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Resource assessment and Habitat analysis of *Daphne bholua* in Bhujung of Annapurna Conservation Area, Central Nepal

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Abstract

The bark of Daphne bholua *Ham. ex D.Don, locally called Lokta, has been used traditionally for preparing Nepali handmade paper and it is an important non-timber forest product (NTFP) for the economic development of the mountain people in the Nepal Himalaya. Though it occurs naturally in Bhujung area of the Annapurna Conservation Area (ACA) of Nepal, the locals have not used it for making paper. In the context of increasing demand of Nepali handmade paper in the international market, there is a good prospect of income generation by sustainable harvesting of this resource in Bhujung area. This study is an attempt to estimate the present stock of* Daphne bholua*, the potential yield of its bark and the population status in Surno Kharka and Wijung Ban of the study area. The mean density of* D. bholua *was 5231 and 6925 stem/ha in Surno Kharka and Wijung Ban, respectively, and the harvestable dry inner bark mass was 288 and 391 kg/ha, respectively. Regeneration was low due to anthropogenic disturbances like livestock grazing and trampling, and the unsuitable microhabitats such as high litter accumulation and dense canopy. The site with low biotic disturbance, presence of tree fall gaps with relatively low litter accumulation and the acidic soil is a suitable natural habitat for the growth of* D. bholua*.*

Keywords: NTFPs, bark yield, disturbance, sustainable harvesting.

Introduction

The Non-Timber Forest Products (NTFPs) includes all kinds of goods derived from forests, of both plant and animal origin, other than timber, fodder and fuel wood[1]. In recent decades, the importance of NTFPs, especially for the subsistence livelihood of the local communities, has been realized along with their potential and real contribution to the economy of many developing countries[2]. Harvesting of NTFPs usually has a lower impact on the forest ecosystem than timber harvesting and can provide social and economic benefits particularly to community operations and can therefore be an important component of forest ecosystem management[3].

Nepal hosts nearly 2000 species of potentially useful plants, including medicinal and food plants[4]. Some of these plants have been traded while others have been used for subsistence livelihood by local people. About 161 plant-based NTFP species have been harvested from wild for trade in Nepal[5]. Annually, exports of about 42 thousand tons of over 100 NTFPs from Nepal, generates over $30 million[6].

A large part of rural population depends on NTFPs for food, medicine, fibre, condiment, dye and other useful materials. In the mountains of Nepal, 10-100% of households are involved in the collection of medicinal plants and other NTFPs; and in certain rural areas this contributes up to 50% of the family income[7, 8]. NTFPs are relatively abundant in rural areas where other income generating opportunities are limited[9]. In those areas, NTFPs-based SMEs (Small and Medium Enterprises) offer good prospects for enhancing the livelihood and income of local communities[5]. Dependence on NTFPs is further critical to the poor as they are the ones mostly involved in the collection of NTFPs. NTFPs are being increasingly recognized for their role in rural livelihoods, biodiversity conservation and export values[10,11].

Daphne spp. (Fam. Thymelaeaceae), locally known as '*Lokta'* or '*Kagaje'*, is a shrub species, found in the hills of Nepal from east to west. Two species of the genus *Daphne* are common in Nepal they are *D. bholua* Ham ex. D.Don and *D. papyracea* Wall ex. Steud. They grow gregariously and abundantly in Himalayan forests between 1,600 and 4,000 m asl[12]. *Daphne* spp., one of the major income-generating NTFPs of Nepal, has been used since long time in Nepal for making ropes and traditional Nepali handmade paper (*Nepali Kagaj*). The handmade papers are used to make various products which find good market in Europe, the USA and Japan[13]. *Daphne* spp. is available in 2,910,848 ha forests in 55 districts of Nepal, of which 25 districts witness its abundance[14]. The total stock of bark of *Daphne* spp. has been estimated to be 110,481 metric ton, which can support sustainable production of paper over 950 metric ton every year[14].

The species found in the present study area is *Daphne bholua;* it prefers medium to low crown cover and usually avoids sites with dense crown cover (≥70 %)[15] and large open area. The species thrives on a wide range of soil types but generally favour moist sites with organic rich humus layer overlying well-drained sandy

loam. The plant cannot tolerate frequent fires and heavy grazing. The objective of the study was (a) to assess the availability, distribution and population status of *D. bholua* in forests of Bhujung village of Annapurna Conservation Area, central Nepal, (b) to estimate the potential yield of bark from *D. bholua* in the study area, and (c) to understand the relationship between environmental variables and the abundance.

Material and Methods

Study area: Annapurna Conservation Area (ACA, 28º12'48"-29º19'48" N latitude, 83º28'48"-84º26'24" E longitude, area 7629 km^2) is situated in the central Nepal and encompasses 55 Village Development Committee (VDC) areas from Manang, Mustang, Kaski, Myagdi and Lamjung districts. Bhujung is one of the 9 VDCs in the Bhujung sector of ACA. The ACA has been managed by National Trust for Nature Conservation (NTNC), Nepal.

Bhujung is a small and beautiful village that lies at the northwest part of Lamjung district on south facing slopes of Lamjung Himal. Its total area is 55 km^2, in which forest area covers 33.15 km^2, grass land 7.54 km^2 and shrubland 7.89 km^2. Bhujung is the largest Gurung settlement in ACA with >400 households and a few other ethnic groups such as Bishwakarma, Chhetri and Brahmin. Majority of the people are engaged in agriculture. They grow rice, wheat, maize, millet and potatoes and keep sheep and cattle. But for 92.4% households the agricultural output is not sufficient throughout the year. Thus, apart from agriculture, remittance, labour, service and traditional/cottage industry are alternative sources of income. The Bhujung village lies in middle mountains and falls under the warm temperate zone with a mean annual temperature of 22°C. The annual rainfall was 2642 mm, with about 71% of annual rainfall occurring during summer months (July- September)[16].

After identifying the potential of *Daphne bholua* in Bhujung through reconnaissance survey, two sites, Surno Kharka and Wijung Ban, were selected. The general aspect of the slope of Surno Kharka is south facing and of Wijung Ban, north facing. The species composition on both the forest *viz*. Surno Kharka and Wijung Ban is similar with the dominance of *Rhododendron arboreum* Sm., *Eurya acuminata* DC., *Myrsine semiserrata* Wall., *Daphniphyllum himalense* var. *chartaceum* (Rosenthal) Huang and *Berberis* spp. Surno Kharka is drier than Wijung Ban as former lies on the south facing slope and later on north facing slope. Surno Kharka is predominantly a grassland used for livestock grazing (locally called Kharka) whereas Wijung Ban has grassland at lower belt and dense forest at higher belt. The disturbance due to grazing was apparent and more pronounced in relatively flat and easy to graze grasslands. The anthropogenic disturbance was more in lower altitudes and it decreased with the increase in elevation but grazing was nearly uniform across the elevation range.

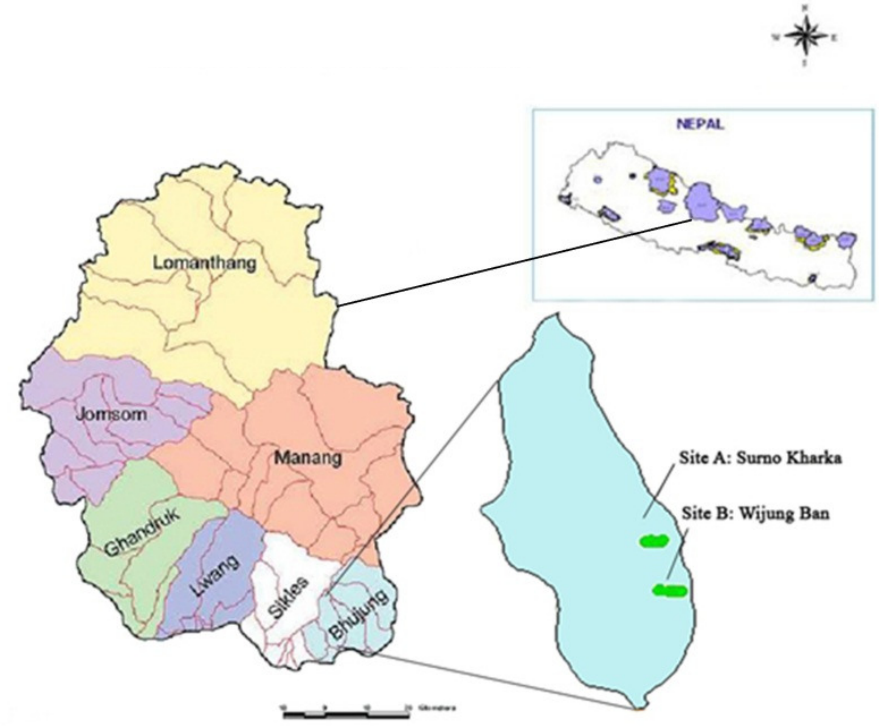


Figure-1
Annapurna Conservation Area, its sectors and Bhujung VDC

Field sampling: In each site (Surno Kharka and Wijung Ban), three plots of 50 m × 100 m were marked along the elevation gradient from 2140 to 2480 m asl in Surno Kharka and 2100 to 2455 m asl in Wijung Ban. The first plot was marked from where *Daphne bholua* was observed. The surface distance between two successive plots varied from 50-100 m. In each plot seventeen 5 m × 5 m quadrats were located randomly. Altogether 102 quadrates were sampled in two sites. In each quadrat, GPS coordinates (Garmin *e*trex GPS), slope (Clino meter) and aspect (Brunton compass) were recorded. Disturbance (in the scale of 0-3), rock cover (% of ground surface) and tree canopy (%) were visually estimated. Depth of the soil was measured with the help of calibrated rod (up to 50 cm.) that was pierced inside the ground until it was stopped by the rock. The average litter cover was estimated using Leaf Litter Index[17] by driving a sharpened wire stake into ground at each corner and the center of 5 × 5 m^2 quadrat. The mean number of leaves pierced at the five points, hereafter called leaf litter index (LLI), was used as an estimate of mean litter cover. Soil samples were collected from the four corners and middle of each quadrat at a depth of 15 cm using a soil digger. These sub-samples were mixed thoroughly and about 200 g was collected in zipper polythene bag. The soil samples were air dried in shade and stored in air tight plastic bags until laboratory analysis. There were 51 soil samples from each sampling site. Number, height and girth (at 20 cm above ground surface) of individual *Daphne bholua* within the plot were noted. Associated species of shrub layer was also noted.

Soil analysis: Soil pH, organic matter (OM), and total nitrogen (N) were estimated in the soil samples using methods described by Trivedi and Goel[18]. Available phosphorous was measured by spectrophotometer method and available potassium by flame photometer.

Data Analysis: Density: Density (stem/ha) of *Daphne bholua* was calculated for individual quadrat as well as for the large plots. The population of *D. bholua* was divided into various growth classes according to the criteria suggested by Ghimire and Nepal (2007): seedling - germinating plants of less than one year of age (<1 cm girth); juvenile - small sized plants of <4 years of age (1-4 cm girth); immature - medium sized plant of <8 years of age (>4-8 cm girth); mature - large sized plants of >8 years of age (>8 cm girth); adult 1 - >8-12 cm girth; and adult 2: >12 cm girth.

Frequency: Frequency of *D. bholua* was calculated as percentage of quadrats in which the species occurred.

Dry mass of inner bark: The dry mass of inner bark (bast) of *Daphne bholua* was calculated by using the following regression equation: $lnY = 2.165 + 2.052\ lnD_{20}$ where, Y is the total dry mass of the inner bark, D_{20} is diameter of *Daphne* at height 20 cm above the ground[19]. Using the above formula dry bark mass was estimated for all individual plant that was ≥20 cm high. Total dry mass of inner bark was calculated as sum of the dry mass of all the individual *D. bholua* in the quadrat that was ≥ 20 cm in height. The harvestable dry mass of inner bark was calculated as the sum of the dry mass of *D. bholua* having diameter > 2.5 cm or girth > 8 cm (i.e. mature individuals only).

Statistical analysis: Linear regressions were done to understand the variation of density and growth attributes (e.g. height, girth and bark mass) of *D. bholua* with the environmental variables such as soil pH, soil nutrients, litter index, rock cover, canopy cover, elevation, etc. The density and growth attributes were considered as response variables and environmental variables as predictor. Only the statistically significant relations have been presented in the results. All the statistical analyses including standard deviation were done using Statistical Package for Social Sciences (SPSS ver.11.5).

Results and Discussion

Habitat characteristics of *Daphne bholua:* In the study site the *Daphne bholua* was observed from 2100 to 2500 m asl. The species was more prevalent in shady and moist places with low disturbances. In places with no trees i.e. shrub land, the species occurred under the canopy of shrubs, but when the canopy was too dense, as in *Rhododendron* stands, the density was quite low. In the higher altitude, the gaps created by the natural falling of trees promoted the growth and regeneration of *D. bholua*. It is a shade loving plant which grows as under-storey vegetation in forests. However, a partial shading of >30% canopy cover is necessary for good growth of *Daphne* species[20]. *Daphne* was found to occur in both plain and sloppy terrain.

The soil was acidic in both the sites with pH ranged between 4.23 and 5.08 (table- 1). The organic matter ranged 8.53 -15.07 %, total nitrogen 0.27 – 0.43 %, available phosphorus 55 – 77 kg/ha and exchangeable potassium 68 - 102 kg/ha.

Frequency and Density of *Daphne bholua:* *Daphne bholua* was more frequent in Wijung ban (98%) than in Surno Kharka (78%). The frequency of *D. bholua* ranged from 59 to 100 % in Surno Kharka and 94 to 100% in Wijung Ban. The average density of *D. bholua* in Surno Kharka was 5231 stem/ha and that in Wijung Ban was 6925 stem/ha but the difference was not significant. The density increased from the plots at the lowest elevation (Plot I and IV) to the plots at the highest elevation in both samplings sites (figure- 3). Higher anthropogenic activities including livestock grazing could be responsible for having low density in these plots at low elevation (Plot I and IV). The result was consistent with the result obtained by Koirala in Tinjure-Milke region, east Nepal where the density of *D. bholua* in less degraded forest was higher than in highly degraded forest[21]. Therefore, it appears that disturbance can substantially reduce the density of this species. In Surno Kharka, 11 quadrats out of 34 in two plots at lower elevation (I and II) did not have *D. bholua* due to high disturbance, dense coverage, rocky terrain, thick litter and south facing aspect. Occurrence of *D. bholua* is found to be less or absent in places having heavy biotic interference such as haphazard exploitation of *D. bholua*, frequent fires and heavy grazing[14]. Excessive grazing damages the seedling and juveniles by trampling and also makes the soil compact.

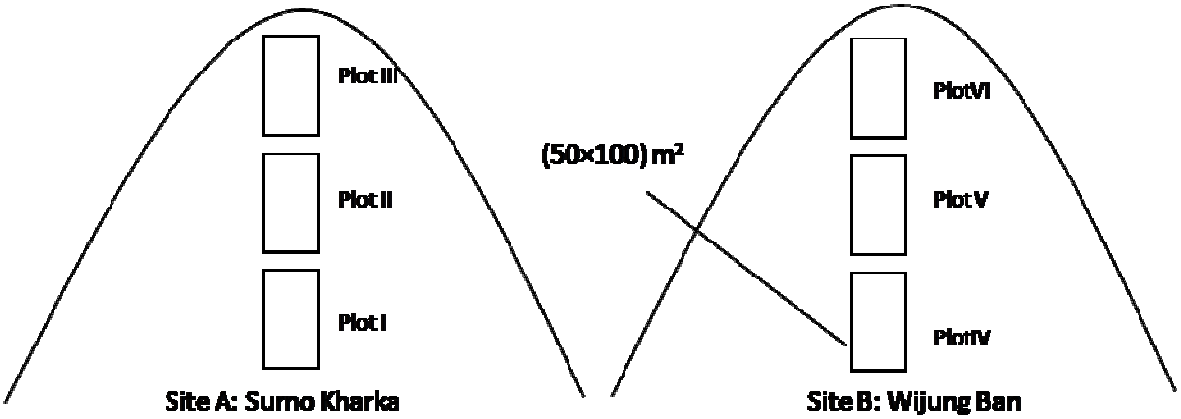


Figure-2
Plot layout for the inventory of *Daphne bholua* in the study sites

Table- 1
Soil characteristics of the habitat of *Daphne bholua* in the study sites

Sites	Plots	pH	Organic matter (%)	Total Nitrogen (%)	Available Phosphorus (kg/ha)	Exchangeable Potassium (kg/ha)
Surno Kharka	I	5.08	12.75	0.35	63	79.80
	II	4.96	15.07	0.43	77	83
	III	4.60	12.69	0.36	75	68
	Mean (±SD)	**4.89 ± 0.47**	**13.50 ± 5.07**	**0.38 ± 0.09**	**72 ±23**	**77 ± 21**
Wijung Ban	IV	4.84	8.78	0.27	59	71
	V	4.55	10.68	0.3	55	102
	VI	4.23	8.53	0.3	71	69
	Mean (±SD)	**4.54 ± 0.45**	**9.33 ± 3.06**	**0.29 ± 0.62**	**62 ± 31**	**81 ± 32**

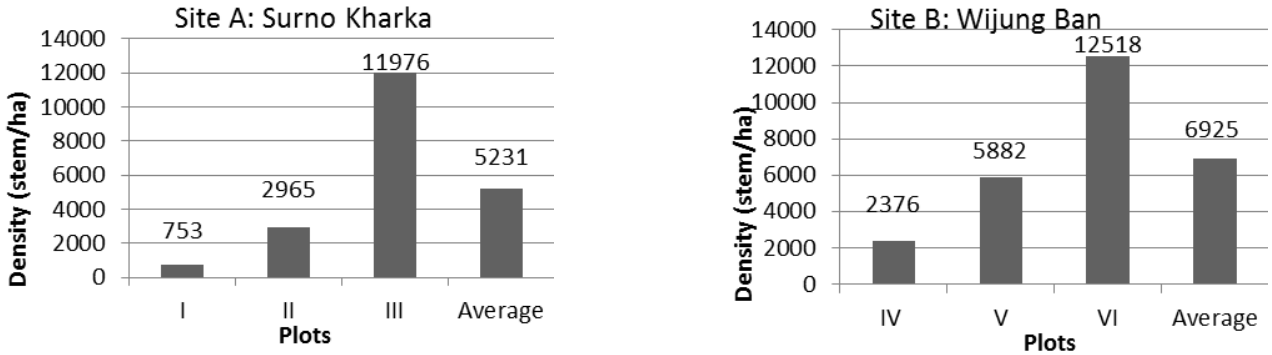


Figure-3
Density of *Daphne bholua* in different plots

In plot IV of Wijung Ban, *D. bholua* occurred in all the plots but its density was low because of heavy grazing. The species prefers partial shade; therefore it avoids places with both closed canopy and large forest gaps[14]. In places where there was no tree, *D. bholua* was found to occur under the canopy of other shrub species like Chutro (*Berberis* spp.) and Ainselu (*Rubus* spp.) which are grazing resistant species. In Plot V, the density was comparatively higher as the canopy cover was suitable (15-25%). The Plot VI, was comparatively moist and shady, hence presence of tall *D. bholua* were observed except in a few quadrats where grazing pressure was high. In higher altitude there was low human disturbance and presence of tree-fall gaps, thereby promoting the growth and regeneration of *D. bholua*. It was either absent or less frequent in the sites where harvesting of nigalo (*Himalaya calamus*) was extensive, an observation similar to that of Ghimire and Nepal[19]. The observation on the variation of density and frequency of *D. bholua* indicated that they were significantly influenced by canopy and disturbance.

Population structure: Density of smaller individuals (i.e. seedlings and juvenile) were relatively low in most of the plots. The immature (1992 stem/ha) in Surno Kharka and juvenile (2086 stem/ha) in Wijung Ban had the highest density. In plot I seedling was completely absent. The average density of mature individuals (adult 1 and adult 2) in Surno Kharka and Wijung Ban were 1521.57 and 2196.08 stem/ha, respectively.

Population structure of *D. bholua* showed higher density of intermediate class and lesser density of immature and mature classes (figure 4). Thus, the diagram resembled bell-shape which indicates decline in regeneration. For sustainable regeneration the density of seedling and and juvenile should higher than the larger individuals. Though the stock was good, its sustainability was questionable due to poor regeneration. In community managed forests of Kanchenjunga Conservation Area (KCA) the regeneration of *D. bholua* was good with higher proportion of smaller size classes[19].

Though *D. bholua* is not a preferred species for the livestock, small individuals could be easily damaged mechanically by trampling when grazing pressure was high. Improper harvest of other NTFPs (e.g. Nigalo, Allo) could also damage young as well as mature individuals of *D. bholua*. Closed canopy and thick litter might have also hampered the regeneration of this species. Under such condition seedling mortality is relatively high due to lack of sufficient light and high frequency of fungal infection. Earlier research has also reported that canopy cover of >80% is not favorable for the growth of *Daphne* species[20]. The combined effects of high trampling damage and dense tree canopy could have resulted in low regeneration of this species in the study area.

Dry mass of inner bark: Total as well as harvestable dry mass of the inner bark of *Daphne bholua* (height >20 cm) was the highest in the plots lying at the highest elevation in both the sites (figure 5). The mean total as well as harvestable bark mass were higher in Wijung Ban (501 and 391 kg/ha, respectively) than in Surno Kharka (367 and 288 kg/ha, respectively).

According to Forest Survey and Research Office the air dry mass of bark of *Daphne* spp. ranged from 6.13 to 25.9 kg/ha in different districts of Nepal[14]. The dry harvestable bark of *Daphne* spp. in various community managed forests of Kanchenjunga Conservation Area (KCA) ranged from 3.06 to 56.7 kg/ha with the mean of 33.74 kg/ha[19]. The harvestable dry mass of the bark of *D. bholua* in the present study site was is almost ten times higher than the value reported by Ghimire and Nepal[19]. This disparity is because of the difference in the harvesting intensity. While in KCA, the *D. bholua* has been harvested periodically, there was no commercial harvest in the present study area. Therefore, the Surno Kharka and Wijung Ban of Bhujung have large stock of the bark of this plant awaiting sustainable harvesting. If financial and technical assistance is provided on harvesting the bark and paper making then this could be an attractive source of income to the people. According to guidelines given by Ghimire and Nepal[22], except plot I all the other plots were good for collection of the bark. But serious measure has to be taken to improve the regeneration of seedlings to make the resource sustainable.

Variation of density and growth attributes of *Daphne bholua* with environmental variables: Density of *D. bholua* did not vary significantly with soil N and P but it declined with increasing soil pH and K concentration (figure 6). Increase in density with elevation could be attributed to low biotic disturbance (e.g. grazing) at higher elevation which is far from the settlements.

The maximum height of *D. bholua* declined with increasing litter index (figure 7). High tree canopy cover also had negative impact to average height of the plant. Though *D. bholua* is a moderately shade loving plant, the habitat with low canopy cover and litter accumulation were suitable habitat for its proper growth. Decline in maximum girth with increasing rock cover (figure 8) indicates that rocky habitat is not suitable for the growth of this plant. Maximum girth as well as total dry mass of the bark both increased with increasing elevation in the study area (figure 8, 9). Within the elevation range of the study area (2000-2500 m asl), the environmental condition appeared to be more suitable at higher elevation than in lower. The above trends of density and growth attributes indicates that the site with low biotic disturbance, presence of tree fall gaps with relatively low litter accumulation and the acidic soil is a suitable natural habitat for the growth of *D. bholua*. These habitat conditions need to be taken into consideration while selecting sites for cultivation of this species for commercial purpose.

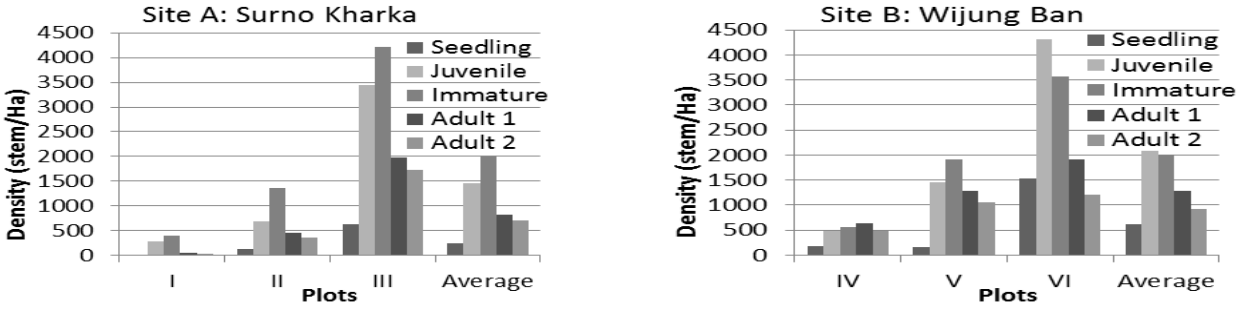


Figure-4
Density of *Daphne bholua* of diffeent age/size class

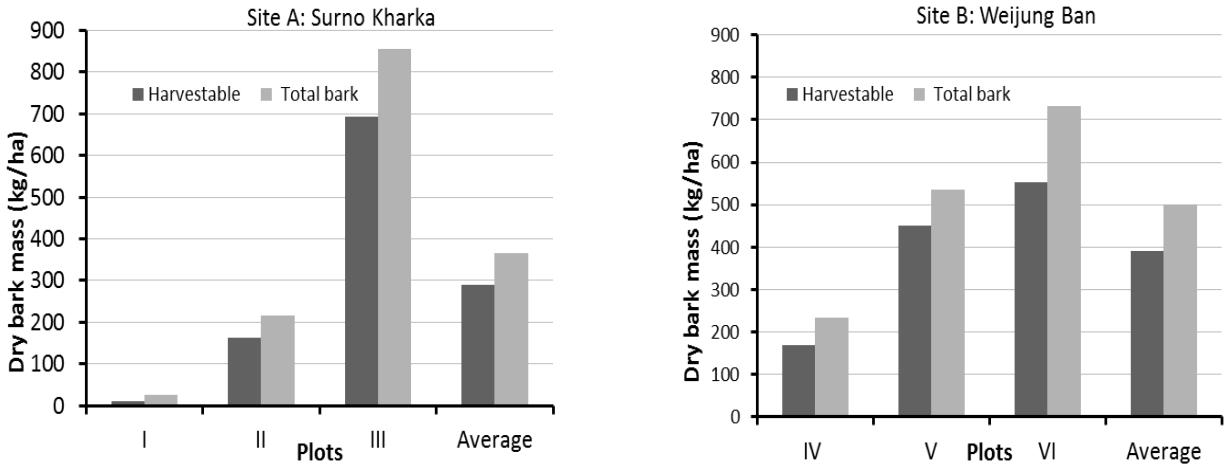
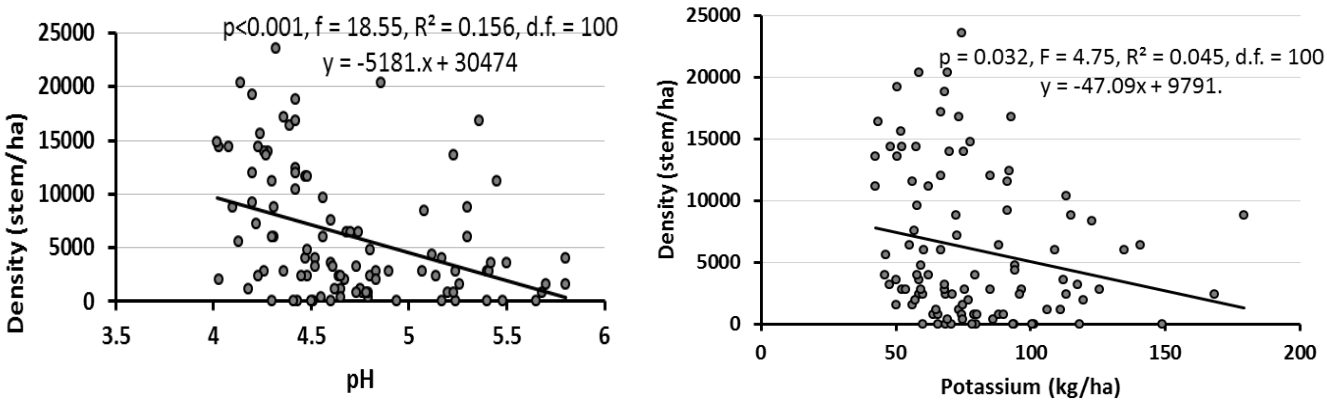


Figure-5
Dry mass of inner bark of *Daphne bholua*



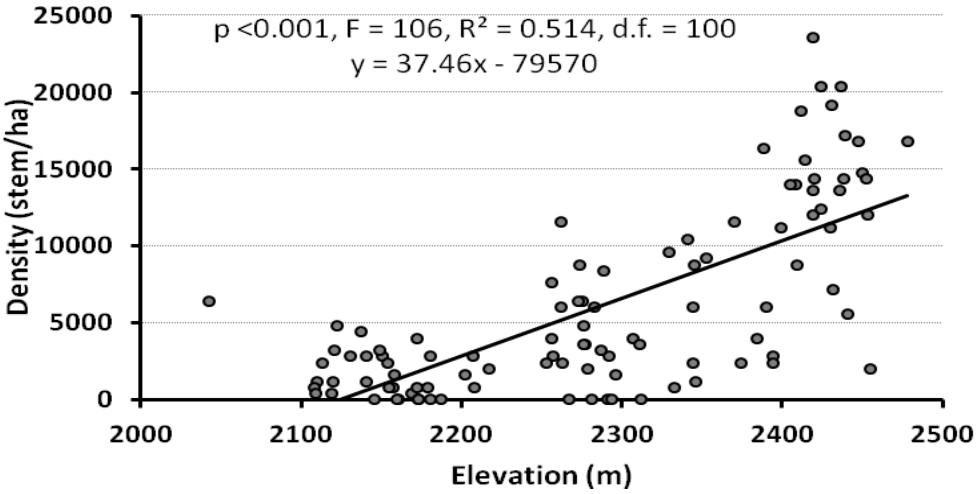


Figure-6
Change in density of *Daphne bholua* with a) soil pH, b) potassium (K) and c) elevation in the study area

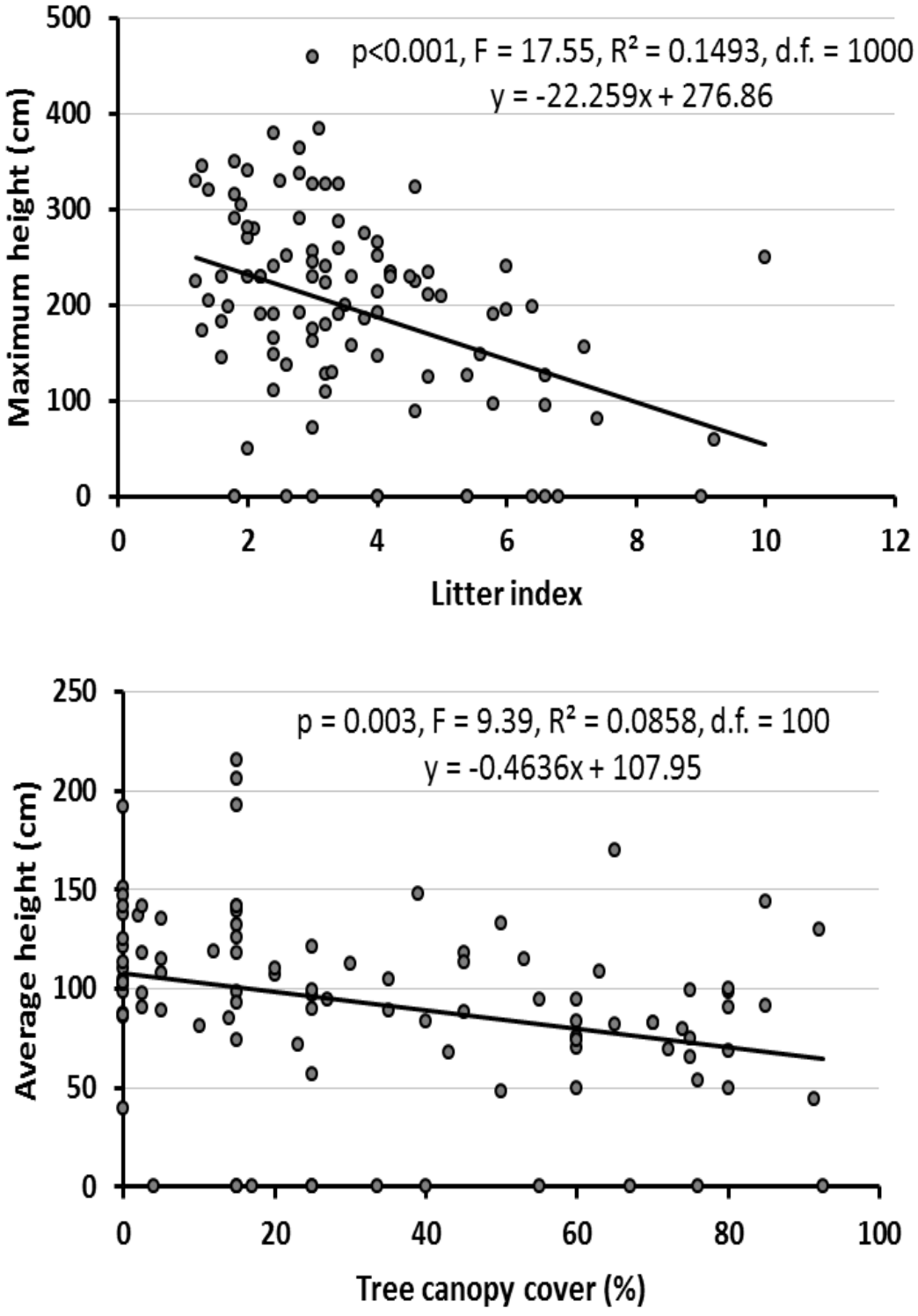


Figure-7
Relation between a) maximum height of *Daphne bholua* and litter index, b) average height of *D. bholua* and tree cover

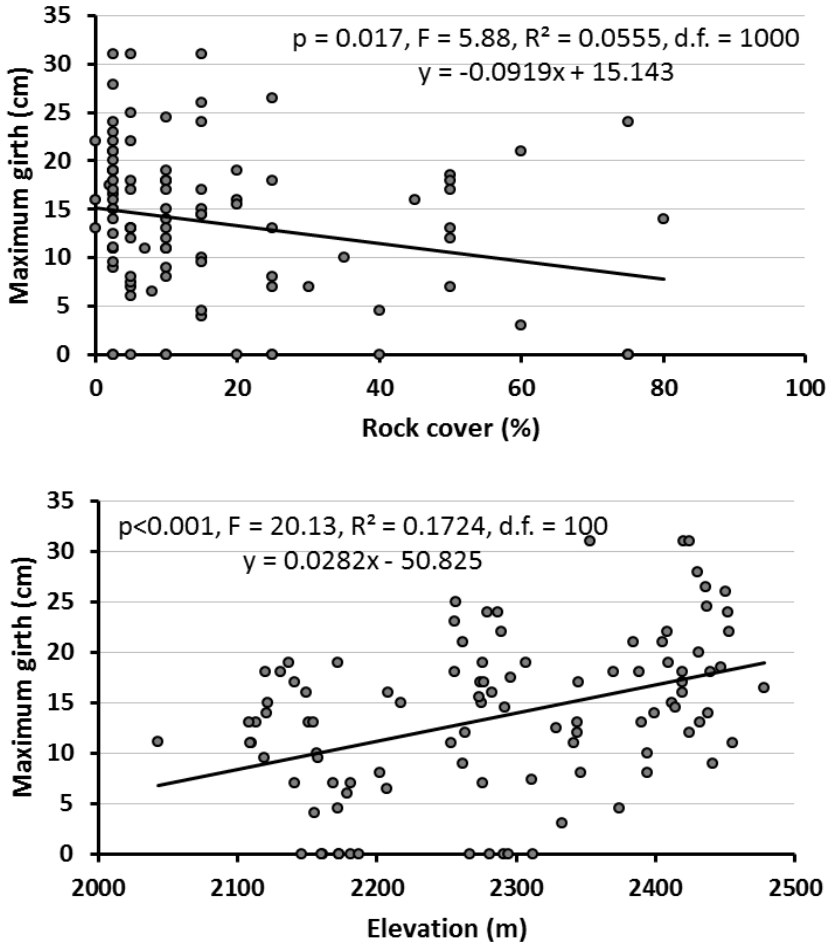


Figure-8
Variation of maximum girth of *Daphne bholua* with a) rock cover and b) elevation

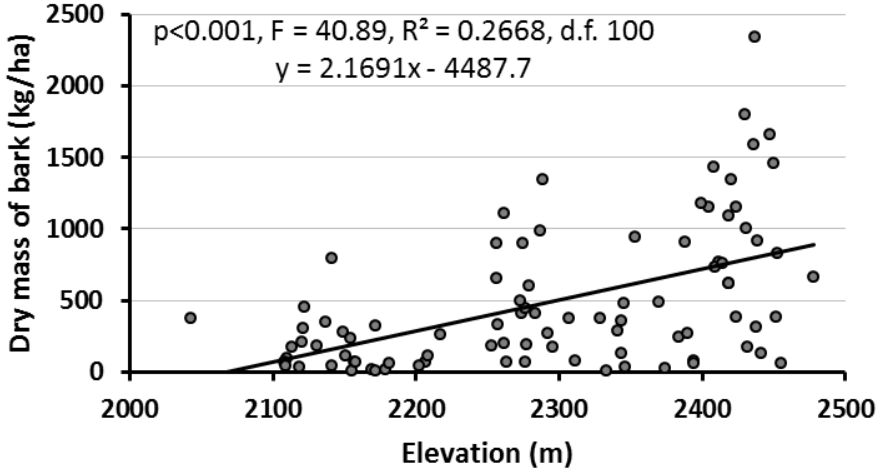


Figure-9
Relation between dry mass of bark of *D. bholua* and elevation

Conclusion

The present stock of *Daphne bholua* available in Bhujung area of ACA was relatively high with potential for sustainable harvesting of its bark for commercial purpose. However, the regeneration of the plant was not sustainable which was evident by the low representation of young individuals in the population. The low regeneration was attributed to the anthropogenic disturbances (e.g. livestock grazing) and unsuitable microhabitats (e.g. high litter accumulation, closed canopy). The site with low biotic disturbance, presence of tree fall gaps with relatively low litter accumulation and the acidic soil is a suitable natural habitat for the growth of *D. bholua*.

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