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Variation in Plant Functional Traits along Altitudinal Gradient and Land Use Types in Sagarmatha National Park and Buffer Zone, Nepal

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Abstract

Functional traits are predictors of plants in response to environmental stimuli. They represent specific functional adaptations to various environmental stresses. This study deals with the variation in plant functional traits along elevation gradient and land-use types in Sagarmatha National Park and Buffer Zone, Nepal. Two field investigations in April and September, 2011 were made to collect samples. Sampling was done from 2200 - 3800 m asl varying approx. 400 m. East and west facing aspects of each valley were chosen. In each aspect four land-use type categories including disturbed (cultivated land, exploited forest and meadow) and less disturbed natural forest were selected. A transect of 25 m long and 2.5 m wide was laid. Different eight traits of plants including lifeform, plant height, clonality, spinescence, leaf dry matter content, stem specific density, twig dry matter content and twig drying time were examined for 60 plant species belonging to 31 families, collected from 40 sampled plots. Nine different types of growth forms were recorded. Plant height of the investigated species ranged from 0.03 - 15 m. The stolon consisting species were dominant in exploited forests. Diversity of clonal species was more in meadow and non-clonal species were dominant in all the altitudes. Only eight species consisted of spines. In the disturbed land-use categories, we found high variation in a particular trait. Correlation analyses revealed the significant relationship ($p < 0.01$) among different traits. Herbs and shrubs were dominant at higher elevation and in disturbed land-use categories. Species from high altitude were mostly short basal herbs, while spinescence and tall trees were observed at lower altitudes. Species recorded in meadows and exploited forests showed high variation in traits due to disturbance mainly grazing, fire, litter collection and trampling. Altitudinal variation, climatic conditions and disturbance most strongly influence trait expression in the study area.

Keywords

Functional Traits, Altitudinal Gradient, Land-Use Types, Disturbances

1. Introduction

Functional traits are those properties of an organism or a part of an organism which strongly influences fitness through their effects on growth, reproduction and survival [1]. They are biological attributes of a species that respond to the environmental conditions or processes in an ecosystem [2] [3]. Plant eco-physiological traits are clearly linked with biotic interactions involving plants, and ecosystem level properties and processes [4]. Traits are expressed in response to the influence of biotic and abiotic factors [1]. Plant functional trait (PFT) are therefore very useful in predicting changes in vegetation and biodiversity as an effect of environmental and disturbance changes and land-use shifts at regional and global scales [5]. The presence, abundance and diversity of PFT including morphological, eco-physiological and life history characteristics could be used for estimating particular components of biodiversity and together form a term called "functional indicators of biodiversity" [6]. Important questions can be answered effectively beginning with a thorough understanding of how and why key "functional" traits are related, and how these traits affect ecological outcomes such as where a species grows best and where it is most competitive [7]. Single traits cannot be the only basis for predicting vegetation changes. So, a functional analysis between key traits is necessary [8].

1.1. Species Traits and Elevation Gradient

Functional attributes including physiological, life history and ecological traits are directly related to variation in elevation that change with climatic factors as well as land area surface. Temperature, air pressure, and solar radiation are the climatic factors that vary with elevation influencing on the distribution of species [9]. Elevation, slope inclination and aspect exposition are the topographic factors playing an important role in determining the abundance of PFTs. Elevation is a complex combination of related climatic variables closely correlated with numerous other environmental properties like soil texture, nutrients, substrate stability and many more [10].

1.2. Species Traits and Land-Use Types

Land-use change includes modified and fragmented habitats, which are more vulnerable to invasive species and plays an important role in shaping and maintaining ecosystem structures and functions. According to [11], land-use changes involve two main impacts on the biosphere: first, the conversion (*i.e.* natural habitats altered for human use) and second, intensification (e.g. greater intensity and frequency of disturbance, increased use of external inputs). Habitat loss and fragmentation are the major factors which cause biodiversity loss by decreasing suitable habitats of species and thereby forcing the species to extinction [12]. Land conversion for agricultural purposes, population growth, socio-economic conditions drive land cover changes.

The present study deals with the variation in plant functional traits along the different land-use types and altitudinal gradient in Sagarmatha National Park and Buffer Zone. Further, the study aims to know the major traits the dominant plant species present in the study area; to assess variation in the traits of dominant species among major land use types; and to identify the plant species best suited for specific altitude and land-use type.

2. Materials and Methods

2.1. Study Area

Sagarmatha National Park (SNP) is located in the north-eastern part of Nepal in Solukhumbu district. SNP covers an area of 1148 sq·km of Namche and Khumjung VDCs. The park is located between 27˚46'19" to 27˚06'45"N latitudes and 86˚30'53" to 86˚99'08"E longitudes. The buffer zone was declared in January 1, 2002, with an area of 275 sq·km [13]. This study has been carried out starting from Surkey (2200 m) upto Khumjung (3800 m). Annual precipitation occurs in the monsoon season from June to September, maximum in the July and the remainder of the year is fairly dry. Annual precipitation is 984 mm in Namche Bazar, 733 mm in Khumjung and 1043 mm in Tengboche. The mean temperature of the coldest month, February is −0.11˚C. Mainly from July to August, the average annual rainfall is approximately 100 mm. **Figure 1** reveals the map of the study area.

2.2. Study Design

Two field investigations at April and September in 2011 were made for collecting samples. Sampling was done from 2200 - 3800 m asl varying approx. 400 m. Two different aspects (east and west facing) of each valley were chosen. In each aspect four land-use types were selected. A transect of 25 m long and 2.5 m wide was laid [14]. Eight plant functional traits were examined for 60 plant species belonging to 31 families, collected from 40 sampled plots. Eight functional traits *i.e.* Growth form, plant height, clonality, spinescence, leaf dry matter content, stem specific density, twig dry matter content, twig drying time were conducted and analysed.

Land-use types category included four different types namely, Natural forest, Exploited forest, Meadows and Cultivated land [14]. Natural forests are area

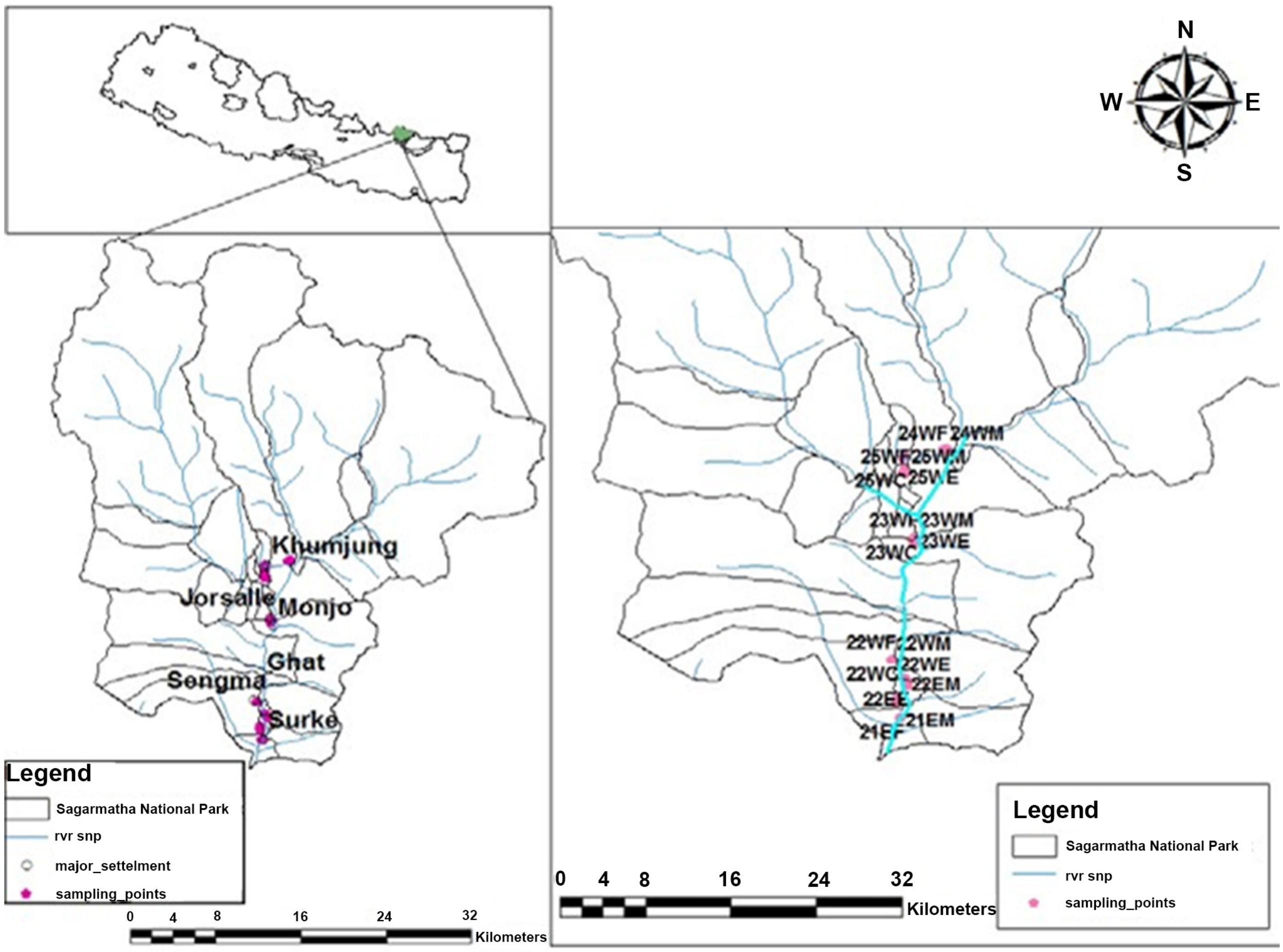


Figure 1. Map of the study site.

with either pristine character or with a low anthropogenic influence. Exploited forests are areas with a relatively closed canopy but with an altered stand structure and tree species composition compared to natural forests, either because of intensive exploitation for agriculture, livestock, and collection of fodder and fuel woods or plantation after intensive domestic or commercial forest management. Meadows are open grasslands with less than 20% tree coverage. Cultivated lands are intensively managed, fertilized, sometimes irrigated and yearly ploughed areas.

For Laboratory techniques, the protocol for standardized and easy measurement of plant functional traits worldwide [15] was followed. Functional traits were either directly measured in the forest, at the research station in the evening after collecting, in the laboratory or deduced later from measured traits.

2.2.1. Selection of Plants

Selection of species in a community or ecosystem: The most abundant species present in high number were chosen by counting the individuals. In forest and other predominantly woody vegetation, the most abundant species of the lower (shrub or herb) vegetation were also selected, even if their biomass was much lower than that of the woody species.

Selection of individuals within a species: Well grown plants, preferably of unshaded condition were chosen. Plants strongly affected by herbivores or pathogens were ignored. Fresh and dry weights of the plants were measured by using weighing machine.

Identification of selected species: The species in the field were identified by observation by researchers, taxonomist and field members consulting pictorial plant identification book like Flowers of Himalayas and its supplement. The species were tagged, for further confirmation by cross tallying with specimen deposited at National Herbarium and Plant Laboratories (KATH), Godawari and Tribhuvan University Central herbarium (TUCH), Kritipur.

2.2.2. Plant Traits Measurement

1) Vegetative traits:

a) Growth form: Species were assigned as: Short basal, long basal, semi basal, erect leaf, cushions, tussocks, dwarf shrubs, shrubs, trees, palmoids, and climbers and scramblers.

b) Plant height: For herbaceous plants the height was measured using the measuring tape, in meters. For tree height, clinometer was used.

c) Clonality: It is the ability of a plant to reproduce itself vegetatively, thereby producing new ramets (underground units) and expanding horizontally. Species were assigned as Non-clonal, clonal aboveground and clonal belowground.

2) Spinescence:

A spine is usually a pointed modified leaf, leaf part or stipule. The type, size and density of spines, thorns and/or prickles play an obvious role in antiherbivore defense.

3) Leaf traits:

Leaf dry matter content (LDMC) is an estimate for plant tissue density. Fresh weight of each leaf was taken and tagged. And dried in an oven at 60˚C for 72 hrs and reweighted for dry mass. It was calculated by dividing Oven dry wt. of leaf (mg) by Fresh wt. (gm).

4) Stem traits:

a) Stem specific density (SSD): SSD = Oven dry mass of the stem (mg)/Volume of the stem when fresh (mm^3). Oven dry mass of a section of a plant's main stem was taken drying the stem at 60˚C for 72 hrs. For calculating the volume of very thin stem, Volume of the fresh stem = (0.5 Diameter of the stem) 2 × π × Length of the stem formula was used.

b) **Twig dry matter content (TDMC):** 1 - 3 terminal twigs of 20 cm long from five individuals of dominant trees and shrubs were collected. Fresh mass of the twig was taken and oven dried at 40˚C. In every 24 hour, each sample was reweighed. TDMC = Oven-dry mass (mg) of a terminal twig/Fresh mass (gm).

c) **Twig drying time:** It is defined as the number of days a twig takes to dry out completely. In each 24 hours dry mass of twig was measured to see the decrease in weight unless there was no further decrease.

2.3. Statistical Analyses

For analyses of quantitative traits, the overall data was divided into three growth forms (*i.e.* herb, shrub and tree). Each trait was then tested to find significant difference with land-use types and altitude for three growth forms. After a normality test (Shapiro Wilk), traits such as plant height, LDMC and SSD of herbs and shrubs were square root transformed to meet the normality assumption while the remaining data was considered normal and left untransformed.

One-way Analysis of Variance (ANOVA) was used to find the variability across means of quantitative traits with land-use types and altitude. Post hoc analysis (Tukey's HSD test) at 5% level of significance was carried out within the results of ANOVA to find more pairwise significant difference of traits with environmental variables. ANOVA was also used to find the altitude wise variation in quantitative traits along different land-use types. Spearman's correlation was done to test the relationship among functional traits in overall altitude and to explore the relationship among functional traits for each five altitude. ANOVA was performed using statistical computer program R version 2.12.1. Correlation was done in SPSS Statistics 17.0.

3. Results

Sixty dominant species belonging to 31 families including five gymnosperms were selected in the 40 sampled plots (see in **Appendix** for the list of investigated plant species) of which 28 species were also observed in other altitudinal as well as land-use gradients (for example; *Rhododendron arboreum*, *R. lepidotum*, *Artemesia vulgaris*, *Pinus wallichiana*, *Senecio diversifolia*). Hence, categorical traits were determined for the repeated species also. The plant communities examined in the present study were composed of trees, shrubs, dwarf shrubs and herbs. The number of the investigated dominant species ranged from 2 - 3 per transect.

3.1. Growth form along Land-Use Type and Altitude

Nine different types of growth forms were recorded from the study site. The plant species collected (both dicots and monocots) included 12 trees, 19 shrubs, 28 herbs and 1 climber. The herbaceous plants included 5 short basal, 1 long basal, 1 semi basal, 13 erect leafy, 3 tussocks and 5 palmoid. The most abundant form was the herbaceous erect leafy followed by trees and shrubs. Trees were dominant in natural forest. Short basal and erect leafy herbs were found to be dominant on meadow. The number of shrubs was higher in the exploited forest in comparison to other land-use types (**Figure 2(a)**). Along the altitudinal gradient, trees and erect leafy herbs decreased in number in comparison to other growth forms. Dwarf shrub and tussocks were dominant at 3400 m (**Figure 2(b)**).

3.2. Plant Height

Plant height of the investigated species ranged from 0.03 - 15 m. Among the

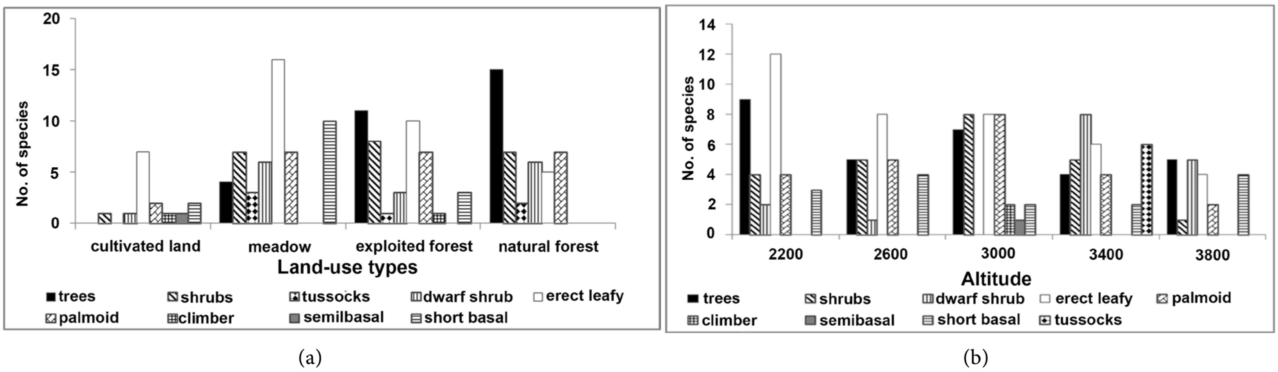


Figure 2. Distribution of different growth forms along (a) land-use types and, (b) altitudinal gradient.

herb and shrub species, height showed highly significant difference with altitude. Height of the tree species showed significant difference with land-use type and altitude (Table 1). From post hoc analysis, significant difference was observed between meadow and natural forest ($p < 0.01$). Outlier was observed at 3000 m showing the highest height of herb. Herb height showed the lowest value at 3800 m with outlier (Figure 3(a)). Shrub height showed the lowest value at 2600 m and the highest value at 3000 m and 3800 m (Figure 3(b)). Taller tree was present at natural forest and tree with less height were observed in meadows (Figure 3(c)).

3.3. Clonality

The stolon consisting species such as *Anaphalis busua*, *Androsacae sarmentosa*, *Fragaria nubicola*, and *F. indica* were dominant in exploited forest. Diversity of clonal species was more in meadow (Figure 4(a)). Non-clonal species were dominant in all the altitudes. At 3400 m, stolon, bulb and adventitious bud forming species were dominant. At 2200 m, non-clonal species were most dominant followed by stolon and vegetative bud forming species (Figure 4(b)). Species with vegetative buds were *Arundinaria maling*, *Impatiens urticifolia* and *Rosa sericea*; and others clonal belowground were *Commelina maculata*, *Iris clarkei*, *Malaxis cylindristachya*, *Senecio diversifolius* and *Rumex nepalensis.*

3.4. Spinescence

Among the investigated species, only eight consisted of spines. The species with longer spines were dominant mostly at the meadows (Figure 5(a)). In comparison to lower altitude, spine consisting species decreased at highest altitude (Figure 5(b)). Spinescence was observed in *Berberis aristata*, *Cotoneaster microphyllus*, *Dipsacus inermis*, *Rosa sericea*, and *Zanthoxylum armatum*, occurring at the meadow whereas *Rubus ellipticus* and *Quercus semecarpifolia* were occurred at the natural forests.

3.5. Leaf Dry Matter Content (LDMC)

The highest LDMC was recorded in *Rhododendron arboreum* (736.360 mg/g) followed by *Pinus wallichiana*, *Quercus semecarpifolia* and *Abies spectabilis*

Table 1. Results of One-way ANOVA of height of herbs, shrub and tree species.

	Herbs		Shrubs		Trees	
Df	F value	p-value	F value	p-value	F value	p-value
LUT 3	1.2112	0.3055	1.6977	0.1695	11.775	<0.001***
Altitude 4	15.365	<0.001***	7.516	<0.001***	4.8228	0.03071*

Note: ***Significant at p < 0.001; **Significant at p < 0.01; *Significant at p < 0.05; p value without asterisk being insignificant.

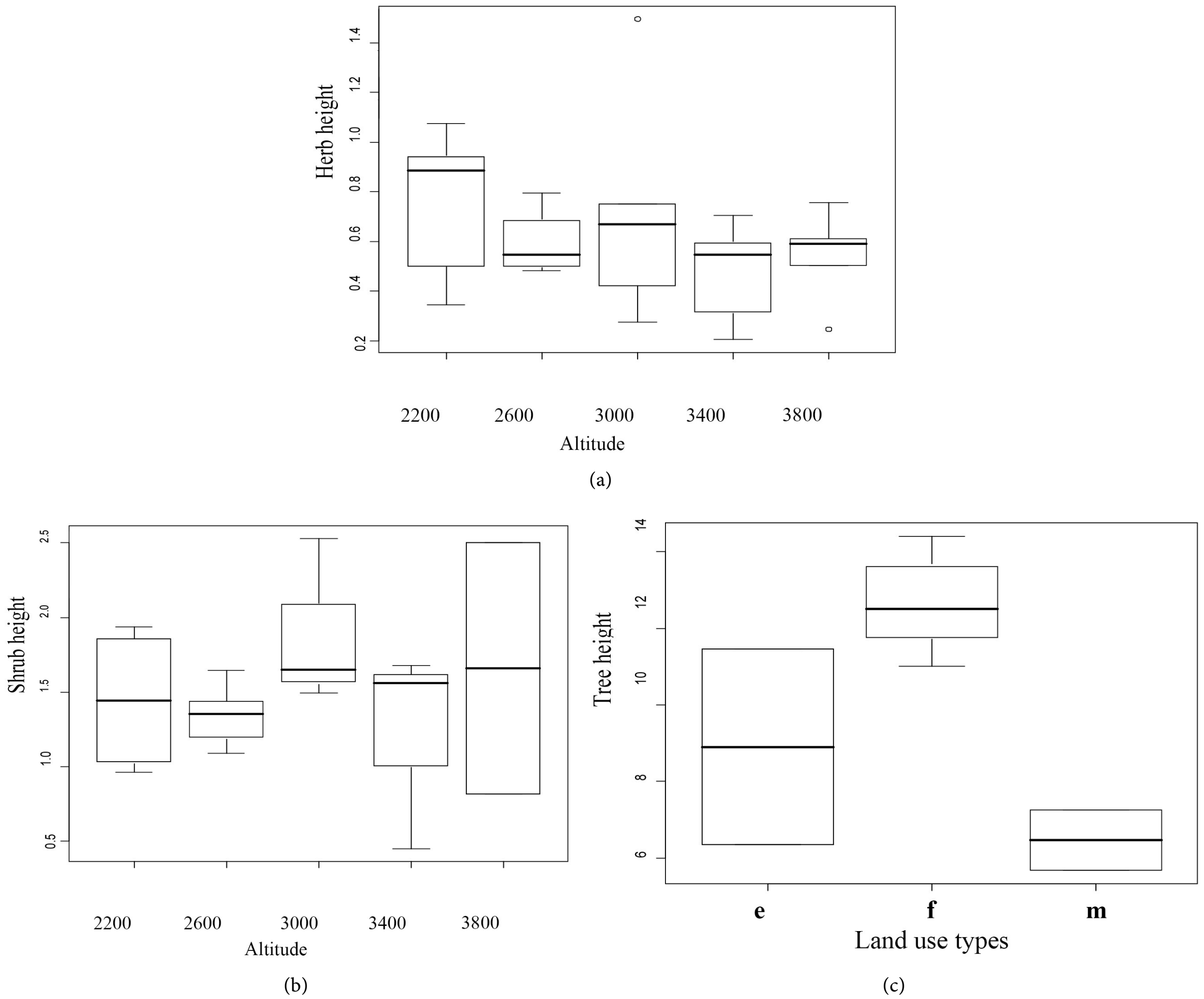
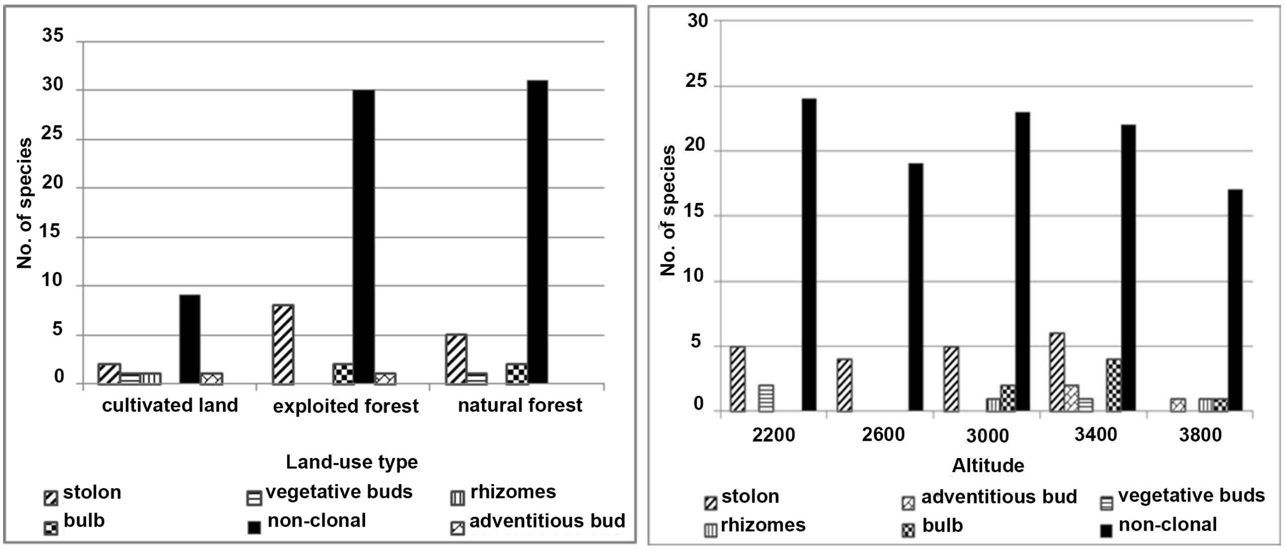


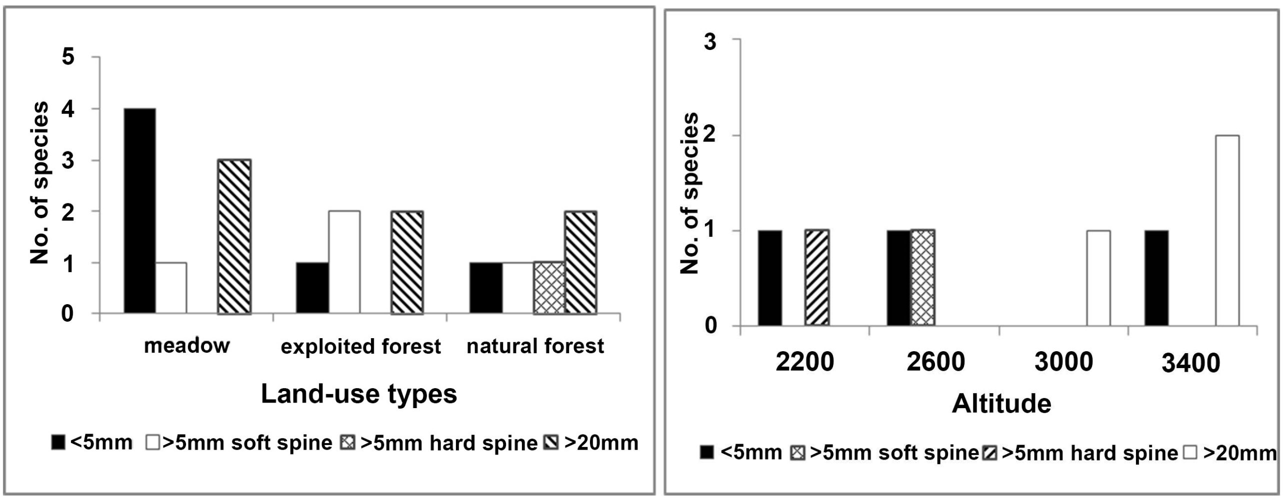
Figure 3. Box-plot showing relationship between (a) herb height along altitude, (b) shrub height along altitude and, (c) tree height in different land use types. The dark line in the box plot represents the median or mid value and its arm represents the quartile value. e represent exploited forest, f for natural forest and m as meadow.

while the lowest LDMC was of *Pilea umbrosa* (35 mg/g). LDMC of herb was significant with land-use type. From post hoc analysis, significant difference (p < 0.01) was found in natural and exploited forest. LDMC of shrub was found significantly different with altitude. Similarly, LDMC of trees showed significant difference with land-use type and altitude (**Table 2**). Lowest LDMC of tree was



(a) (b)

Figure 4. Distribution of different clonality categories along (a) land-use types and, (b) altitudinal gradient.



(a) (b)

Figure 5. Distribution of spines in various (a) land-use types and, (b) altitudinal gradient.

Table 2. Results of One-way ANOVA of LDMC of herbaceous, shrub and tree species.

			Herbs		Shrubs		Trees
	Df	F value	p value	F value	p value	F value	p value
Land-usetype	3	3.5342	0.0150*	0.5483	0.65	10.695	<0.001***
Altitude	4	0.9735	<0.001***	0	<0.001***	9.525	0.0027**

Note: ***Significant at $p < 0.001$; **Significant at $p < 0.01$; *Significant at $p < 0.05$; p value without asterisk being insignificant.

observed in natural forest (Figure 6(a)). Highest value of shrub LDMC was observed at 2600 m with outliers and the lowest value at 3400 m (Figure 6(b)). Highest value of herb LDMC was observed at 3400 m and lowest at 2200 m with outliers (Figure 6(c)).

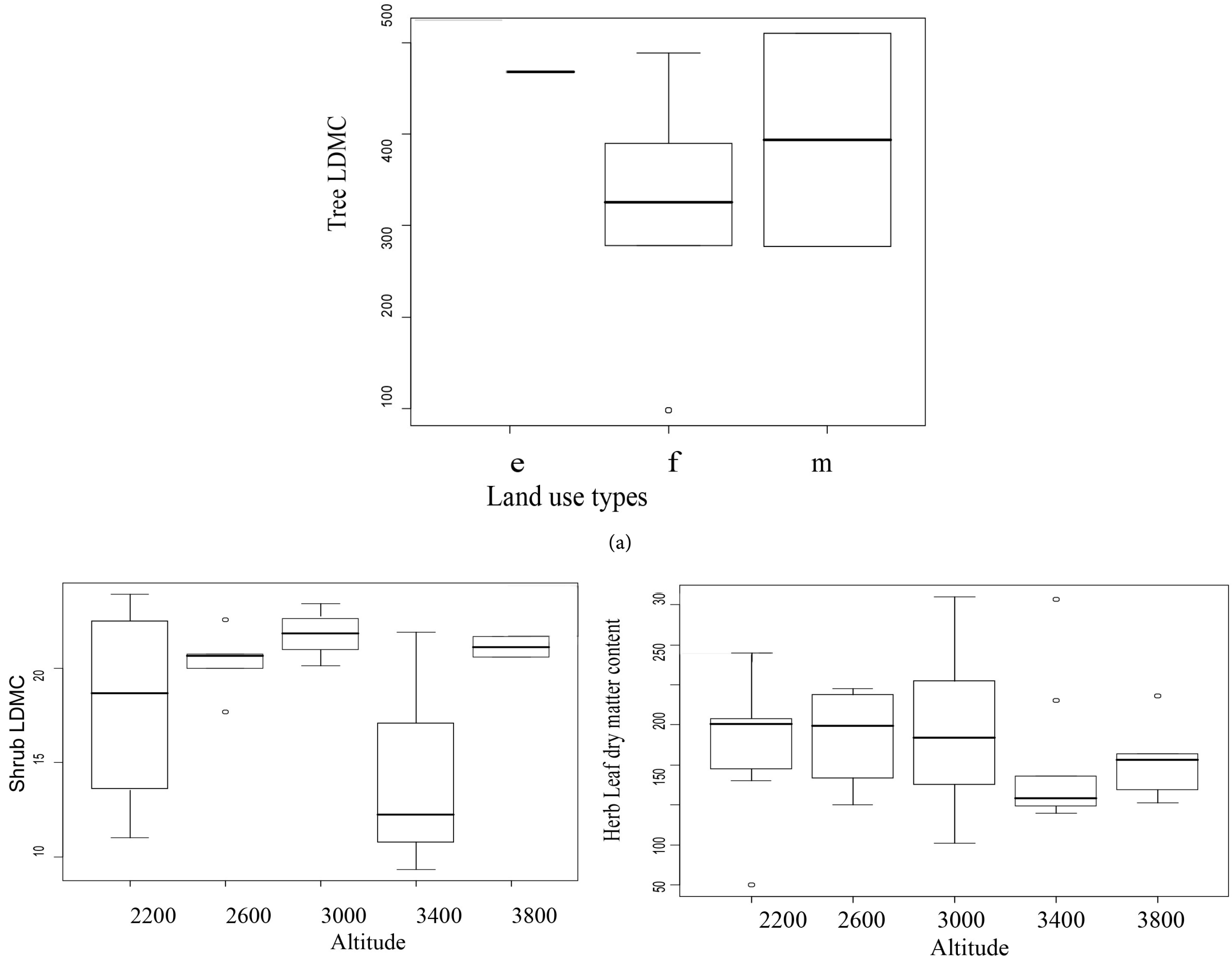


Figure 6. Box-plot showing relationship between (a) tree LDMC along land use types (b) shrub LDMC along altitude and, (c) herb LDMC along altitude. e represents exploited forest, f for natural forest and m as meadow.

3.6. Stem Specific Density (SSD)

Altogether 27 trees and shrub species were collected and among them stem specific density of 15 shrubs were measured. The highest value of SSD was recorded in *Rhododendron lepidotum* (9.35 mg/mm^3) while the lowest value was observed in *Anaphalis busua* (0.19 mg/mm^3). Stem specific density for herbs showed significant difference with land-use type (Table 3). More difference was seen in between exploited forest and cultivated land ($p < 0.001$) as well as natural forest and exploited forest ($p < 0.001$) from post hoc analysis. Similar result was observed from boxplot showing lowest value of SSD at exploited and natural forest with presence of outliers and highest value at natural forest (Figure 7).

3.7. Twig Dry Matter Content (TDMC)

Twig dry matter content was calculated for tree and shrubs. The highest value of TDMC was 875 mg/gm in *Gaultheria fragrantissima*, while the lowest was 251.57 mg/gm in *Abies spectabilis*. TDMC of shrub species was found significant with

Table 3. Results of One-way ANOVA of SSD of herbaceous and shrub species.

		Herbs		Shrubs	
	Df	F value	p value	F value	p value
Land-usetype	3	10.100	<0.001***	1.5936	0.1979
Altitude	4	0.0875	0.7677	3.2544	0.0751

Note: ***Significant at p < 0.001; **Significant at p < 0.01; *Significant at p < 0.05; p value without asterisk being insignificant.

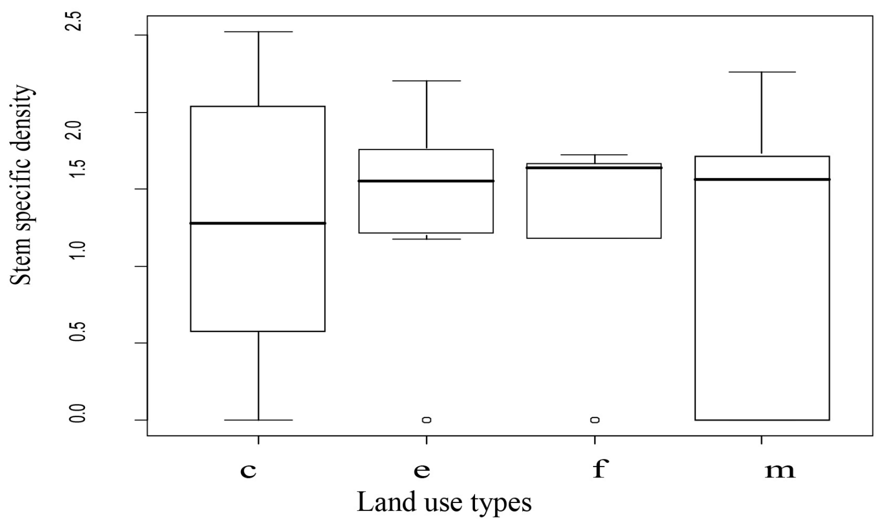


Figure 7. Box-plot showing relationship between stem specific density in different land use types. c represents cultivated land, e is exploited forest, f for natural forest and m as meadow.

land-use and altitude (**Table 4**). More difference was found between meadow and exploited forest. Similarly, twig dry matter content for trees showed significant difference with land-use type (**Table 4**). Outlier was present showing the highest value of tree TDMC at the natural forest and lowest mean value was observed at meadow (**Figure 8**).

3.8. Twig Drying Time

There was not much difference in the twig drying time of the plant species. TDT ranged from 2 - 4 days. The twigs of *Juniperus indica*, *Pieris formosa*, *Pinus wallichiana* and *Quercus semecarpifolia* dried in 4 days, while *Osbekia* took the lowest drying time *i.e.* 2 days. All the other remaining species took 3 days to dry out completely.

3.9. Correlation between Traits

Spearman's Correlation Analysis revealed significant relationships among a number of traits (**Table 5**). Significant correlation (p < 0.01) were observed between Plant height and LDMC (r = 0.553), Plant height and SSD (r = 0.462), Plant height and TDMC (r = 0.802), Plant height and TDT (r = 0.801), LDMC and TDMC (r = 0.610), LDMC and TDT (r = 0598.), SSD and TDMC (r = 0.371), SSD and TDT (r = 0.426), and TDMC and TDT (r = 0.976).

Table 4. Results of One-way ANOVA of TDMC of shrub and tree species.

			Shrubs		Trees
	Df	F value	p value	F value	p value
Land-usetype	3	6.6064	0.002**	9.5956	<0.001***
Altitude	4	11.999	0.001**	1.6489	0.2058

Note: ***Significant at p < 0.001; **Significant at p < 0.01; *Significant at p < 0.05; p value without asterisk being insignificant.

Table 5. Correlation coefficient between different traits of overall altitudes (values with bold entries showed statistically significant).

	Plant height	LDMC	SSD	TDMC	TDT
Plant height	1.000				
LDMC	**0.553****	1.000			
SSD	**0.462****	.236	1.000		
LDMC	**0.802****	**0.610****	**0.371****	1.000	
TDT	**0.801****	**0.598****	**0.426****	**0.976****	1.000

Note: **Correlation significant at p < 0.01; *significant at p < 0.05; other correlations being insignificant.

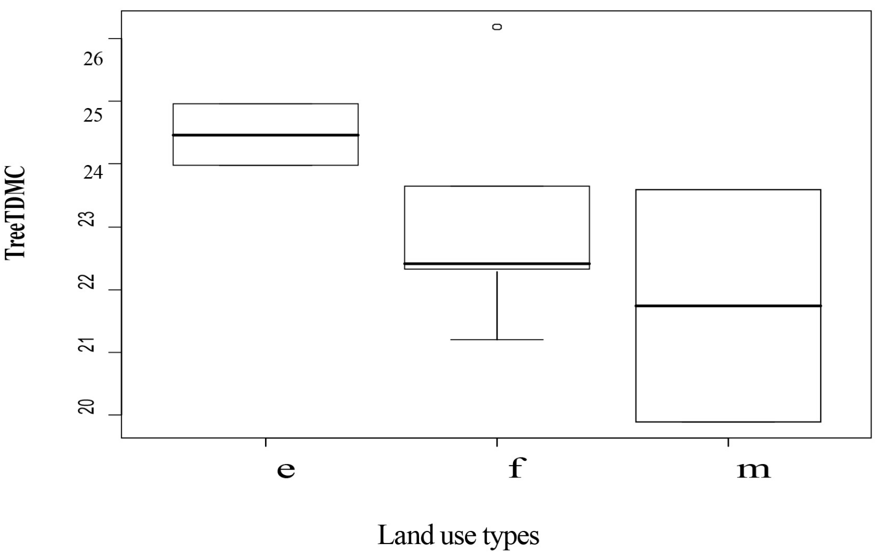


Figure 8. Box-plot showing relationship between tree TDMC in different land-use types.

The correlation coefficient value showed significantly different result within same altitudes as well as other altitudes. Along each of the five altitudinal gradients, plant height showed positive correlation with TDMC and TDT. Higher significant correlation between traits was found in the lower altitude (2200 m). LDMC also showed positive correlation with TDMC and TDT at 2200 m and 2600 m.

4. Discussion

4.1. Growth form along Land-Use Type and Altitude

The result achieved shows variation in different traits along altitude as well as land-use types. Among the various growth forms, tree was dominant in natural forest while different categories of herbs were less dominant. This might be because herbs do not grow well under canopy due to difficulty in light intensity much reaching to the ground [16] [17]. Shrubs and erect leafy were found to be dominant at meadow and exploited forest which may be an adaptation to grazing. The height and positioning of the foliage may be both adaptations and responses to grazing by different herbivores [15]. Along the altitudinal gradient, tree and erect leafy herb species decreased in number whereas other herb and dwarf shrub species were found to be dominant along higher altitude. Similar result of increment in herbs at higher altitudes was found by Wana and Beierkuhnlein (2009) [18] in southwest Ethiopian highlands. The distinction of growth forms informs us about the specific adaptations to environmental conditions such as climate and wind [19] [20], solar energy partitioning [21], water use efficiency [22] and resource partitioning [23] in the ecosystem.

4.2. Plant Height

Herb and shrub height showed a significant difference with the altitude. A study by Bhattarai and Vetaas (2003) [24] in the Himalayan range indicates that woody species display a uni-modal pattern of diversity while herbaceous species do not show any relationship to altitude which is different from the result of present study. The reason behind it could possibly be the effect of an incomplete gradient length of the study ranging of 2200 - 3800 m asl. Plant height in case of shrubs showed significant difference between natural forest and exploited forest as well as between meadow and exploited forest. Significant difference was observed with land-use types mainly between meadow and natural forest in case of tree height. It may be due to the presence of very few trees of short stature in meadow, and low disturbance such as grazing, mowing, firing, etc in natural forest in comparison to the meadow. Short plants were found most dominant in the meadows because they have higher quality and growth rate, and are more tolerant to herbivory than taller plants [25].

4.3. Clonality

Rhizomes and other clonal species were dominant in high altitudes for adaptation to chilling and grazing, similar to the finding of Wana and Beierkuhnlein (2009) [18]. Increase of clonal species in the colder sites was also found by [26] in East Ladakh, Western Himalayas. Diversity of clonal species was high in the meadows as they grow well in harsher environment [10] and nutrient-poor conditions [27]. In response to severe environments, plants either develop adaptations that enable protection of renewing buds or spread the risk of bud mortality by multiplying buds through clonal growth [28]. Clonal behavior may also be an effective means of short distance spread under circumstances of poor seed dispersal or seedling recruitment [15].

4.4. Spinescence

Plant species with spines were mostly shrubs and were dominant at the meadows as disturbance level is high due to grazing, trampling, etc. Another reason may be defense mechanism to protect them from herbivores. They can play an additional role in reducing heat or drought stress [15] by dissipating heat loading on the surface of the leaves and stems or absorbing solar radiation, in addition to their role as a mechanical deterrence against vertebrate herbivory [29]. Spines were found to be more abundant in lower altitudinal ranges in response to drought and grazing which is similar to the findings Wana and Beierkuhnlein (2009) [18] and Dalacho (2009) [20].

4.5. Leaf Dry Matter Content (LDMC)

Leaf dry matter content of tree varied significantly with land-use type and altitude. Significant differences were found between meadow and cultivated land as well as natural forest and cultivated land. In the natural forest, trees with high LDMC were present while in the cultivated and meadow more herbs with low LDMC were present. Species with low LDMC are associated with highly disturbed environments, intensive land-use and colder sites [30]. At higher altitude, fast-growing and shorter species also have low LDMC and lower toughness [31]. Plants found in highlight, less intensive land-use and warmer sites usually have thick leaves with high LDMC [30] [32]. LDMC was significant with altitude in the herbaceous species. Spinescence, growth form, clonality, Twig drying time and plant height were positively correlated with LDMC.

4.6. Stem Specific Density (SSD)

Stem specific density for herbs showed significant difference with land-use type. More difference was observed between exploited forest and cultivated ($p < 0.001$) as well as natural forest and exploited ($p < 0.001$). Trees present in the natural forest had more stem specific density than the ones present in the exploited forest. Best competitors for light are those plants that allocate large fractions of their biomass to above ground organs *i.e.* stems and leaves [1]. SSD is correlated with plant height and TDMC. The higher the plants are the higher is their stem density as well as twig dry matter content. A dense stem provides the structural strength that a plant needs to stand upright and the durability it needs to live sufficiently long. The lower the stem density is the higher is their plant growth rate.

4.7. Twig Dry Matter Content (TDMC)

Twig dry matter content of tree differed significantly with altitude and land-use type. High significance was between meadow and exploited forest. Low TDMC may be positively correlated with high potential relative growth rate. Twig drying time was positively correlated to twig dry matter content in case of trees. Twigs with high dry matter are expected to dry out relatively quickly during the dry season in fire-prone regions [15]. Highest TDMC value in this study was recorded in *Gaultheria fragrantissima* which indicates that it has stronger avoidance characteristics than the others as reported by Olivero (2011) [33].

5. Conclusions

Both quantitative as well as qualitative traits show a great deal of variation among different environmental gradients (altitude and land-use types). Four different land-use types exhibited a significant relationship with traits. Plant traits were found to vary significantly between disturbed (*i.e.* cultivated land, meadow and exploited forest) and less disturbed (natural forest). Some contrasting results found in this study pave the way towards a better understanding of how species cope with varying habitat conditions.

Both natural as well as anthropogenic disturbances are responsible for the shift of PFTs. The main disturbances were grazing, fire, trampling, litter collection, etc. Grazing favors species that are short-lived, herbaceous growth form and clonal. The study site being a Himalayan region, especially in the higher altitude a more harsher environment persist due to cold climate as well as other disturbance factors which cause less diversity of growth forms and more variation in traits. The variation in the abundance of certain plant functional traits at a particular habitat informs us about the strength of the dominant environmental constraint such as climate, resource availability and disturbance level in that ecosystem.

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Conflicts of Interest

The authors declare that they have no any conflict of interest.

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Appendix. Name of the investigated plant species.

S.N.	Name of the species	Family	Life form	Growth form
1	Abies spectabilis (D. Don) Mirb.	Pinaceae	P	T
2	Aconogonum molle (D. Don) H. Hara	Polygonaceae	C	S
3	Alnus nepalensis D. Don	Betulaceae	P	T
4	Anaphalis busua (Buch.-Ham. ex D. Don) DC.	Compositae	He	H
5	Anaphalis triplinervis (Sims) C. B. Clarke	Compositae	He	H
6	Androsace sarmentosa Wall.	Primulaceae	He	H
7	Artemisia indica Willd.	Compositae	C	H
8	Arundinaria maling Gamble	Graminae	P	S
9	Aster flaccidus Bunge	Compositae	He	H
10	Avena sativa L	Graminae	Th	H
11	Berberis aristata DC.	Berberidaceae	P	S
12	Betula utilis D. Don	Betulaceae	P	T
13	Bistorta amplexicaulis (D. Don) Greene	Polygonaceae	He	H
14	Capsella bursa-pastoris (L.) Medik.	Brassicaceae	He	H
15	Commelina maculata Edgew.	Commelinaceae	He	H
16	Cotoneaster microphyllus Wall. ex Lindl.	Rosaceae	C	S
17	Daphne bholua var. glacialis Buch.-Ham. ex D. Don	Thymelaceae	P	S
18	Dipsacus inermis Wall	Dipsacaceae	C	H
19	Elsholtzia fruticosa (D. Don) Rehder	Labiatae	P	H
20	Eupatorium adenophorum Spreng.	Compositae	C	H
21	Euphorbia sikkimensis Boiss.	Euphorbiaceae	C	H
22	Fragaria indica Andrews.	Rosaceae	He	H
23	Fragaria nubicola Lindl. ex Lacaita	Rosaceae	He	H
24	Gaultheria fragrantissima Wall.	Ericaceae	P	S
25	Geranium pratense L.	Geraniaceae	He	H
26	Geum elatum Wall. ex G. Don	Rosaceae	He	H
27	Hedera nepalensis K. Koch	Araliaceae	He	H
28	Heracleum nepalense D. Don	Umbeliferae	He	H
29	Impatiens urticifolia Wall.	Balsaminaceae	He	H
30	Inula cappa (Buch.-Ham. ex D. Don) DC.	Compositae	C	S
31	Iris clarkei Baker ex Hook. f.	Iridaceae	G	H
32	Juniperus indica Bertol.	Cupressaceae	P	T
33	Juniperus recurva Buch.Ham. ex D. Don	Cupressaceae	P	S
34	Lonicera angustifolia Wall. ex DC.	Caprifoliaceae	P	S
35	Lyonia ovalifolia (Wall.) Drude	Ericaceae	P	T
36	Malaxis cylindrostachya (Lindl.) Kuntze	Orchidaceae	G	H

Continued

37	Osbeckia stellata Buch.-Ham. ex D. Don	Melastomataceae	P	S
38	Pedicularis siphonantha D.Don	Scrophulariaceae	He	H
39	Phlomis rotata Benth. ex Hook. f.	Labiatae	P	H
40	Pieris formosa (Wall.) D. Don	Ericaceae	P	S
41	Pilea umbrosa Blume	Urticaceae	C	H
42	Pinus wallichiana A. B. Jacks.	Pinaceae	P	T
43	Plantago major L.	Plantaginaceae	He	H
44	Potentilla fructicosa var. rigida L.	Rosaceae	He	H
45	Primula denticulata Sm.	Primulaceae	He	H
46	Quercus semecarpifolia Sm.	Fagaceae	P	T
47	Rhododendron arboreum Sm.	Ericaceae	P	T
48	Rhododendron campanulatum D. Don	Ericaceae	P	T
49	Rhododendron lepidotum Wall. ex G. Don	Ericaceae	P	S
50	Rhododendron setosum D.Don	Ericaceae	P	S
51	Rosa sericea Lindl.	Rosaceae	P	S
52	Roscoea purpurea Sm.	Zingeberaceae	G	H
53	Rubus ellipticus Sm.	Rosaceae	P	S
54	Rumex nepalensis Spreng.	Polygonaceae	He	H
55	Salvia campanulata Wall. ex Benth.	Labiatae	C	H
56	Saxifraga parnassifolia D. Don	Saxifragaceae	He	H
57	Senecio cappa Buch.-Ham. ex D. Don	Compositae	C	H
58	Senecio diversifolius Wall. ex DC Sene.div	Compositae	C	H
59	Tsuga dumosa (D. Don) Eichler	Pinaceae	P	T
60	Zanthoxylum armatum DC.	Rutaceae	P	T

Growth forms: T = Tree; S = Shrub; DS = Dwarf Shrub; H = Herb. **Life forms:** Th = Therophyte; He = Hemicryptophyte; P = Phanerophyte; C = Chameophyte; G = Geophyte.