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Regeneration, Stand Structure and Species Composition of *Magnolia lanuginosa* (Wall.) Figlar & Noot. Forest in Kengkhar, Bhutan

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Abstract

This study aimed to understand the regeneration, stand structure and associated species composition of *Magnolia lanuginosa* along the altitudinal gradient, assessed its conservation threats and looked into its suitable habitat niche for its growth and development model in the country using ArcGIS. A systematic sampling along the altitudinal gradient with the altitude difference of 100 m as the plot to plot distance was adopted in a natural forest at Nyugphu Goenpa in Kengkhar for data collection. Plot size of 20 x 20 m for trees (DBH ≥ 10 cm and H ≥ 1.3 m), 5 x 5 m for regeneration (DBH < 10 cm and H < 1.3 m) and 2 x 2 m for groundcover were used to collect vegetation data. Soil samples were collected using soil auger from the centre of each plot. A total of 279 plant species under 64 families were recorded from the study area. Hamamelidaceae was found to be the most dominant family in the study area. The associated tree species of *M. lanuginosa* were *Exbucklandia populnea*, *Quercus glauca*, *Cinnamomum bejolghota*, *Macaranga denticulata*, *Pinus bhutanica*, *Symplocos racemosa*, *Quercus lamellosa, Quercus oxyodon, Eurya acuminata* and *Engelhardia spicata*. The study covered slope ranging from 23% to 47% on south and north aspect. The maximum DBH of 115 cm and maximum height of 46 m were recorded. The total basal area of *M. lanuginosa* was 32,456 cm²/6,000 m² while the stem density was 17 stem/6,000 m². Over extraction and illegal felling were the highest conservation threats known to the species. However, regeneration of *M. lanuginosa* was minimal in close canopy forest compared to the human disturbed and open areas.

Keywords: composition, habitat modelling, *Magnolia lanuginosa*, regeneration, structure

Introduction

Magnolia lanuginosa (Wall.) Figlar & Noot. belongs to the family Magnoliaceae and the genus *Magnolia* consists of 219 species around the globe (Mabberley, 2008). Nine species under Magnoliaceae are recorded in Bhutan (Grierson and Long, 1984). *M. lanuginosa* is one of the less commonly found tree species around the globe in genus *Magnolia* (Wheeler and Rivers, 2014). Species in the family Magnoliaceae consists of evergreen or deciduous trees and shrubs (Cicuzza*et al*., 2007).

Magnolia lanuginosa can be found in north-east India, Bhutan, Nepal and China (Yunnan and Xizang) and its extent of occurrence is estimated between 112,000 and 950,000 km^2 (Wheeler and Rivers, 2014). It is a tropical and

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subtropical species, and extends into temperate region (Li and Conran, 2003). In Bhutan, this species can only be found in few districts; Chhukha, Gelephu, Punakha, Trongsa and Mongar at elevation ranging from 1800-2100 m above sea level (Grierson and Long, 1984). *M. lanuginosa* is widely used in timber production, medicinal purposes and ornamental-urban planting (Xai and Nooteboom, 2008; Mir *et al.,* 2016). The International Union for Conservation of Nature (IUCN) Red List has classified *M. lanuginosa* as data deficient as there is no information on existing subpopulations and its threats and uses are unknown (Wheeler and Rivers, 2014). Mir *et al*. (2016) reported that it has greatly been reduced in Meghalaya due to over exploitation and has classified it as an endemic threatened tree species.

Magnolia lanuginosa is 'regionally extinct' in China (Wheeler and Rivers, 2014), Vulnerable in India (Rana *et al.,* 2012), and there is no information of its occurrence, regeneration and conservation threats in Bhutan (Bhutan Biodiversity Center, 2019). Therefore, this study attempts in creating baseline information on its regeneration, stand structure, associated species composition and identification of conservation threats in Kengkhar, Eastern Bhutan. Finally, suitability habitat/niche model for the occurrence of *M. lanuginosa* in the country using ArcGIS (version 10.3) has been attempted.

Materials and Methods

Study area

Kengkhar Gewog is located in Mongar Dzongkhag (Figure 1) between 27°04'0.527" - 27° 11'22.102"N and 91°14'23" - 91°22'.333"E. It covers an area of approximately 100 km^2. The study area covers an altitude range from 306 m asl - 2553 m asl. The forest types are mainly

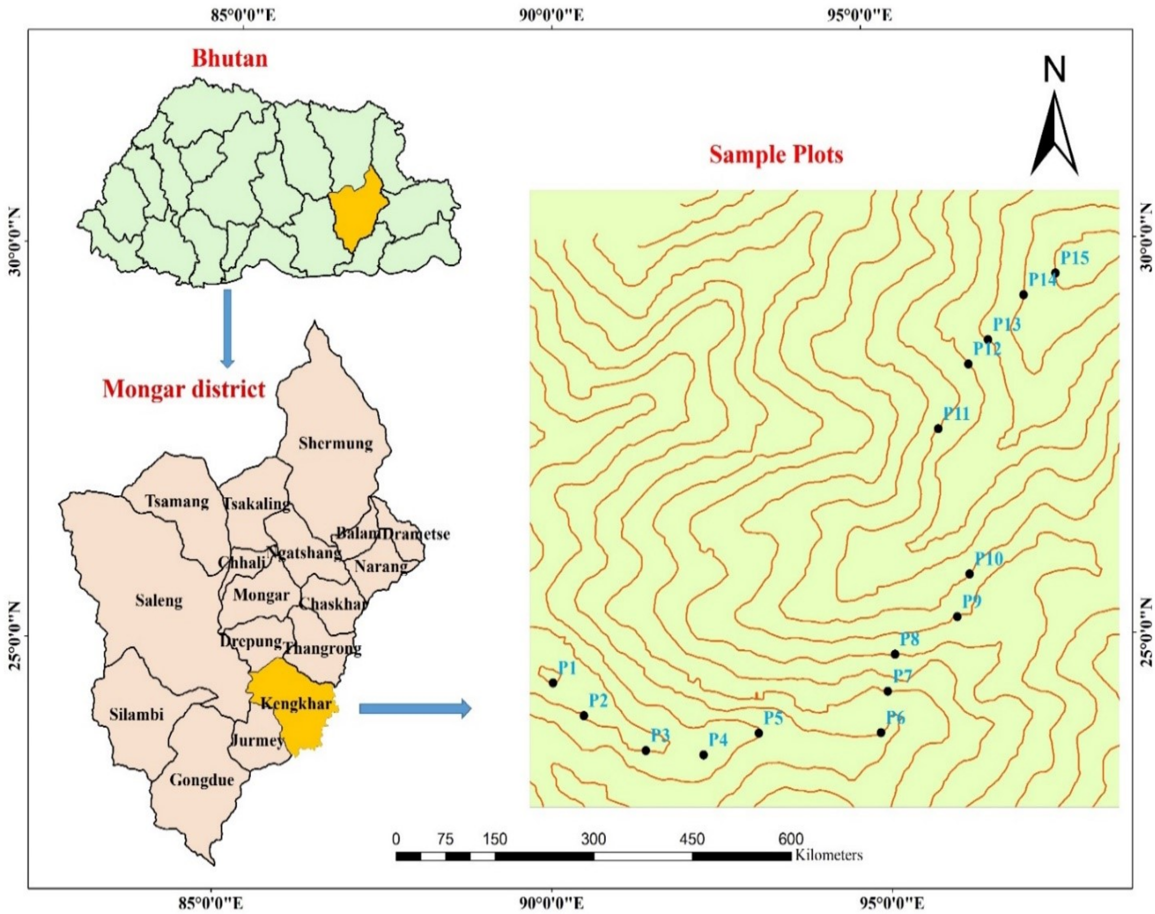


Figure 1: Map of study area showing sampling plots

dominated by Chirpine (*Pinus roxburghii* Sarg.) and broadleaved forests.

Sampling method

Systematic sampling method was used to identify the sampling plots which were assigned along the altitude gradient keeping the altitude difference of 100 m as the plot to plot distance. The survey covered different aspects and slopes along the altitudinal gradient starting from an altitude range of 1100 – 2500 m asl with plot number 1 being the lowest point and plot number15 being the highest survey point.

Plot design

Plots of 400 m^2 each were placed in quadrats of 20 x 20 m each for tree samples, 5 x 5 m for regeneration and 2 x 2 m for groundcover for data collection. Soil samples were collected using soil auger from centre of each plot.

Vegetation survey

All species ≥10 cm Diameter at Breast Height (DBH) and heights above 1.3 m were recorded as trees. In regeneration plots, all tree saplings (DBH< 10 cm and height ≤ 1.3 m) and shrubs were counted. In ground cover plots, all herbs were recorded.

Topographic data collection

Topographic attributes (geographic coordinates, altitude, aspect and slope) were recorded using instruments such as GPS, altimeter, compass and clinometer.

Climatic data collection

Variables under the climatic factors included mean annual rainfall and temperature obtained using climatic model (Dorji *et al.,* 2016).

Data analysis

The preliminary data were processed using Microsoft Excel 2013 and the species composition compiled. PC-ORD (version 5) was used for cluster analysis to determine the forest type. Statistical analysis using Statistical Package for Social Sciences was used in findings associations among variables.

Suitability area modelling

Suitable habitat for *Magnolia lanuginosa* growth or plantation in Bhutan was estimated using Times tool of QGIS (Quantum Geographic Information System) by feeding in slope, precipitation, temperature, and elevation in the Bhutan's Land Use and Land Cover (LULC) data of 2010. All the layers were converted to raster format with standardized cell size, projection and coordinate system, and geographic boundaries or extent (i.e., Bhutan boundary). The elevation and aspect layers were extracted from the DEM layer using spatial analyst tool in ArcMap. Settlements, rivers and roads were avoided using erase tool and a proximity of 100 m for river and 50 m for road was maintained using buffer tool. The final result was multiplied (Times tool) with the raster data to get the suitable area map for the growth and development of *M. lanuginosa*.

Results and Discussion

Site factors

On average, the soil moisture content was 6.62%, and soil pH was 5.74, indicating dryness and moderately acidic environment. Spearman's rho correlation coefficient between soil pH and soil moisture was not significant (r_s = .207, p > .05). This was expected since the data was collected in dry winter season, when nutrients from leaf litter are not released into the soil.

Floristic composition by major life form

A total of 136 tree species under 30 families were recorded and they were classified into five major life-forms consisting of evergreen forest, deciduous forests, evergreen shrub, deciduous shrub and conifer forest (Figure 2A). The result indicated dominance of evergreen forest along the gradient starting from 1500 m to the ridge top (2500 m) and the evergreen forest, deciduous forest and evergreen shrub dominated almost equally below 1500 m. Ground vegetation

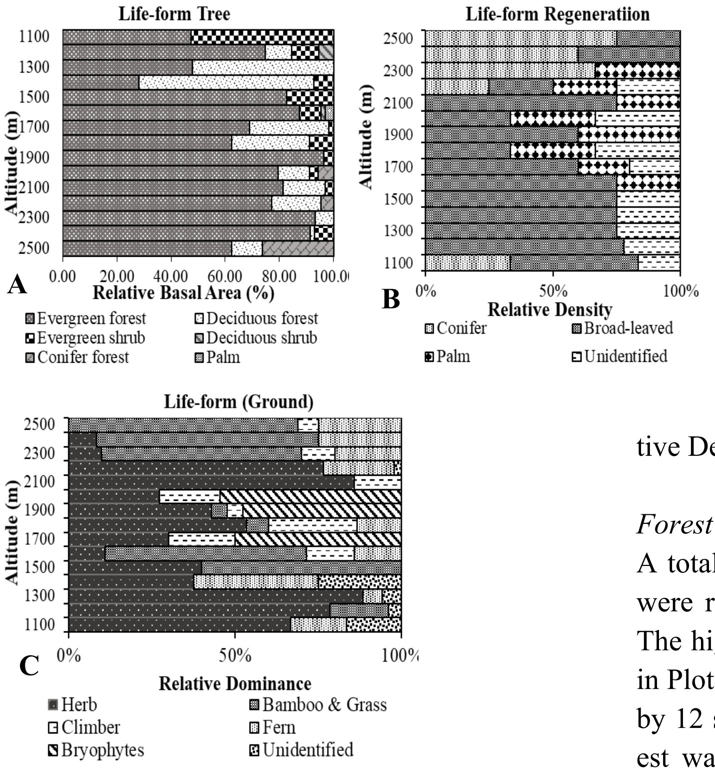


Figure 2: Altitudinal distribution of major life-forms: (A) tree layer, (B) regeneration, and (C) ground layer in *Magnolia lanuginosa* forest

comprised of 63 species consisting of 23 families dominated by herbs with 43.73% followed by bamboo and grasses with 22.99% (Figure 2B). Similarly, tree seedlings consisting of 14 families with 29 species, dominated by broad-leaved species, were observed (Figure 2C). The life-form analysis indicated that *Magnolia lanuginosa* found within the altitudinal gradient of 1600 m to 2200 m.

Dominant tree species

The Important Value Index (IVI) of 45 tree species in the study area showed *Exbucklandia populnea* (Griff) Brown with 20.50 as the most dominating tree species next to *Magnolia lanuginosa* (29.75) indicating strong association of species with *M. lanuginosa*, while *Betula utilis* David (1.55) resulted with lowest IVI signifying low association (Table 1). Important Value Index (IVI) was calculated using relative frequency, density and dominance (Mishra et al., 2008).

(IVI = Relative Frequency + Relative Density + Relative Dominance.)

Forest composition

A total of 279 plant species under 64 families were recorded from the study area (Table 2). The highest number (13 species) was recorded in Plot 11 at an altitude of 2100 m asl followed by 12 species in Plot 9 at 1900 m asl and lowest was recorded in Plot 1 with 6 species at 1100 m asl.

Classification of Magnolia lanuginosa forest

The Relative Basal Area (RBA) of dominant tree species in each plot was used in classification of forest type using a cluster dendrogram with a 50% similarity threshold. The forest was classified into three types; Type I = Pine-Oak dominated forest, Type II = *Schima khasiana* dominated forest and Type III = *Quercus* sp. dominated forest.

Type I (Pine-Oak dominated forest)

This forest was situated in upper part of the study site where altitude ranged from 1700 to 2500 m asl. This forest type was dominated by *Pinus bhutanica* and Fagaceae species. This forest type has an average soil moisture of 6.08%, mean annual temperature of 14.13 ^{0}C

Table 1: Important Value Index (IVI) of species

Species	Individuals	RD	RF	RDo	IVI	Remarks
Exbucklandia populnea	7	5.15	5.15	10.3	20.59	Highest
Betula utilis	1	0.74	0.74	0.08	1.55	Lowest

Note: RD = Relative density, RF = Relative frequency, RD_0 = Relative dominance, IVI = Important value index

Table 2: Associated species composition

Species	Family	Species	Family
Conifer		**Deciduous Tree**	
Juniperus recurva	Cupressaceae	*Acer oblongum*	Aceraceae
Pinus bhutanica	Pinaceae	*Alnus nepalensis*	Betulaceae
Pinus roxburghii	Pinaceae	*Betula alnoides*	Betulaceae
Evergreen tree		*Betula utilis*	Betulaceae
Aphanamixis polystays	Meliaceae	*Cheorospondias axillaris*	Anacardiaceae
Castanopsis indica	Fagaceae	*Cladrastis sinensis*	Fabaceae
Castanopsis hystrix	Fagaceae	*Corylus ferox*	Betulaceae
Castanopsis tribuloides	Fagaceae	*Ficus neriifolia*	Moraceae
Cinnamomum bejolghota	Luaraceae	*Juglans regia*	Juglandaceae
Engelhardia spicata	Juglandaceae	*Maddenia himalaica*	Rosaceae
Exbucklandia populnea	Hamamelidaceae	*Populus ciliata*	Salicaceae
Goniothalamus sesquipedalis	Annonaceae	*Prunus carmesina*	Rosaceae
Helicia nilagirica	Proteaceae	*Quercus griffithii*	Fagaceae
Ilex sikkimensis	Aquifoliaceae	*Toona ciliata*	Meliaceae
Lindera heterophylla	Luaraceae	**Evergreen shrub**	
Lithocarpus elegans	Fagaceae	*Brassaiopsis mitis*	Araliaceae
Macaranga denticulata	Euphorbiaceae	*Eurya acuminata*	Theaceae
Mallotus philippensis	Euphorbiaceae	*Ilex godajam*	Aquifoliaceae
Magnolia doltsopa	Magnoliaceae	*Lindera heterophylla*	Luaraceae
Magnolia lanuginosa	Magnoliaceae	*Lindera pulcherrima*	Luaraceae
Persea duthiei	Caprifoliaceae	*Meliosma simplicifolia*	Sabiaceae
Quercus glauca	Fagaceae	*Myrsine seguinii*	Myrsinaceae
Quercus lamellosa	Fagaceae	*Persea clarkeana*	Lauraceae
Quercus lanata	Fagaceae	*Phoebe* sp.	Lauraceae
Quercus oxyodon	Fagaceae	*Rhus hookeri*	Anacardiaceae
Quercus semicarpifolia	Fagaceae	*Saurauja napaulensis*	Actinidiaceae
Schima khasiana	Theaceae	**Deciduous shrub**	
Schima wallichii	Theaceae	*Populus rotundifolia*	Salicaceae
Symplocos racemosa	Symplocaceae	*Prunus rufa*	Rosaceae
Syzygium kurzii	Myrtaceae	**Palm**	
		Trachycarpus fortunei	Arecaceae
		Caryota urens	Arecaceae
		Unknown	Arecaceae
		Cycad	Cycadaceae

and annual rainfall 1,204 mm. The highest elevation (2500 m asl) had vegetation cover dominated by *Quercus lanata, Symplocos racemosa* Roxb., *Quercus lamellosa* and *Castanopsis tribuloides* (SM.) A.DC. Study done by Mir *et al.* (2016) in mixed pine forest in Northeastern India also listed the dominant species such as *Pinus kesiya, Lithocarpus elegans* and *C. tribuloides.*

Type II (Schima khasiana dominated forest)

This forest type was situated in mid altitude ranging from 2100 to 2200 m asl with an average soil moisture content of 4.67%, mean annual temperature of 14.09 ^{0}C and annual rainfall of 1,078.1 mm. This forest type is domi-

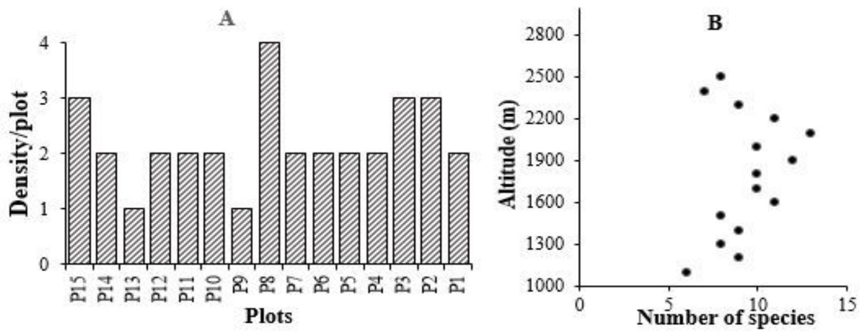


Figure 3: Density of Dominant species /plot (A), Species richness (B)

nated by *Schima khasiana*. The co-dominant species found in this forest type were *Exbucklandia populnea, Magnolia lanuginosa*, *Macaranga denticulata* and *Betula alnoides*.

Type III (Quercus dominated forest)

This forest type was situated at the lower part of the study site with altitude ranging from 1100 to 2200 m asl, 8.03% soil moisture content, 17.56 ^{0}C mean annual temperature and 1,349.3 mm of annual rainfall. This forest type was *Quercus* sp. dominated forest. The dominant tree species found in this forest type were *Quercus glauca*, *Quercus semecarpifolia*, *Engelhardtia spicata, Syzygium kurzii* and *Lithocarpus elegans*.

Structural features of Magnolia lanuginosa forest

Structural organization of forest communities along the altitudinal gradient was described based on five features; maximum height, maximum DBH, basal area (BA), stem density, and species richness. Theaceae (*Schima khasiana* Dyer) with maximum height of 46 m and DBH of 115 cm was recorded in Plot 7 at 1700 m. Luaraceae (*Lindera pulcherrima* (Nees) Benth) with minimum height (5 m) and DBH 13.3 cm was recorded in Plot 10 at 2000 m. The total BA was found greater at altitude falling within the range of 1400 to 2300 m asl and was found decreasing above 2400 m asl. Maximum BA was recorded at an altitude of 2200 m asl in Plot 12 with 19,208.6 m^2. Variation in BA along the altitudinal gradient confirmed with the observation made by Numata (1983) who stated that the decline in BA is with respect to temperature and some other factors related to altitude.

Similarly, higher species richness was recorded between altitude ranging between 1600 m to 2200 m asl and highest number of species was recorded in Plot 12 at 2100 m asl. As altitude increases, species richness decreased which may be due to decrease in temperature and soil moisture content (Figure 3). This finding agrees with the statement provided by Numata (1983) who observed that species composition increases with rise in altitude up to certain lower temperate region and then gradually decreases at higher altitude. The maximum DBH of *Magnolia lanuginosa* recorded was 89 cm which was encountered at plot 9 (N-27.152911^0 E-91.280781^0 at an altitude of 1900 m asl and minimum of 27 cm was recorded in plot 3 (1300 m asl). Likewise, a maximum height of 37 m was recorded in plot 9 and minimum of 16 m was recorded in plot 3.

The maximum basal area of total species 19,208.6 cm² was recorded in plot 12 at altitude of 2200 m asl. Basal Area of *Magnolia lanuginosa* increased from altitude 1500 m to 1800 m and the Total Basal Area increased from altitude 1300 m to 2200 m. The highest stem density of *M. lanuginosa* (n = 3) was recorded in plot 9 (1900 m asl) and the highest stem density (n = 13) of total species was recorded in plot 11 (2100 m asl). The reason could be due to disturbances, where the plot 1 to plot 6 were heavily disturbed due to the construction of gewog center road. Hara *et al*. (1996) also reported that the difference in stability of the surface is likely to be the cause of the stand structure within a given slope.

A total of seven *Magnolia lanuginosa* (≥

1.3 m) trees were encountered in 15 plots which is less compared to that of other associate tree species. Mir *et al*. (2016) also observed that the population of the species is very low and suggested the urgent need for its conservation. Maximum basal area (6479.6 cm^2) was recorded for the tree height of 22 m, located in plot number 9, located at an altitude of 1900m asl. However, one individual having a height of 23 m, located in plot 6 at an altitude of 1600masl was having basal area of only 62.9 cm^2.

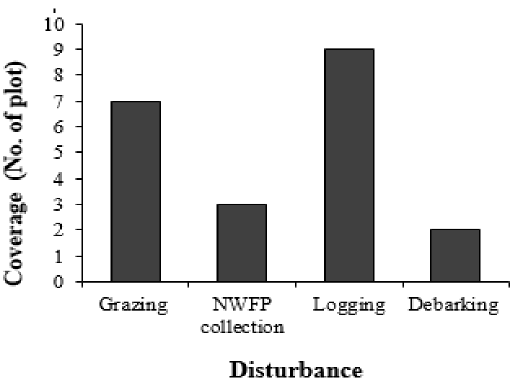
Magnolia lanuginosa was found within the range of 1600–2200 m asl (P6 to P12). Spearman's rho correlation coefficient between altitude and DBH of *Magnolia lanuginosa* was not significant (r_s = .325, p = .23). Similarly, the association between altitude and height was not significant (r_s = .275, p = .32). Altitude gradient was also not significantly related to total basal area (r_s = .286, p = .30), total density (r_s = .217, p = .43) and diversity (r_s = -.021, p = .94). The non-significant association could be due to heavy extraction of the species in the study site. However, there was significant correlation between total DBH and total stem density (r_s = .788, $p < .05$), but Sahoo *et al.* (2009) have shown that the stem density decreases with age and increasing DBH which could be due to competition among species for space, nutrient, light and other environmental factors.

Regeneration dynamics of Magnolia lanuginosa

Regeneration of *Magnolia lanuginosa* was recorded only in 46.6% of the total plots. The maximum regeneration count (n = 3) of *M. lanuginosa* was recorded in plot 5 at an altitude of 1500 m asl on a west facing slope where canopy closure was 30–40%. These plots were heavily disturbed and the diversity of regeneration was very high compared with other less disturbed plots. However, the areas were fully covered by invasive plants such as *Ageratina adenophora* and other non-timber species. Tenzin and Hasenauer (2016) also reported that felling and resource extraction can create gaps which could change the forest structure dominated by non-timber species. The highest regeneration count of tree species (n = 12) was recorded in plot 3 at an altitude of 1300 m asl. A total of nine different tree species were recorded that were regenerating with *M. lanuginosa* such as *Castanopsis tribuloides, Exbucklandia populnea, Trachycarpus fortunei, Alnus nepalensis*, *Myrica esculenta*, *Quercus glauca* and *Schima wallichii* which fall into five different life-forms.

Assessment of environmental factors

Environment factors such as soil pH and soil moisture content were analyzed. *Magnolia lanuginosa* grows on soil with pH ranging between 5.11–6.73 ($\bar{x}$ = 5.74 ± 0.43 *SD*). Spearman's rho correlation of soil pH with



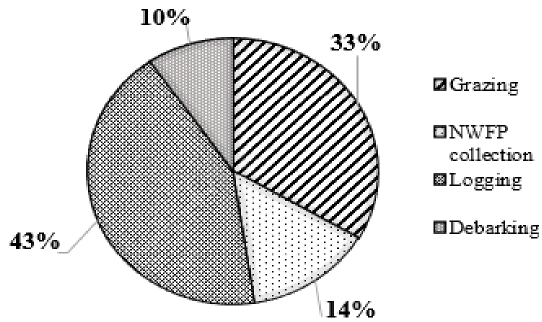


Figure 4: Different manmade threats to *Magnolia lanuginosa*: plot coverage by different threats (A) and percentage of threats (B)

altitude showed no significant correlation (r_s = .146, p = .60), but Badia *et al.* (2016) reported that there is a negative relation (when elevation increases soil pH decreases). Soil moisture content had no effect on the soil pH (r_s = -.207, p = .59), but Valdaz *et al.* (2006) found that soil moisture had positive association with soil pH (increased in soil moisture increases soil pH).

There was strong negative correlation between soil moisture and soil temperature (r_s = -.811, p < .05). This may be attributed to collection of soil samples in winter months (December and January) where the atmospheric temperature was below 20 ^{0}C. However, Onwuku and Mang (2018) reported that temperature ranging between 25–39 ^{0}C has positive association due to more denaturation of organic acids occurring at high soil temperature resulting in soil pH increases.

Conservation threats of Magnolia lanuginosa

Major man-made (anthropogenic) threats of *Magnolia lanuginosa* were grazing, collection of non-wood forest product (NWFP) and excessive logging among which grazing and tree felling were the most prominent threats (Figure 4). Collection of NWFPs were encountered in three plots (P4, P7 and P8) where the people have collected bamboo (*Yushina* sp. for making arrow and *Neomicrocalamus andropogonifolius* for making bamboo products) and Cane shoot (*Plectocomia himalayana* for vegetables*)*.

The study sites had cattle herders' sheds where the cattle browsed seedlings and saplings freely. Only 11 seedlings and saplings of *Magnolia lanuginosa* were recorded of which some were browsed. Mir *et al*. (2016) stated that disturbances in the form of timber extraction reduce densities of naturally occurring plants.

Suitable areas for growth of Magnolia lanuginosa in Bhutan

Environmental data from Nyugphu Goenpa, Kengkar were considered for modelling suitable areas for species growth in the country.

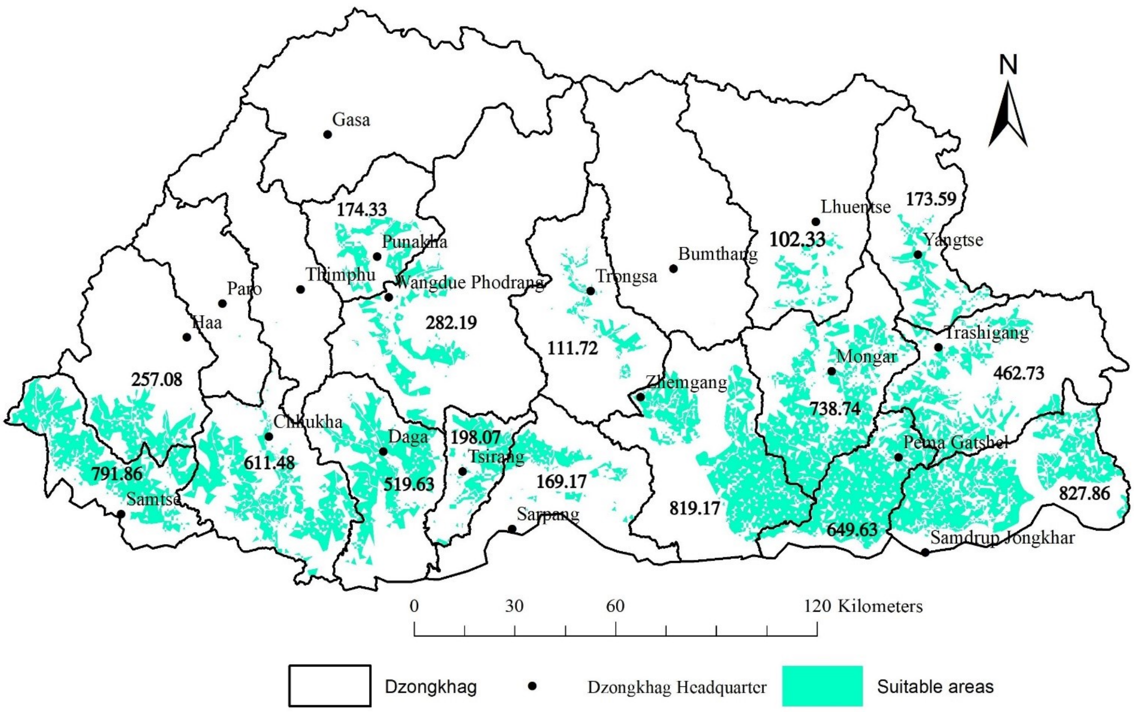


Figure 5: Map representing suitable areas (km^2) for the growth and development of *Michelia velutina* in Bhutan

The raster data were reclassified to suitable ranges and all the line vector data were buffered to maintain the proximity of 100 m for river buffer and 50 m for road buffer. All the restriction (built up areas like buildings, roads, airport, dams etc.) were erased and the final result was multiplied (Times tool) with the raster data to get the suitable area map for the growth of the species (Figure 5).

The QGIS suitability area analysis resulted in a total area of 6,669.82 km² (17.37% of the total area of the country) that has potential for *Magnolia lanuginosa* growth. The four districts (Paro, Thimphu, Gasa and Bumthang) out of 20 districts of Bhutan are not suitable for the growth of *M. lanuginosa.* Samdrup Jongkhar has the largest suitable habitat with a total area of 827.86 km² and Trongsa district has the least suitable area with 111.72 km².

Conclusions

Magnolia lanuginosa has high timber quality and its population in its natural habitat is declining due to heavy extraction. A total of 279 plant species under 64 families were recorded in 15 plots from natural *M. lanuginosa* forest. Hamamelidaceae and Fagaceae families dominated the natural stands of *M. lanuginosa*. It prefers slightly acidic soil with average annual rainfall and temperature of 1,071.4–1,427.7 mm and 12.17–19.26 ^{0}C respectively. Over extraction including illegal felling followed by grazing and debarking were the main conservation threats. An area of 6,669.82 km^2 is suitable for *M. lanuginosa* growth. Since the sample plots in this study were limited, further study needs to be conducted to understand the ecology and threats of *M. lanuginosa*.

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