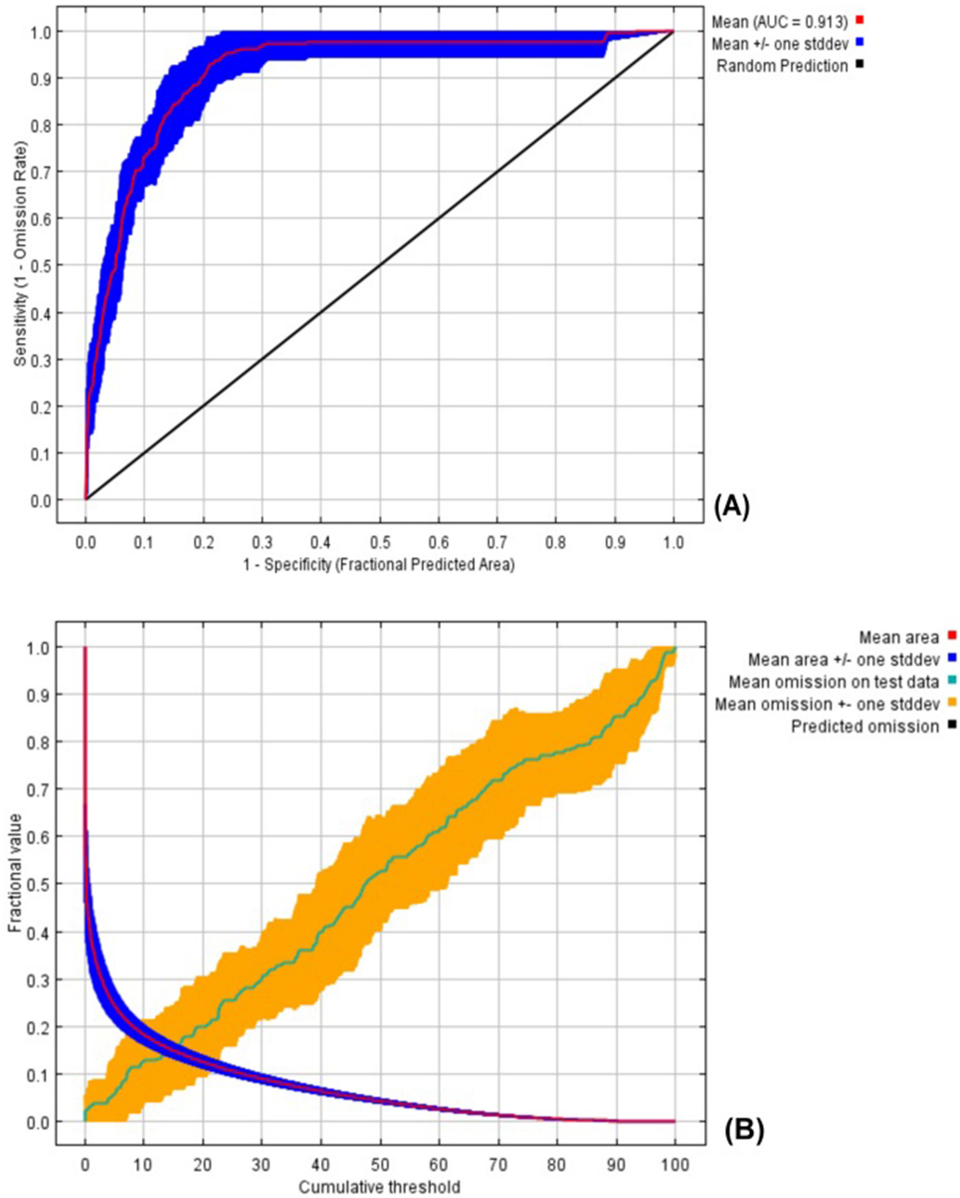


Fig. 4 Omission and receiver operating characteristic curve; **A** Receiver operating characteristic curve with area under curve (AUC) and **B** Omission versus predicted area

Table 5 Estimates of relative contributions and permutation importance of the predictor environmental variables to the MaxEnt model

Variable	Description	Permutation importance (%)	Variable contribution (%)
BIO19	Precipitation of coldest quarter	65.5	19.3
BIO12	Annual precipitation	23.7	36
ASPECT	Aspect	5.9	13.8
DEM	Elevation	2.4	0.4
BIO7	Temperature annual range (BIO5–BIO6)	2.3	1
BIO1	Annual mean temperature	0.1	0.1
BIO4	Temperature seasonality (standard deviation*100)	0	25
BIO3	Isothermality (BIO2/BIO7)*(100)	0	4.3

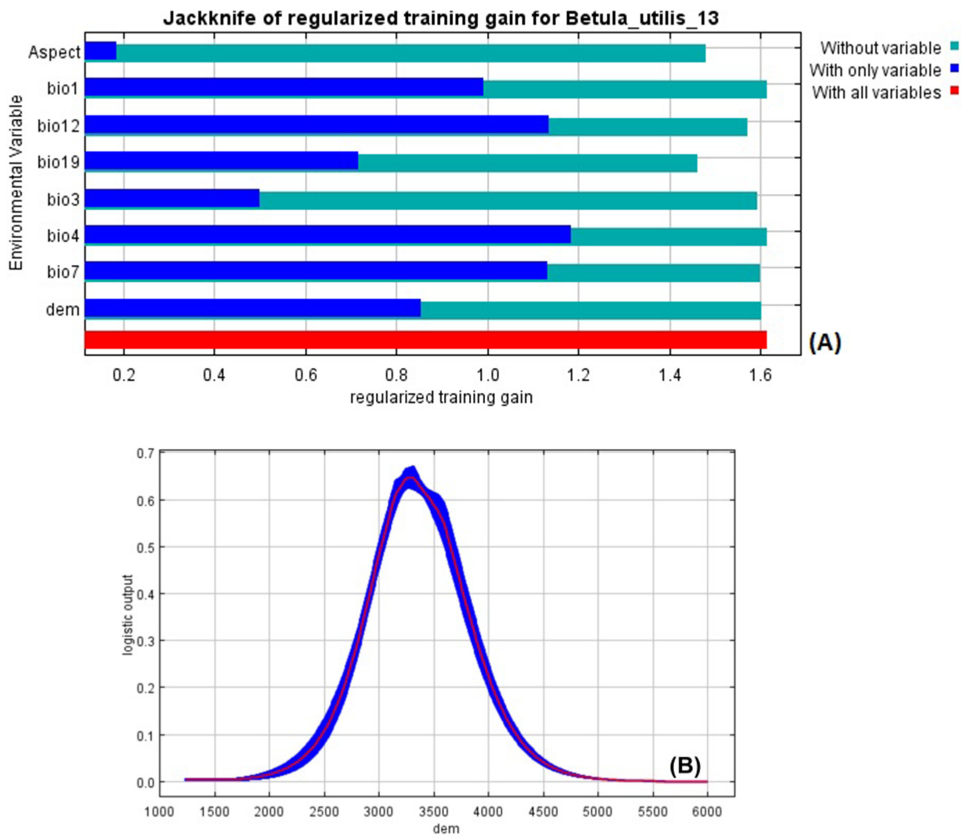


Fig. 5 **A** Result of Jakknife test for evaluating the relative contribution of the predictor environmental variables to the habitat model of *B. utilis* and **B** Elevation output of *B. utilis* through MaxEnt

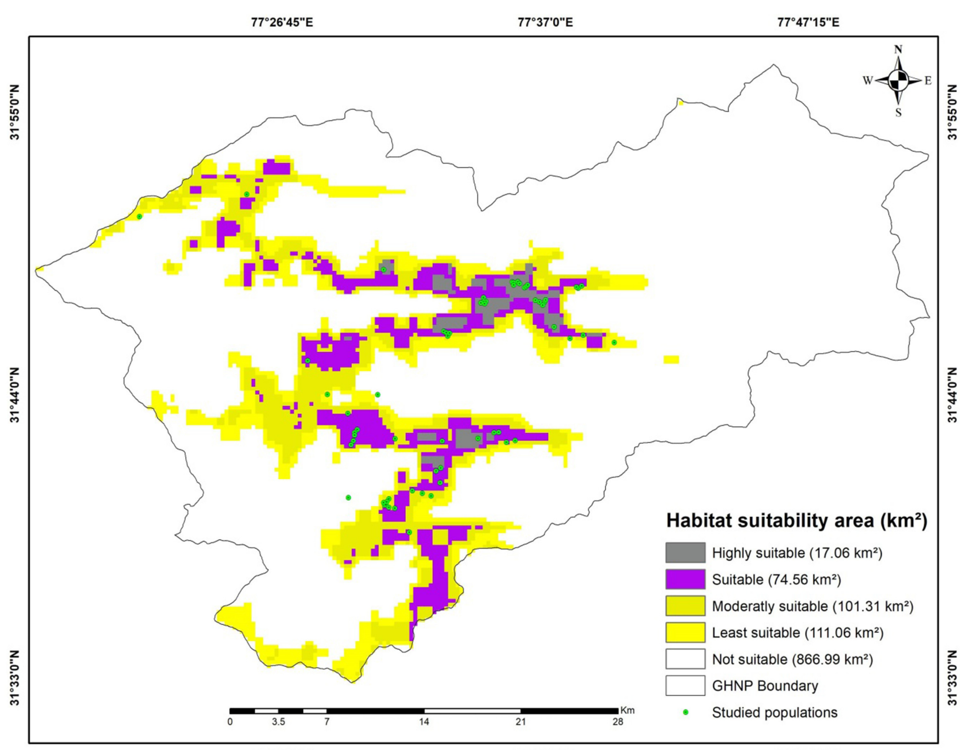


Fig. 6 Probability distribution map of *B. utilis*

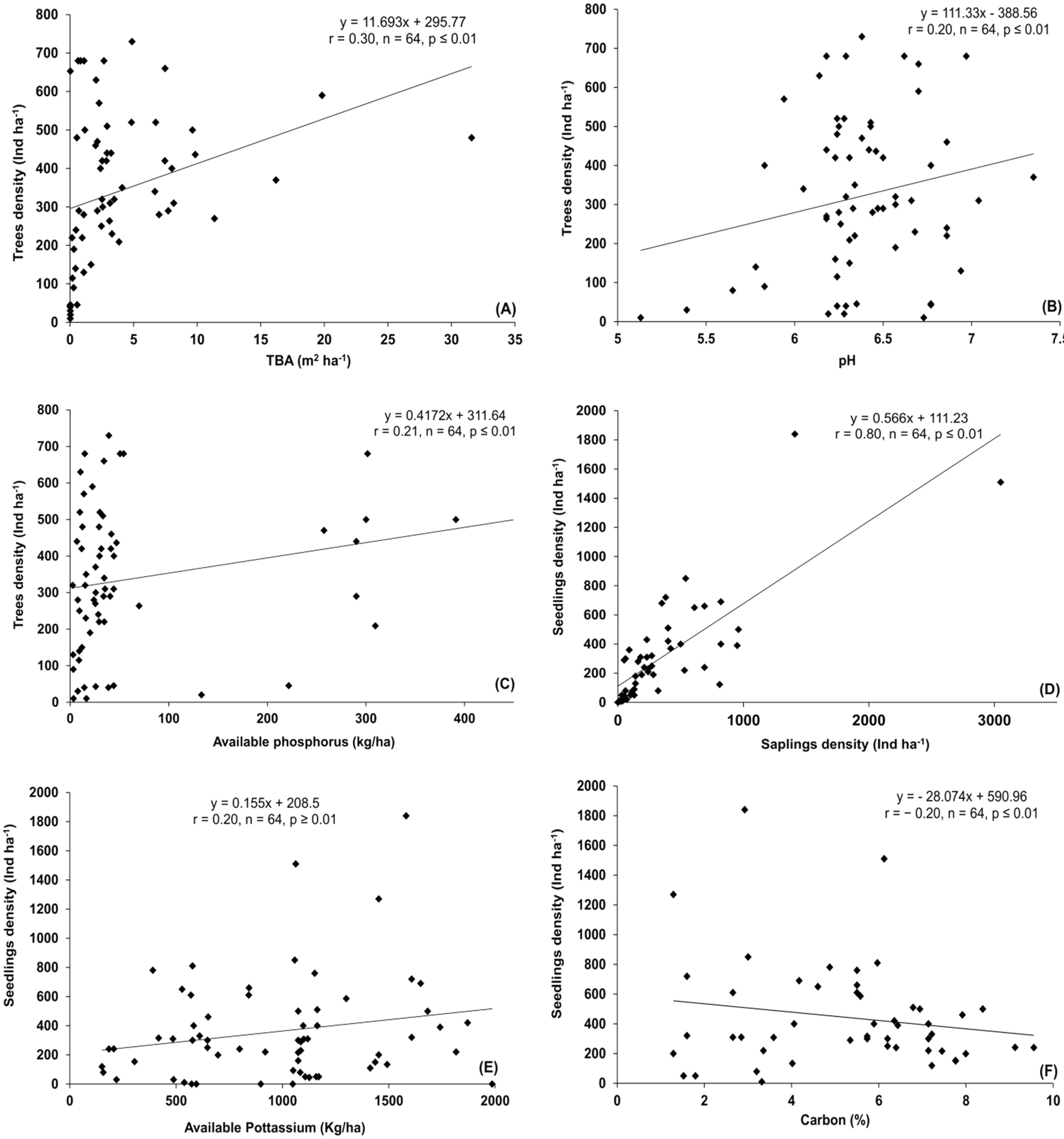


Fig. 7 Correlations between: **A** Trees density and TBA; **B** Tree density and pH; **C** Tree density and available phosphorus; **D** Saplings and seedlings density; **E** Seedling density and available potassium; and **F** Seedlings density and carbon

and showed discontinuous pattern and hence, didn't show sustainable regeneration. Further, the adult trees were relatively very less compared to the young trees, but the proportions of the trees in different size classes were not encouraging. Such profile of *B. utilis* is the indication of high biotic and abiotic pressures on the species.

For habitat suitability modeling, MaxEnt model is very suitable and the overall accuracy of the model is high. Amongst the habitat suitability classes, three classes i.e., highly suitable, suitable and moderately suitable classes can be considered for the reintroduction (*in- situ* conservation) of the species. The area under these classes falls in sub-alpine and north facing aspects of GHNP. These sites are Parkachi Sheera 2, Bhujaradi, Satholi 1, Rakti Khol 2, Kholi Poi 4, Parkachi Sheera, Mandrach 2, Shatholi 2 and Upper Parkachi and are highly suitable for persistence of the species. The areas identified with the high suitability revealed high density of trees, saplings and seedlings and validates these sites in terms of high suitability. The areas which fall under low probability showed low density of trees, seedlings and saplings. The results showing the extent and locations of species distribution provide the valuable insights for the *in-situ* conservation of species in GHNP.

B. utilis is an ecologically and economically important multipurpose tree species of the sub-alpine ecosystem and tree line across the Himalaya. In addition of the value of species, it also supports high value economically important medicinal plants such as *Trillium govanianum*, *Valeriana jatamansi*, *Picrorhiza kurroa*, *Sinopodophyllum hexandrum*, *Dactyloriza hatagirea*, *Angelica glauca,* etc. Therefore, periodical monitoring of the populations of this species and education and awareness among the local inhabitants and other stakeholders about the values and conservation of this species are suggested.

Conclusion

The sub-alpine ecosystem of GHNP is mostly dominated by *Betula utilis*, *Abies pindrow*, *A. spectabilis*, *Quercus semecarpifolia*, *Taxus wallichiana* and *Prunus cornuta* between 2800 and 3800 m amsl, Among the species, *B. utilis* is multipurpose ecologically and economically important species. The population structure of this species revealed the discontinuous pattern and is great concern for the conservation. The Ecological Niche Model validated the results of the present study. Therefore, protection of highly suitable sites and reintroduction in the identified suitable sites are suggested. The changing environmental conditions coupled with high anthropogenic pressures, however may lead to depletion in population of the species and replacement by other species with no or very little economic values in near future (Rana and Samant 2010). Further, frequent monitoring of the populations, awareness among the inhabitants, and participation of local communities and Forest Department in the in-situ and ex-situ conservation are suggested.

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Author contributions SSS originally formulated the idea, did identification of species, gave necessary inputs while the development of manuscript and finally edited manuscript. SN gave important inputs on maps preparation, AS worked on original idea, conducted field surveys, compiled and analyzed data and wrote the manuscript.

Declarations

Conflict of interest No potential conflict of interest was reported by authors.

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