ECOLOGICAL STUDY AND DISTRIBUTION OF PTERIDOPHYTE ALONG THE ELEVATIONAL GRADIENT OF PHULCHOWKI HILL, CENTRAL NEPAL

A DISSERTATION

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June, 2022

DECLARATION

I, hereby declare that the dissertation work entitled "**Ecological Study and Distribution of Pteridophyte along the Elevational Gradient of Phulchowki Hill, Central Nepal"** is carried out by myself and has not been submitted elsewhere for any other academic degree. All the sources of information have been specifically acknowledged by reference wherever adopted from other sources.

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RECOMMENDATION LETTER

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CERTIFICATE OF ACCEPTANCE

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LIST OF ABBREVIATION

p	Level of Significance
masl	Meter above sea level
KATH	National Herbarium and Plant Laboratories, Godavari, Lalitpur
SPSS	Statistical Package for the Social Science
GPS :	Global Positioning System
RF :	Relative Frequency
RD :	Relative Density
RC :	Relative Coverage
IVI :	Importance Value Index
D :	Samson's diversity Index
H' :	Shannon Wiener Diversity Index
TUCH :	Tribhuwan University Central Herbarium
MDE:	Mid Domain Effect

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ABSTRACT

The present study aims to find the relationship between pteridophyte richness along the elevational gradients of Phulchowki Hill, Central Nepal. The study was carried out in three elevational zones namely lower (1500-1900 masl), middle (1900-2300 masl) and upper elevation (2300- 2700 masl), starting from 1550 masl and ending to 2698 masl of Phulchowki Hill at an interval of 100 m. Random number of quadrats having 5m × 5m sizes were laid at each elevation band. SPSS- Software and Microsoft Excel were used to perform the statistical analysis. All together 46 (39 terrestrials and 7 epiphytic) pteridophyte species belonging to 28 genera and 14 families have been documented. Among the 14 families Polypodiaceae was found to be the largest family having highest number of genera followed by Pteridiaceae. However, Pteridiaceae was found as largest family on the basis of highest number of species followed by Dryopteridaceae and Polypodiaceae. Plant community properties such as species richness, diversity, and composition vary along environmental gradients. Species richness of tree species showed asymmetric hump shaped pattern of distribution with elevational gradients. The pteridophyte species richness significantly differs along the elevational gradients within different sites. Pteridophyte species like *Selaginella chrysocaulis*, *Dryopteris carolohopei* were dominant in lower elevational zone; *Polystichum squarrosum*, *Drynaria moliis* were dominant in middle and *Polypodiodes hendersonii*, *Drynaria moliis* were observed dominant in upper elevational sites. The Spearman's correlation analysis table shows elevational gradient strongly affects the pteridophytes richness.

Keywords: *Fern, Species richness, asymmetric hump pattern, correlation*

CHAPTER - ONE

INTRODUCTION

1.1 Background

Pteridophytes are higher cryptogams with a well developed vascular system with about 13,271 living species documented in a checklist of Ferns and Lycophytes of the world (Hassler, 2018), which forms nearly 3% of the world flora. They are from two phylogenetically distinct groups: the lycophytes (less than 1500 species) and the ferns (some 10,500 species) (PPG I 2016). Pteridophytes also called Fern and Fern allies are spore bearing non-seeded vascular Cryptogamic plants having well developed root, stem and leaves (Kumar, 2014). They are the connecting link between non-vascular plants and higher group of seeded plants. The Devonian and Carboniferous periods of Paleozoic era shows the origin and evolution of Pteridophytic flora (Pandey *et al*., 1977). The Pteridophytes are generally characterized by dominant sporophyte, reduced gametophyte, jacketed sex organs, requirement of water during fertilization; alternation of generations etc. (Pandey *et al*., 1977).

Pteridophytes grow in many different habitats around the world and are abundantly found in humid and shady forests. Diversification of pteridophytes is highest in the tropics, in Nepal they form an attractive component of the vegetation on different climatic zones of its hills and forests showing different ecological habit as terrestrial, epiphytic, lithophytes, tree ferns, hanging club mosses, climbers and hydrophytes (Hogan 2004, Rajbhandary 2013, Rajbhandary 2016), but some species occur in more than one habitat. The Fern and Fern allies generally thrive well in shady moist and humid tropical and temperate forests of different geographical regions. They show different ecological habit as epiphytes, lithophytes, terrestrial, climbers and hydrophytes. They are widely distributed, from the tundra to tropical forests, being more diverse in the equatorial region (Tryon 1972, Tryon & Tryon 1982, Moran 2008).

A fully revised annotated checklist of pteridophytes of Nepal includes a critical account of 550 species and an additional 30 subspecies of pteridophytes, with a total of 580 species (DPR, 2015). Recent publication reported a total of 583 taxa (550 species and 33 subspecies) of pteridophytes occur in Nepal (Fraser-Jenkins *et al.,* 2015, Fraser-Jenkins & Kandel 2019, Kandel & Fraser-Jenkins 2020). In Nepal, pteridophytes are distributed all over the country from east to west and low land terai to high altitude Himalayas. Central Nepal of altitude about 2000 masl harbors maximum species richness of the nation (Bhattarai *et al.*, 2004). They are found in varied habitat like terrestrial, lithophytes, climbers, aquatic, epiphytes etc. and many ferns are also found in more than one habitat (Thakur & Rajbhandary 2018). Some common Pteridophytic genera of Nepal are *Selaginella*, *Pteris*, *Asplenium*, *Thelypteris*, *Dryopteris*, *Lepisorus* etc. (Fraser-Jenkins *et al.*, 2015).

Locally pteridophytes are not randomly distributed, as their presence or absence reflects microhabitat characteristics, such as soil texture and fertility, atmospheric temperature and humidity, precipitation, and light intensity (Nóbrega *et al.*, 2011, Patil *et al*., 2016). Hence the distribution of pteridophytes being strongly related with abiotic variables, that presents a great potential as environmental indicators. In addition, a large number of genera or species are easily recognized in the field (Tuomisto & Ruokolainen 1993, Salovaara *et al*., 2004).

Fern and fern allies have been used since pre-historical period of time for foods, medicine and ornamental for gardening and decoration (Gurung 1988b, Rajbhandary 2010). Pteridophytes are considered economically important for their food value and ornamental decorative value as well as equally important with medicinal properties. The tender young leaves of *Tectaria coadunata* (Kalo niuro), *Diplazium esculentum* (Saune niuro) etc. are used locally as vegetables. Likewise, *Nephrolepis cordifolia*, *Drynaria coronans* etc. are used as decorative and ornamental plants in Nepal. Similarly, *Aleuritopteris bicolor*, *Adiantum capillus-veneris* etc. are medicinal Pteridophytes of Nepal (Annual progress report 2014-15, www.kath.gov.np). Edible pteridophytes are good sources of proteins, vitamins, crude fiber, and minerals (Chettri *et al*., 2018). Some ferns play a great role in ecological succession, growing from the crevices of rocks and in open marshes before the advent of forest vegetation. Ferns were identified to have various ethnobotanical uses which could either be for food consumption, medicine and aesthetic value (Delos Angeles, 2012). Ferns are found to provide food, fiber, crafts and building material, abrasives and of course decoration (Srivastav, 2016).

Environmental gradients related to climate, topography and vegetation are most critical environment factors influencing the broad scale pattern of species richness in mountain areas (Cantlon, 1953; Moura *et al.*, 2016). For the mountain areas, land use and geographic factors such as aspect and elevation, slope degree and fluctuations are considered as the main topographic factors that affect the vegetation diversity and distribution patterns indirectly (Sanders *et al.,* 2007; Sanders & Rahbek, 2012). The light environment has a significant effect on the vegetation. The canopy covers of trees check the solar radiation which has direct influence on the diversity of ground vegetation. Panthi *et al.*, 2007 have noticed the significant correlation of moisture with canopy cover and found canopy as the main underlying environmental gradient for species richness and composition (Veetas, 1997). The large scale canopy disturbance will reduce the diversity and change the plant species composition. Sagar *et al.*, (2008) observed that woody plant canopies and canopy type significantly maintains the light availability on the forest floor which controls the pattern of herbaceous floral composition. Jennings, (1999) have summarized forest canopy as a chief determinant to affect plant growth, survival and nature of vegetation. The forest canopy modifies the availability of understory resources such as light, water and soil nutrients (García *et al.,* 2006). Hence affect the plant growth and consequently influences the richness and composition of understory vegetation.

Species richness is the number of total species present in an ecological community (Colwell 2009). It is the widely used measure of biodiversity (Stirling & Wilsey 2001), which is assumed to be a simple and easily interpretable indicator of biological diversity (Peet 1974). Species richness is found to be affected by elevation (Bhattarai & Vetaas 2003, Grau *et al*., 2007, Baniya *et al.*, 2010), land use type (Bobo *et al.,* 2006, Bhattarai & Vetaas 2013), aspect (Panthi *et al.,* 2007) and many other factors. Mountain slopes with significant bioclimatic amplitude generally have more species at the bottom than at the top (Vetaas & Grytnes, 2002). In mountainous areas, such as the Himalayas, the maximum number of endemic species is expected to occur at high elevations, due to isolation mechanisms (Shrestha & Joshi, 1996). A study of species richness along the elevation gradient found that about 50% show a hump-shaped trend in species richness with a maximum species at mid-elevation, and another 25% show a monotonic decline in species in species richness from low elevation to high elevation (Rahbek, 1995) and remaining shows nearly constant from the low lands to mid-elevation and strong decline further i.e. diversity plateau at low elevations with increasing elevation have found a decreasing trend in species diversity, richness, whereas others have found a hump shaped relationship between species richness and elevation (Vetaas & Grytnes, 2002; Klimeš, 2003). More recent studies show maximum species richness at middle elevation for vascular plants, Pteridophytes however the monotonic decline in species richness as the elevation increase is also found (Vetaas & Grytnes, 2002).

The species richness and composition patterns are also affected by the slope and aspect of the sampling plots (Nuzzo, 1996). The south facing and steeper slopes are drier than the north facing slopes; Northern and Northeastern slopes have low temperatures and higher soil and air moisture contents as compared to southern and other slopes at the same elevation due to less solar exposure and higher moisture content and evapotranspiration which is akin to other Himalayan areas (Baduni & Sharma, 1996). Kutiel & Lavee, (1999) studies the effect of slope aspect on vegetation and found the significantly higher vegetation cover on north facing slope than on south facing slope. Panthi *et al*., (2007) report the effect of aspect on plant species richness and composition and found to be significantly higher species richness on north aspect rather than on the south. Aspect is found to be a less significant predictor, but it could improve explanatory ability of precipitation in describing the plant richness pattern. It indicates combined influence of topography and climate in defining plant richness pattern. Shah *et al.,* (2011) had advocated that the heterogeneity in vegetation and species distribution in the Himalayas be characterized by topography, soil, climate and its geographic location.

Nepal has diverse vegetation types. It has South to North longest and steepest altitudinal gradients. Vegetation changes with these altitudinal gradients ranging from Terai hard wood mixed forest to alpine scrub land (Stainton, 1972). Vegetation with in a forest is greatly affected by differences in the microclimate, aspect and elevation; hence there are great variations in vegetation from tropical to subtropical and temperate to alpine regions of Nepal (Stainton & Schilling, 1973; Jackson, 1994). There is a great variation in the vegetation along the rainfall gradient across the country along the different elevational gradient. Human interferences have a prominent role in changing understory vegetation structure. These effects were overgrazing, wood cutting for fuel and construction activities especially road and infrastructure (El-Juhany & Aref, 2012).

With the addition of altitudes, the bio-physical gradients start differing which in turn brings changes in diversity, distribution, and abundance of pteridophyte species at varying altitudinal ecosystems. Biophysical gradients mainly floral components, altitude, and temperature are responsible to bring changes in the species community. Rainfall and temperature act directly upon plant vegetation thus affecting the distribution of pteridophytes in a certain locality. Pteridophytes were the dominant flora on this earth millions of years ago during the Triassic period and are now replaced by flowering plants, but they still grow abundantly in moist tropical and temperate forests (Dixit, 2000). Pteridophytes show a peculiar type of life cycle, that combines wind-dispersed spores and mostly with free-living gametophytes. This unique characteristic feature improves a surplus level of complexity when making biogeographical comparisons of pteridophytes with other vascular plants (Watkins *et al*., 2006). So the richness of pteridophyte species and bio-physical gradients are inter-related phenomenon. This not only increases diversity richness but also limits the distribution of fern flora. Thus, exploration is the foremost step for the documentation of species for certain area, place, regional or global scale.

1.2. Justification of study

Pteridophytes have been a popular subject of studies on species–elevation relationships, with the highest diversity in tropical and subtropical mountains (Linder, 2001; Bhattarai *et al*., 2004). How the pteridophytes are distributed at various ecosystems and their species richness in the Nepalese Himalayas, the largest altitudinal gradient in the world is a matter of extensive research in the present context.

The same altitudinal range at different mountains within the same region also differs in diversity, distribution and abundance of species. There have been few investigations of the distribution of pteridophytes over the altitudinal gradient in the Himalayas of Nepal. There is a large data gap and paucity of information about the diversity of pteridophytes species across the elevational gradients of Phulchowki Hill. To know how the distribution of pteridophytes species changes along the elevation gradient it would be helpful to make future policies for conservation and management of species. Here, my aim is to explore the role of elevation in shaping the pattern of pteridophyte species distribution along the Phulchowki Hill of central Nepal.

Research questions

This study was designed to obtain better knowledge and general understanding of the following research questions:

- What is the current status of pteridophytes of Phulchowki Hill?
- How does pteridophyte diversity change along elevation gradient of Phulchowki Hill?

Hypothesis

The proposed study is driven by following hypotheses:

- There is a significant relation between elevational gradient and diversity of pteridophytes species.

Objectives of study

The overall objective of the proposed research is to study the changes in diversity and richness of pteridophytes species along the elevational gradient in Phulchowki Hill. The **specific objectives** are as follows.

- To enumerate the pteridophyte species in the studied area.
- To study the ecological parameters (Density, Frequency, Coverage, Importance Value Index (IVI), Similarity and Diversity Indices) of pteridophytes status.
- To investigate the patterns of changes in pteridophytes species richness.

Limitation of the study

This study was carried out specifically on the roadside and foot trails of Phulchowki Hill forest in Central Nepal extending from 1500 m to 2700 m and could not cover additional forest area. Species richness pattern is assessed for pteridophytes species only. Due to the limitation of time and resources, analysis of tree species, shrub species, other NTFPs species, hydrophytic pteridophytes, and soil quality could not be made. Therefore, only pteridophytes species were taken into consideration.

CHAPTER – TWO

LITERATURE REVIEW

Pteridophyte diversity and elevational gradient

The general pattern of plant species richness reflects the species composition and abundance of the area and the similar factors like slopes, altitude, aspect and other environmental factors also influence species composition (Ellu & Obua, 2005). Diversity of life forms i.e., species composition, usually changes with increasing altitude and one or two life forms only remains at extreme altitudes (Pavon *et.al*, 2000). It is generally accepted that tropical regions are reported to have higher species richness than temperature areas (Pianka, 1966), but documentation of diversity patterns within tropics is limited in particular to vascular cryptogams (Gentry, 1982).

The general concept of species richness pattern with altitude has revealed that as the altitude increases the species richness decreases (Woodward, 1987; Stevens, 1992; Körner, 1995; Brown & Lomolino, 1998; Fossa, 2004). However, Species richness on elevation gradient studies focused on two main correlation patterns such as monotonic and humped. Monotonic has been referred to as decrease in species richness with increasing elevation and humped referred to as th highest distribution and species richness near the middle of the elevation gradient (Rahbek 1995; Grytnes & Beaman, 2006). A majority of previous studies on distribution of pteridophytes along elevation gradients in different geographical regions have shown a humped shaped distribution pattern (Kessler, 2000; Kessler, 2001; Hemp, 2002; Bhattarai *et al*., 2004; Kluge *et al*., 2006; Watkins *et al*., 2006). In recent years, MDE or geometric constraints has been recognized as one of the most important factors influencing a hump-shaped pattern (Colwell & Hurtt 1994; Colwell & Lees 2000; Colwell *et al*., 2004). MDE predicts that geometric constraints with hard boundaries result in an increased overlap of species ranges toward the centre of the domain and lead to a hump-shaped pattern of species richness along altitudinal gradients (Colwell & Lees 2000). The empirical study on species density and elevation from the eastern Nepal has shown a unimodal pattern for understory plants and trees (Carpenter, 2005). A monotonic decrease (Bhuju & Rana, 2000; Paudel *et al*., 2010) and a unimodal pattern (Rijal, 2007, 2009) were also found as different patterns of species richness on eastern and central

Nepal respectively. Similarly, 49% of altitudinal gradient studies across the globe on different vegetation showed a humped species richness trend (with major groups of insects, small mammals, birds, and vascular plants with maximum species richness) at 500 m or lower to 1500 m or higher elevation and 24% of the studies showed little change in species richness at lower elevations and decline at higher elevations (Carpenter, 2005). Plant species richness declines monotonically above an elevation gradient of 1500 m (Vazquez & Givnish, 1998).

Plant diversity and aspect

Land use and geographic factors such as aspect and slope play major roles in distribution of pteridophytes species in any area (Sanders & Rahbek, 2012). Nahidan *et al*., (2015) established that slope aspect can significantly affect the quantity of soil organic carbon (SOC), Total nitrogen (TN), and enzyme activity by altering the rate of litter decomposition and the activity of soil microbes. Soil nutrient conditions, especially C and nitrogen N contents, are affected by slope aspect, which are among the most important factors shaping soil microbial activity. The topographical variables such as slope angle, aspect or regional differences were rarely analyzed in the Himalayan region (Paudel & Vetaas, 2014). Similarly, the epiphytic and terrestrial niches operates the Pteridophytes distribution at largely different scales: whereas terrestrial microhabitats change due to point temperature, water availability, soil nutrients, soil moisture, and topographic parameters over distances of several dozen meters (Geiger *et al*., 1995; Cicuzza *et al.*, 2013), epiphytic niche differentiation is driven by small-scale features due to tree crown architecture (Kromer *et al*., 2007). Similarly, Zhang *et al*., (2015) observed that high canopy openness increased light but reduce moisture and thus decrease the ground fern diversity. In the Himalayas, northern aspects are relatively moist than south aspect, and the pteridophyte species richness was found to be high in north facing slope than south facing slope (Panthi *et al.*, 2007; Sharma, 2012). The different microhabitats in the forest understory determine the high diversity of epiphytes (Kromer *et al*., 2007). The number of epiphytic ferns found in dense and moist forests was comparatively higher than those found on trees in open and dry areas (Rajbhandary, 2016).The south-facing and steeper slopes are drier than the north-facing slopes, and more number of species was expected towards the wet areas (Kassas & Zahran, 1971; Pook & Moore, 1966).

The diversity of pteridophytes depends on the topography, and is typically higher on the slopes than on ridges (Kessler & Lehnert, 2009). Yan *et al*., (2011) observed higher fern diversity on the east- and north-facing slopes in comparison to west- and south-facing slopes of South China. Nettesheim *et al*., (2014) concluded that slopes only affect species composition but not the species richness of ferns and lycophytes in tropical forest of Brazil. The inter-specific interactions, and especially competition, also contribute to the local diversity of ferns (Salazar *et al*., 2013; Zhang *et al*., 2017). Adhikari *et al*., (2017) studied the diversity, composition and host-species relationships of epiphytic orchids and ferns in two forests (Naudhara community forest (CF) and the national forest (NF) in Shivapuri Nagarjun National Park) in Nepal and observed that fern species richness significantly decreased with increasing altitude and was lower in sites that faced south, whereas it increased on trees with rough bark. They also observed fern species richness did not show significant differences between the different forest management types i.e. community forest (CF) versus national forest (NF) but was higher on *Schima wallichii* than on *Quercus lanata* trees in both the CF and NF.

CHAPTER - THREE

MATERIALS & METHODS

Site description

Location

The study was carried out at Phulchowki Hill which lies within Naudhara Community forest (27° 33'N, 85° 22'E), 10 km southeast of Kathmandu, Nepal. It is a part of sub-Himalayan Mahabharat region with an altitudinal range of 1400 to 2715 masl with extensive diverse forests mostly dominated by broad leaved evergreen trees. It covers an area of approximately 50 square km consisting of a vast range of flora. The study area is spread over Godawari municipality of Lalitpur District of Bagmati Provience. The study area has typical warm temperate monsoon climate with three seasons round the year: cold and dry winter (October to February), pre monsoon dry summer (March to May) and monsoon (June to September). There is no perennial source of water above 1600 m in Phulchowki Hill. Mean temperature ranges between 2.6 to 18.7 C in winter and 15.8 to 28.2 C in summer. Mean annual rainfall is 1882 mm with about more than 80 percent between mid June to mid September. The forest stand is dominated by naturally regenerating *Quercus lanata* and *Castanopsis tribuloides* forming a closed tree canopy layer. The canopy cover in this area is approximately 80% on average (Adhikari *et al*., 2012b).

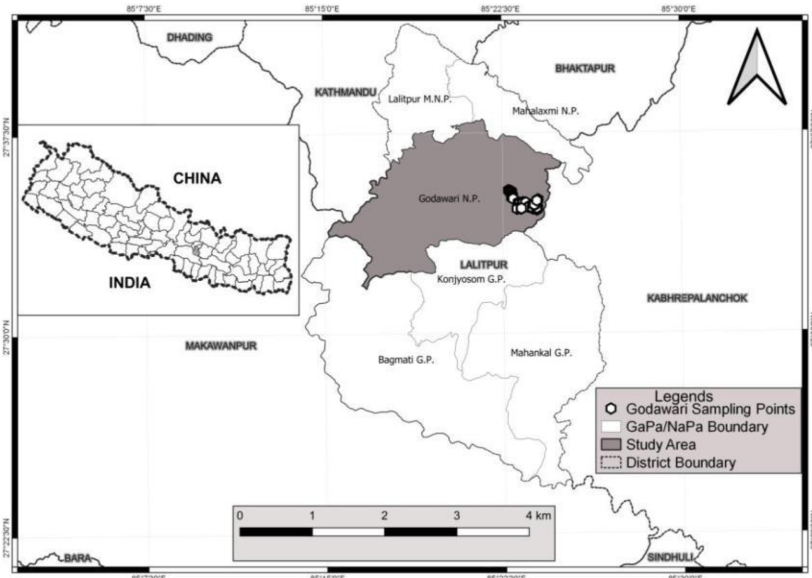

Figure 1: GIS map showing sample site under Godawari municipality; Ward no. 3, Phulchowki Hill**.**

Climate

The impact of any climate change on high altitude regions is of fundamental importance to the region itself, its resources, and its surrounding environments (Bradley *et al*., 2006). The most influencing factors of central Nepal are two great mountain ranges; the great Himalayan and the Siwalik range. The study area has four seasons rounded the year: cold and dry winter (December to February), pre-monsoon dry summer (March to May); monsoon (June to September) and post monsoon (October-November). Monsoon climate is prevalent in the study area.

Meteorological data (from 1990-2019) were collected from the Godavari Station of Department of Hydrology and Meteorology, Kathmandu, Nepal located at a distance of 1 km from the study site at 1527 masl. Mean maximum temperature ranged from 16.21°C to 26.79°C, with a mean minimum temperature of the coldest month (January) of 2.8°C and a mean maximum temperature of the warmest month (June) of 26.79°C. The annual rainfall was 1676.49 mm on average with about more than 80% of this occurring between June to September. Relative humidity (RH) was recorded higher in the months of July to August and low in March and April. The average rainfall and temperature is illustrated in Figure 1.

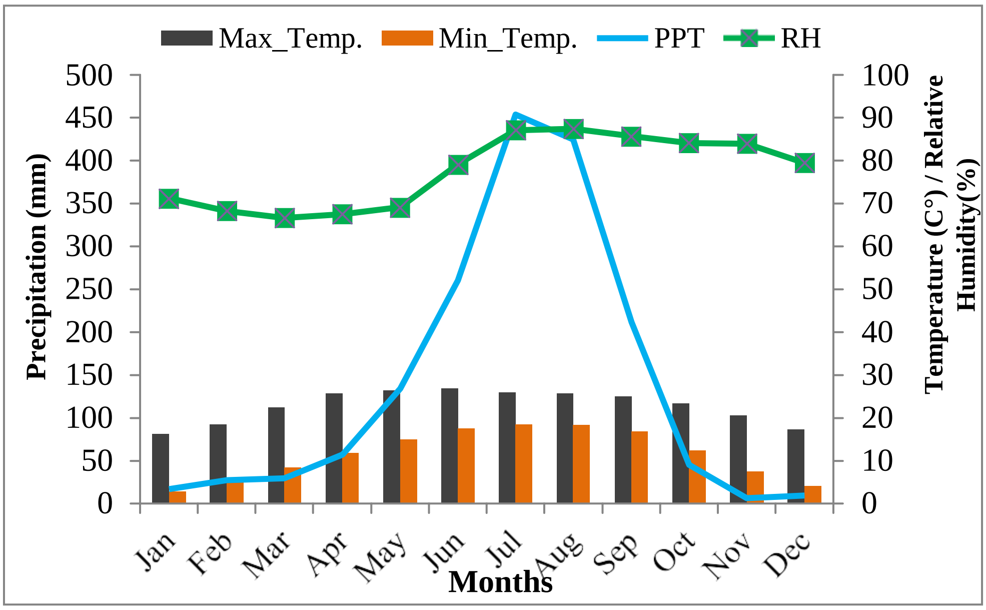

Figure 2: Temperature, precipitation and humidity records of Godawari station in Lalitpur District for thirty years (1990-2019). (Source: Department of Hydrology and Meteorology / Government of Nepal, Kathmandu, 2020).

Biodiversity of Phulchowki Hill

Flora

Malla, (1986) have enumerated 527 species of Angiosperms and 2 species of Gymnosperms species from Phulchowki and Godavari Area. Pradhan, (2018) counted total 205 species of bryophytes in the Phulchowki hill. The vegetation of Phulchoki hill is characterized by three distinct evergreen broad leaved forest types: mixed *Schima Castanopsis* forest at the base (1400 m to 1800 m), Oak- Laurel forest (1800 m to 2400 m) and evergreen oak forest (2000 m above) (Kattel *et al*., 2015).

Species distributions in this region are: *Schima wallichii* (DC.) Korth., *Castanopsis indica* (Roxb.) Miq., *Alnus nepalensis* D. Don, *Quercus glauca* Thunb., *Myrica esculenta* Buch.-Ham. ex D. Don, *Myrsine capitellata* Wall., *Phyllanthus parvifolius* Buch.-Ham. ex D. Don. is most dominant species among shrub species. *Melastoma malabathricum* (L.) Smith., *Berberis aristata* DC, *Sarcococca coriacea* (Hook.) Sweet, *Crotalaria cytisoides* Roxb. ex DC., *Osyris wightiana* Wall. ex Wight, were associated common shrub species. The common associated species were *Berberis asiatica* Roxb. ex DC., *Rubus acuminatus* Sm., *Rubus paniculatum* Sm., *Lindera pulcherrima* (Nees) J. D. Hooker, *Indigofera atropurpuria* Buch.-Ham.ex Horn., *Arundinaria falcate* Nees., *Aconitum ferox* Wall., *Eupatorium adenophorum* Spreng are most dominant species among herbaceous species (Kattel *et al*., 2015).

Study design

Sampling method

Random sampling method was used in the field to record data. The sampling was done by quadrat of (5×5) m² from 1550-2698 masl elevation. Elevation gradients (from 1500 to above 2700 masl) were divided into 12 elevation zones with 100 m intervals. Quadrats were laid randomly in each gap of 100 m difference. 71 quadrats were set for the study. Each plot was sampled thoroughly for 15 minute - 1 hour, and the time period depends on species richness in the studied transects. In each transect, habit, habitat, associated host species, the total number of pteridophyte species, the total number of individuals, and the pattern of distribution were noted in a field notebook as per the standard procedure followed for field studies on pteridophyte species richness along elevation gradients (Kessler & Bach, 1999).

Field visit

The study area was visited twice (first in Summer, 14th August- 22th August, 2018 and second in Autumn, 12th September - 17th September, 2019) for data collection. Quadrats were laid down with the help of Global Positioning System (GPS) coordinates and nylon rope. Pteridophytes species occurring inside each transect were recorded. Data for each individual specimen within quadrats were recorded on the basis of their number, coverage and habitat. Associated plant species were noted down inside each quadrats. Pteridophytes species along the main trail was noted down by general observation. Latitude, Longitude and elevation of each sample quadrats were recorded by Global Positioning System (GPS, Garmin 60csx).

Plant collection and identification

Some of the plant species were identified in the field by using the field guide books such as Fern and Fern Allies Volume-1, (Jenkins *et al.*, 2015), Fern and Fern Allies Volume-2, (Jenkins & Kandel, 2019). Species that could not be identified in the field were collected, tagged, dried along with their local names and brought to Amrit Campus, Lainchaur; KATH for further identification. Digital photographs of live plant species were taken in the field and the photo-number and tag were noted. The unidentified specimens were compared with relevant specimens deposited at Amrit Campus and further confirmed with those deposited at KATH Herbaria. The unidentified specimens were verified by consulting related literatures and book (such as, Vasistha, *et al.*, 2015; Grand report on pteridophyte of Bhutan, 2012) and National Herbarium, Godawari (KATH).

Data analysis

Numerical analysis

Quantitative analysis of community structure was done using Curtis and Macintosh, (1950) as follows:

Density is the numerical strength of a species where the total number of individuals of each species in all the quadrats is divided by the product of total number of quadrats studied and area of single quadrat. Density is calculated by the equation:

$$\text{Density (D)} = \frac{\text{Total no. of Plants of any species}}{\text{Total no. of Quadrats studied} \times \text{Area of quadrats}}$$

Relative density is the study of numerical strength of a species in relation to a total number of individuals of all the species and it is calculated as:

$$\text{Relative density (RD) (\%)} = \frac{\text{Density of individual species}}{\text{Total density of the all species.}} \times 100$$

Frequency and Relative Frequency (RF)

Frequency is defined as the number of sampling units in which the particular species occur, thus it deals about degree of dispersion of individual species in an area and usually expressed in terms of percentage and can be calculated as:

$$\text{Frequency (F) (\%)} = \frac{\text{Number of Quadrats in which species occurred}}{\text{Total number of Quadrats samples}} \times 100$$

Relative frequency is the degree of dispersion of individual species in relation to the dispersion of all the species occurred and calculated as:

$$\text{Relative frequency (RF) (\%)} = \frac{\text{Frequency of a species}}{\text{Total frequency of the all species}} \times 100$$

Percentage cover and Relative cover (RC)

Percentage cover was calculated to describe canopy coverage in percentage of each plant species around its habitat and calculated as:

$$\text{Average Coverage (C)} = \frac{\text{Total coverage of species}}{\text{Total number of Quadrats}}$$

Relative coverage is the coverage of an individual species in relation to the total coverage of the all the species and calculated as:

$$\text{Relative Coverage (RC)} = \frac{\text{Coverage of individual species}}{\text{Total number of all samples}} \times 100\%$$

Importance value index (IVI) deals that which plant species is more important and dominant (i.e. in terms of relative density, relative frequency and relative coverage) in the study area and calculated by using formula given by (Zobel *et al.*, 1987).

Importance Value Index (IVI) = RF + RD + RC

Where,

RF = Relative Frequency

RD = Relative Density

RC = Relative Basal Area

Species diversity is the combination of species richness and species evenness. Species richness is the number of species per sampling unit. Species evenness is the distribution of individuals among the species. Evenness is a maximum when all the species have same or nearly equal number of individuals. Species diversity can be expressed in single index number. Among the several indices most commonly used two indices are Simpson's index (Simpson, 1949) and Shannon-Wiener's index (Shannon & Weaver, 1949). Simpson's index (D) reflects the dominance because it is more sensitive to the most abundant species than the rare species.

Following relations were used to calculate Simpson's (D) and Shannon- Wiener (H') indices. $H' = -\sum p\text{i} \times ln p\text{i}$

Where,

H' = Shannon's diversity index,

Pi = species proportion (based on species count)

ln = natural logarithm.

Simpson's Index (D) = $\sum \text{pi}^2$

Where,

$\sum \text{pi}^2 = (\text{n/N})^2$

N = number of individuals in the n^th^ species,

N = the total number of individuals of all the species,

Evenness Index (Ep): For calculating the evenness of species, the Pielou's Evenness Index (Ep) was used (Pielou, 1966).

$$Ep = H' / \ln S$$

Where,

H' = Shannon – Wiener diversity index.

S = total number of species in the sample.

ln = natural logarithm.

Similarity and dissimilarity indices were calculated by using formulae as per Mishra, (1989) and Sorensen, (1948) which are as follows:

Index of similarity (S) =2C/A+B

Where,

A = Number of species in the community A,

B = Number of species in a community B, and

C = Number of common species in both communities,

Statistical analysis

Shapiro-Wilk test for normality and Spearman's correlation test was done using SPSS to find level of significance as well as correlation between elevation and species diversity parameters. Species diversity along elevation was compared in two ways; firstly, Species numbers present within 100 m interval were recorded making 12 intervals against altitude. For this data sheet was made up of number species present in each quadrat along with respective elevation. Most of the graphical representation was made using MS-Excel.

CHAPTER FOUR

RESULTS

Family and Genera composition

A total of 46 pteridophytes species were documented in Phulchoowki Hill, belonging to 28 genera and 14 families; which were distributed between 1500 masl and above 2700 masl elevation. Among the 46 species collected, 39 species of terrestrial and 7 species of epiphytic pteridophytes were observed (Figure 3). On the basis of genera among 14 families, Polypodiaceae was the largest family that contained six genera and six species followed by Pteridiaceae containing five genera and fourteen species (Appendix 2). Similarly, families like Athyriaceae Dennstaedtiaceae Dryopteridaceae Gleicheniaceae Lindsaeaceae contain two genera however remaining families were mono-generic (Appendix 2). However, on the basis of species Pteridiaceae was found largest family followed by Dryopteridaceae (Figure 4).

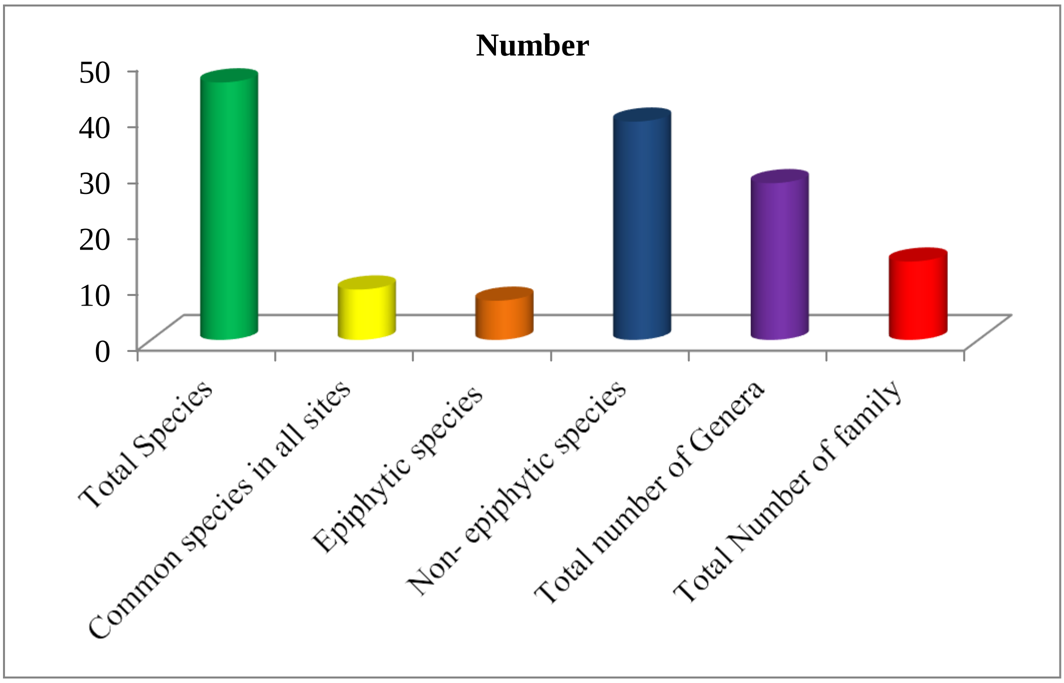

Figure 3: Total distribution of pteridophytes in the study site.

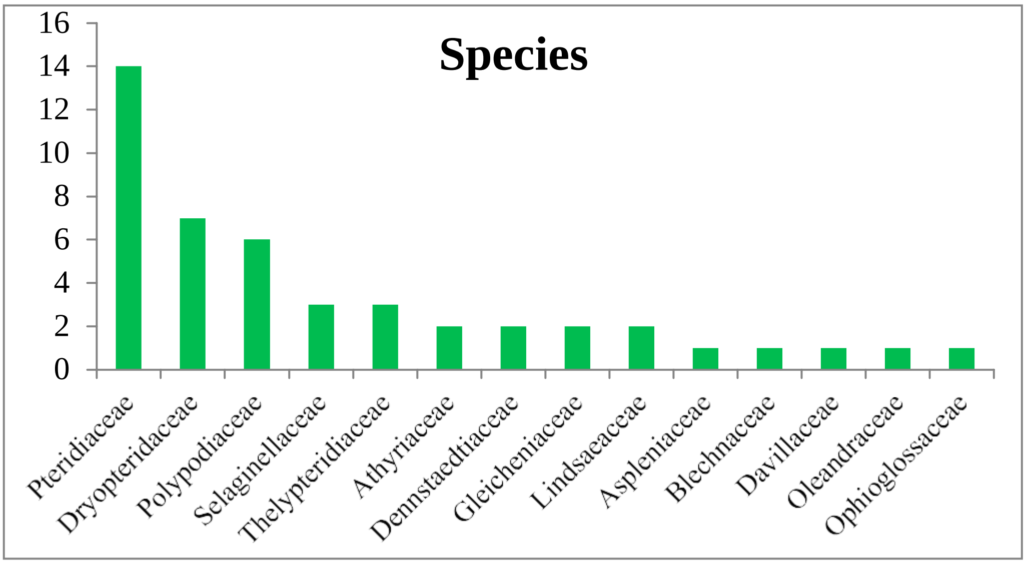

Figure 4: Total number of species belonging to each family.

Description of Pteridophytes from the study site

The distinguishing characters of each species of pteridophytes of different families are given below.

1. Aspleniaceae

Asplenium yoshinagae Makino subsp. *indicum*. (Sledge) Fraser-Jenk

A small tufted, reduced rhizome narrow fronded species with a slightly scaly stipe and rachis, narrow, acute apex pinnae, more or less deeply lobed on their acroscopic side, into narrow paired lobes with longish acute teeth.

Distribution: It is reported from different districts of Terai like Kailali and from far western, central and eastern part of hilly and Himalayan districts.

In the study site it was collected at altitude**:** 2222 m, **La. /Long.:** 27° 34' 42.7"" N / 85° 23' 35.6" E. **Ecology:** epiphyte, found on the *Rhododendron* tree, in a shady area, lower temperate mixed forest. **Voucher specimen**: **Collection Date:** 17/07/2075, **Col. No.: 004(**TUCH**).**

2. Athyriaceae

Athyrium foliolosum T. Moore *ex* R. Sim

It is small to medium sized species about 50 cm, fertile from c. 10 cm upwards, when it has a narrow, rhizome thick, short, erect, often clumped, with a loose crown of apical fronds, pinnules asymmetrical with longer, wider lobes at their acroscopic base.

Distribution: reported from Doti, Dailekh of FW, Jajarkot, Dailekh of midwestern region, Dolkha, Nuwakot, Tanahu, Gorkhaetc of CN region and Solukhumbu, Sankhuwasabha of Eastern region.

In the study site it was collected from altitude 2300-2400m, **La. /Long.:** 27° 34' 47.7'' N / 85° 35' 46" E. **Ecology:** shady places, mixed forest. **Voucher specimen**: **Collection Date:** 28/6/2076, **Col. No.: 14(**TUCH**).**

Diplazium* sub*spectabile (Ching & W.M. Chu) Z.R. He

Plant is evergreen, large (ca.150), rhizome massive, creeping, robust, up to 3 cm in diameter, with dense loose scales at apex, rhizome with apical crown of several fronds, stipe long, pale yellowish, pinnae overlapping, pinnules long, glabrous, pinnules lobe varies rectangular to rounded, sori brownish covers whole pinnules.

Distribution: reported from FW, MW, WN, CN and EN part of hilly and Himalayan region.

In the study site: collected from altitude 2020 m, **La. /Long.:** 27° 34' 59.7'' N / 85° 35' 43" E. **Ecology:** Near stream, Alnus sp., *Juglans* sp. mixed upper sub-tropical forest. **Voucher specimen**: **Col. Date:** 05/07/2075, **Col. No.: 16(**TUCH**).**

3. Bleachnaceae

Woodwardia unigemmata (Makino) Nakai

It is the jewelled chain evergreen fern. It can grow 1.5 m (4.9 ft) tall by 2.5 m (8.2 ft) broad, it bears pinnately divided fronds which emerge red and turn to green when mature.

In the study site: collected from altitude 2100-2200 m, **La. /Long.:** 28° 31' 24'' N / 82° 34' 50" E. **Ecology:** In the moist shady area, near water resources, mixed forest to temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 30(**TUCH**).**

4. Davalliaceae

Kotoella pulchra (D.Don) Fraser-Jenk, Kandel & Pariyar

Distribution.: reported from western to central and eastern districts of hilly region in Nepal.

In the study site: collected from altitude 2000-22000 m, **La./Long.:** 28° 32' 27'' N / 82° 35' 10" E. **Ecology:** In the moist shady area, near water resources, mixed forest to temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 43(**TUCH**).**

5. Dennstaedtiaceae

Denstaedtia appendiculata (Wall. *ex* Hook.) J. Sm.

Its rhizome is thick, semi erect, forming clumps, stipe tufted, starminous, fronds erect, narrowly lanceolate, lamina herbaceous, pinnules apices narrowly rounded, sori terminal at the lobe apices.

Distribution: reported from Darchula, Bajhang of FW region, Dolkha, Nuwakotetc of CN region and Dhankuta, Morang etc of Eastern region.

In the study site collected from altitude 1500-1600 m, 1800-1900 m, **La. /Long.:** 27° 34' 47.7'' N / 85° 35' 46" E. **Ecology:** shady places, mixed forest. **Voucher specimen**: **Collection Date:** 28/6/2076, **Locality:** Phulchowki Hill, Lalitpur, **Collector:** Anita Madhikarmi, **Col. No.: 111(**TUCH**).**

Microlepia platyphyllla (D.Don) J. Sm**.**

It is fairly common, very distinctive large species, with triangular-lanceolate, bipinnate-tripinnated fronds, rectangular pinnules, sori, sub-marginal.

Distribution: reported from Darchula, Bajhang of FW region, Dolkha, Nuwakot etc of CN region and Dhankuta, Morang etc of Eastern region.

In the study site collected from altitude 1800-1900m, **La. /Long.:** 27° 34' 47.7'' N / 85° 35' 46" E. **Ecology:** shady places, mixed forest. **Voucher specimen**: **Collection Date:** 28/6/2076, **Col. No.: 10(**TUCH**).**

Pteridium revolutum (Blume) Nakai

It can grow up to 1 m tall, it has long creeping rhizome, fronds sub leathery when dried, hard Lamina margins often revolute, stipe straw-colored or brown, 35-50cm, 5-8 mm in diameter, pinnules, opposite or alternate, spreading, sessile, lanceolate, base truncate, not adnate to costule.

Distribution.: reported from western to central and eastern districts of hilly region in Nepal.

In the study site: collected from altitude 1500-2300m, **La./Long.:** 28° 32' 27'' N / 82° 35' 10" E. **Ecology:** In the moist shady area, near water resources, mixed forest to temperate region. **Voucher specimen**: **Coll. Date:** 19/07/2075, **Coll. No.: 25(**TUCH**).**

6. Dryopteridaceae

Dryopteris juxtaposita Christ

Fronds bipinnate up to c. 100 cm, long narrowly lanceolate pinna, pale brown scales at very base, pinnules c. 20 pairs, deeply lobed pinnules with more acute apices, sori small in two rows, indusiate, indusial slightly curved.

In the study site: collected altitude 1500 – 1600 m**,** 1700 -1900 m, **La. / Long.:** 27° 34' 24'' N / 85^0 34' 59.8" E. **Ecology:** In the moist shady area, near water resources, mixed forest to temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 50 (**TUCH**).**

Dryopteris carolihopei Fraser-Jenk

Frond stipinnate up to c. 120 cm, long narrowly lanceolate pinna, pale brown scales at very base, pinnae c. 20 pairs and pinnules up to 22 pairs, deeply lobed pinnules with more acute apices, sori small, not crowded, in two rows, shriveling markedly.

In the study site: collected altitude 1500 – 1600 m**,** 1700 -1900 m, **La.** /*D* **Long.:** 27° 34' 24'' N / 85° 34' 59.8" E. **Ecology:** In the moist shady area, near water resources, mixed forest to temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 113(**TUCH**).**

Polystichum lentum (D.Don) T. Moore

Fronds up to c. 40 cm, with large bud, which often bears small frond itself near the frond apex, stipe base densely covered with ovate, serrulate, scales, pinnae markedly lobed with narrow lobes, sori 1-4 per lobe.

In the study site: collected altitude 1500-1600 m**,** 1700 -1900 m, **La. /Long.:** 27° 34' 24'' N / 85° 34' 59.8" E. **Ecology:** In the moist shady area, near water resources, mixed forest totemperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 007 (**TUCH**).**

***Dryopteris* sp**.

Commonly called wood fern, male fern or buckler fern, the sori are round, with a peltate indusium. The stipes has prominent scales.

Distribution: reported from western to central and eastern districts of hilly region in Nepal.

In the study site: collected from Nangkhola. **Alt.:** 1800-2000 m, **La. /Long.:** 28° 32' 27'' N / 82° 35' 10" E. **Ecology:** In the moist shady area, near water resources, mixed forest to temperate region. **Voucher specimen**: **Coll. Date:** 05/07/2075, **Col. No.: 115(**TUCH**).**

Polystichum obliquum (D. Don) T. Moore

It is evergreen Pteridophyte, rhizome erect, short, densely scaly apically, scales reddish brown, membranous, central part of scales hardened and bright castaneous, ovate-lanceolate, pinnae short, ovate-oblong, alternate, serrate margin, indusium conspicuous, large spores. **Distribution**: districts of hilly and Himalayan region like Jumla and from western Bajura to central Ramechhap.

In the study site it was collected from altitude 1900 - 2000 m, **La./Long.:** 27° 34'52.7'' N / 85° 23' 8.7" E. **Ecology:** partially moist places, near rocks, in the mixed forest of *Juniperus* and *Quercus*, upper temperate forest.**Voucher specimen**: **Collection Date:** 17/07/2075, **Col. No.: 24 (**TUCH**).**

Polystichum squarrosum (D.Don) Fée

Plant having rhizome erect, densely covered with broadly lanceolate brown scales, fronds 50-80 cm tall, stipe densely scaly; scales brown or reddish brown, ovate and linear, basal stipe scales dark brown at middle, wide lamina bi-pinnate, pinnae alternate, slightly ascendant, linear-lanceolate or broadly lanceolate, pinnules 8-18 pairs, alternate, slightly ascendant, approximate, sori are found on the tip of pinnules.

Distribution: reported from far western regions Dadeldhura, different hilly and Himalayn districts of Mid-western (MW), Western, central and hilly region.

In the study site it was collected from altitude 2200-2500 m, **La./Long.:** 27° 34' 52.7'' N / 85° 23' 8.7" E. **Ecology:** moist places, in the mixed forest of *Quercus*, lower temperate forest. **Voucher specimen**: **Collection Date:** 17/07/2075, **Col. No.: 71 (**TUCH**).**

Polystichum discretum (D. Don)

Well lobed pinnules, stipe and rachis scales are narrowly lanceolate, lamina alternate, ovate, pinnae alternate, shortly stalked pinnules somewhat long, acroscopic bases with rounded auricles, sori 5-8 pairs per pinnules.

Distribution: far western (FW) Darchula to districts of Himalayan regions like Jumla, Mugu and different districts of central and eastern region.

In the study site it was collected from altitude 1900 -2400 m, **La. /Long.:** 27° 34' 52.7'' N / 85° 23' 8.7" E. **Ecology:** partially moist places, in the mixed forest of *Quercus*, temperate forest. **Voucher specimen**: **Collection Date:** 17/07/2075, **Col. No.: 27(**TUCH**).**

7. Gleachniaceae

Dicranopteris lanigera (D. Don) Fraser-Jenk.

It's underground long, thin and straight, with spaced out erect, stiff, smooth stipes and bush like above with dichotomous branching near the frond apices, frond alternate, longer and short branches further, sori round, exendusiate in single line on each side of the segment mid-rib.

Distribution: reported from Doti, Dailekh of FW, Jajarkot, Dailekh of mid-western region, Dolkha, Nuwakot, Tanahu, Gorkhaetc of CN region and Solukhumbu, Sankhuwasabha etc of Eastern region.

In the study site collected from altitude 2300-2400m, **La. /Long.:** 27° 34' 47.7'' N / 85° 35' 46" E. **Ecology:** shady places, mixed forest. **Voucher specimen**: **Collection Date:** 28/6/2076, **Col. No.: 14(**TUCH**).**

Diploterigium giganteum (Wallich ex Hook. & Bauer) Nakai

Rhizome long, straight, underground, as thick as a finger, bearing tall, smooth, hard stipes, as thick a little finger, at intervals and thus forming tall. Fronds very (about 2 m tall), bifurcated apically, opposite, bipinnatifid to bipinnate pinnae arising beside a large, curled terminal, lamina slightly pale – glaucous beneath, dark green above; each lobe bearing a line of exindusite round, yellow to brown sori on each side of the midrib.

Distribution: reported from FW, MW, WN, CN and EN part of hilly and Himalayan region.

In the study site: collected from 2020 m, **La. /Long.:** 27° 34' 59.7'' N / 85° 35' 43" E. **Ecology:** Near stream, *Alnus* sp, *Juglans* sp. mixed upper sub-tropical forest. **Voucher specimen**: **Col. Date:** 05/07/2075, **Col. No.: 16(**TUCH**).**

8. Lindsaeaceae

Lindsaea odorata Roxb.

A small, simply pinnate species, stipe straminous, lower surface of lower rachis and upper stipe rounded, not quadrangular, fronds always simply pinnate, sori opening outwards, varying considerably in size but usually fertile in all stages, pinnae symmetrically semi lunate.

Distribution: reported from FW Kailali, CN parts like Rasuwa, Kathmandu, Lalitpur, Bhaktapur, Ramechhap etc.

In the study site: it was collected from 1900-2000 m, 2100-2200 m, **La./Long.:** 28° 33' 85'' N / 82° 35' 21" E. **Ecology:** mixed forest, temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 61 (**TUCH**).**

Odontosoria chinensis (L.) J. Sm.

Plants 45-80 cm tall or more, subterranean and long creeping rhizomes ca. 4 mm in diameter, fronds developed separately, branched, stipe erect usually brown to chestnut-brown, lamina 3-4 pinnate, ultimate pinnules or segments mostly 7-10 mm, sori covers almost whole part of pinnules.

Distribution: reported from different part of central (CN) and eastern (EN) region.

In the study site it was collected from altitude 2200-2300 m, **La./Long.:** 27° 34' 42.7'' N / 85° 23' 35.6" E. **Ecology:** partially dry places, above rocky surfaces, mixed forest of *Quercus*, *Lyonia*, Rhododendron upper temperate forest. **Voucher specimen**: **Collection Date:** 17/07/2075, **Col. No.: 008 (**TUCH**).**

9. Oleandraceae

Oleandra wallichii (Hook.) C. Presl

Long creeping rhizome, freely branching, branches often opposite, hairy scales, white waxy under scales, roots restricted to ventral side, fronds scattered or in small tufts, lamina greenish brown when dry, lanceolate, both surface hairy, sori close to costa.

In the study site: collected 2200m, **La./Long.:** 28° 32' 15'' N / 82° 24' 58" E. **Ecology:** epiphyte, on the moist surface, mixed forest, temperate region. **Voucher specimen**: **Coll. Date:** 19/07/2075, **Coll. No.: 23(**TUCH**).**

10. Ophioglosaceae

Botrychium lanuginosum Wall. e*x* Hook. & Grev.

Possess rhizomes erect, short, apex hairy; hairs long, light brown, common stipes stramineous to light brown, 12-30 cm, 3-6 mm in diam., fleshy; hairs sparse, whitish, long, sterile lamina 3 or 4 pinnate, deltoid to sub pentagonal, thin and herbaceous, degree of pubescence variable, pinnules 6-10 pairs, alternate, stalked, basiscopic pinnules larger than acroscopic ones, basal pinnule largest, sori throughout abaxial surface of pinnae; indusia dark, margins entire.

In **the study site:** collected from 2300-2400 m. **La. /Long.:** 28° 33' 85'' N / 82° 35' 21" E. **Ecology:** moist places, *Quercus* sp. mixed forest, temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 106(**TUCH**).**

11. Polypodiaceae

Drynaria mollis Bedd.

Having rhizome creeping, scales soft, tufted, fronds dimorphic, hairy, basal fronds sessile, lower side of costa slightly hairy and with small scales at base, foliage fronds, stalked, stipe-conspicuously winged, lamina pinnatifid, pinnae 15-18 pairs, spreading, lanceolate, margin entire, densely ciliate, obtuse apex, sori in 1 straight row between costa and margin.

Distribution: reported from FW, MW, WN, CN and EN districts of hilly and Himalayan region. ER, Collected from altitude 1500 – 2300 m, **Coll. No.: 105 (**TUCH**).**

Goniophlebium argutum (Wall. *ex* Hook) Bedd.

Reduced rhizome with long hairy branched roots, stipe and rachis glabrous, pinnae sessile, leafy, acute apex, sori inside the rectangular box, which appear linear from lower to upper part.

Distribution: reported from FW, WN, CN and EN districts of hilly and Himalayan region.

In the study site: Lawaremare, **Alt.:** 2108 m, **La. /Long.:** 28° 32' 15'' N / 82° 24' 58" E. **Ecology:** epiphyte on *Lyonia* sp. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 104 (**TUCH**).**

Loxogramme involuta (D. Don) C. Presl

Rhizome short, ascending to creeping, ca. 1.5 mm in diam., densely scaly; scales greyish brown, triangular, thin, margin entire, apex acuminate, fronds in apical tuft, monomorphic, stipe indistinct, or very short and winged, lamina abaxially paler, adaxially deep green, lanceolate, base attenuate and decurrent into stipe, apex caudate-acuminate, sori linear, 3-4 cm, very oblique, well-spaced, continuous from near costa to frond margin.

In the study site: It was collected from 1600-1700 m, 2100–2200 m, **La. /Long.:** 28° 32' 25'' N / 82° 34' 14" E. **Ecology:** epiphyte, mixed forest, temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 37 (**TUCH**).**

Polypodiodes hendersonii (Bedd.) Fraser-Jenk

Distribution.: reported from western to central and eastern districts of hilly region in Nepal.

In the study site: collected from 1700-1800 m, 1900-2300 m, 2500-2700 m **La. /Long.:** 28° 32' 27'' N / 82° 35' 10" E. **Ecology:** In the moist shady area, near water resources, mixed forest to temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 110(**TUCH**).**

Pichisermollodes quasidivaricata (Hayata) Fraser-Jenk.

It has rhizome slender, woody, densely scaly; scales reddish brown, brown, dark brown, or nearly black, rarely whitish, opaque, ovate-lanceolate or lanceolate, branched roots are developed in group, stipe long glabrous, rachis long with jointed pinnae, pinnateley compound, lanceolate pinnae with acute apex, dentate margin.

Distribution: reported from FW, WN, CN and EN districts of hilly and Himalayan region.

In the study site: collected from altitude2108 m, **La. /Long.:** 28° 32' 15’’ N / 82° 24’ 58” E. **Ecology:** epiphyte on *Lyonia* sp., *Quercus* sp.**V. S.**: **Coll. Date:** 18/07/2075, **Coll. No.: 42 (**TUCH**).**

12. Pteridaceae

Adiantum capillus veneris L.

It grows from 15 to 30 cm in height, forms extensive colony, its fronds arising in clusters from creeping rhizomes, 20 to 70 cm tall, pinnae compound with small rounded segments narrowing symmetrically to connate bases, apical margin of pinnae deeply lobed into rounded rectangular lobe, white sori are present at the top of lobe of the pinnae. **Distribution**: reported from central and eastern part of hilly and terai region.

In the study site it was collected from altitude1700-1900 m, **La. /Long.:** 27° 34' 52.7’’ N / 85° 22’ 54.6” E. **Ecology:** moist places, in the *Alnus* forest, upper sub-tropical zone. **Voucher specimen**: **Collection Date:** 17/07/2075, **Col. No.: 72(**TUCH**).**

Adiantum venustum D.Don

It is the evergreen maiden hair or Himalayan maidenhair fern. Black-smooth stipe and rachis, branched, rounded and umbrella like pinnae, pinnae with stalk, teeth like structures in the margin of pinnae, sori present at the tip middle of pinnae.

Distribution: reported from FW part Darchula, Dadeldhura to Himalayan districts Humla, also from different part of central and eastern hilly and Himalayan region.

In the study site it was collected from altitude 1700-1900 m, **La. /Long.:** 27° 34' 52.7’’ N / 85° 23’ 35.6” E. **Ecology:** moist places, near streams, in the *Alnus* forest, upper sub-tropical region. **Voucher specimen**: **Collection Date:** 17/07/2075, **Col. No.: 73(**TUCH**).**

Adiantum philippense L. subsp. ***philippense***

It also known as walking maidenhair fern, or black maiden hair. Delicate, pinnate, stipe thin, glossy black, glabrous, rachis blackish, lamina alternate, semicircular pinnae with shallow lobe, sori elongated around the distal end of pinnae.

Distribution: reported from FW, central and eastern part of Terai, hilly and Himalayan region.

In the study site it was collected from altitude 1700-2100 m, 2200-2500 m. **La. /Long.:** 27° 33' 85'' N / 85° 23' 35.6" E. **Ecology:** partially dray places, under rocky surfaces, mixed forest of *Quercus, Lyonia*, upper temperate forest. **Voucher specimen**: **Collection Date:** 17/07/2075, **Col. No.: 100(**TUCH**).**

Onychium lucidum (D.Don) Spreng

Plants 45-80 cm tall or more, subterranean and long creeping rhizomes ca. 4 mm in diameters, fronds developed separately, branched, stipe erect usually brown to chestnut-brown, lamina 3-4 pinnate, ultimate pinnules or segments mostly 7-10 mm, sori covers almost whole part of pinnules.

Distribution: reported from different part of central (CN) and eastern (EN) region.

In the study site it was collected from altitude 2200-2300 m, **La./Long.:** 27° 34' 42.7'' N / 85° 23' 35.6" E. **Ecology:** partially dry places, above rocky surfaces, mixed forest of *Quercus*, *Lyonia*, Rhododendron upper temperate forest. **Voucher specimen**: **Collection Date:** 17/07/2075, **Col. No.: 008(**TUCH**).**

Aleuritopteris bicolor (Roxb.) Fraser-Jenk.

It is the main silver fern called Rani Sinka. Posses' smooth stipe used to plug ear piercing holes without infection, stipe long, thin dark purplish brown with very narrow, biclorous scales confined to narrow base and non on the upper stipe, rachis, and costae. Lamina markedly deltate, pentagonal, the lowest pinnae longest, lobed, pale, often yellowish green. **Distribution**: reported from FW, CN and EN part of Terai, hilly and Himalayan region.

In the study site collected from altitude 2200-2300, 2400-2500 m, **La. /Long.:** 27° 34' 43'' N / 85° 23' 35.6" E. **Ecology:** partially dry places, above and under rocky surfaces, mixed forest of *Quercus* Rhododendron lower temperate forest. **Voucher specimen**: **Collection Date:** 17/07/2075, **Col. No.: 101(**TUCH**).**

Aleuritopteris albomarginata (C.B. Clarke) Ching

Rhizome erect, short; scales bicolorous, black with broad, pale margins, lanceolate, fronds clustered, stipe dark brown, lustrous, scaly; scales black or dark brown, with conspicuous lighter margins, broadly lanceolate, lamina oblong-deltoid to deltoid, sori marginal. **Distribution**: reported from FW, CN and EN part of Terai, hilly and Himalayan region.

In the study site collected from altitude 2200-2300, 2400-2500 m, **La. /Long.:** 27° 34' 43'' N / 85° 23' 35.6" E. **Ecology:** partially dry places, above and under rocky surfaces, mixed forest of *Quercus* Rhododendron lower temperate forest. **Voucher specimen**: **Collection Date:** 18/07/2075, **Col. No.: 102 (**TUCH**).**

***Pteris cretica* sub sp cretica** L.

Dimorphic frond, the lamina with 2-3 pairs of linear pinnae, impair pinnate, long stipe and rachis without scales, pinnae long and lanceolate, sori throught the pinnae.

Distribution: reported from Bajhang, Mustang, Gorkha, Tehrathum of W, CN and EN region.

In the study site collected from altitude 1700-1800 m, 2100-2200 m, 2500-2600m **La. /Long.:** 27° 34' 47.7'' N / 85° 35' 46" E. **Ecology:** shady places, mixed forest. **Voucher specimen**: **Collection Date:** 18/07/2075, **Col. No.: 007 (**TUCH**).**

Pteris aspericaulis Wall. *Ex* J. Agardh

It is terrestrial herb. It is compound *Pteris*, erect rhizome, stipe and rachis varies in color, lamina long, lower lamina with 2-3 pairs of pinnae with single or sometimes with accessory pinnules, sori on the lobe arch of pinnules.

Distribution: reported from FW, MW, CN and EN part of hilly and Himalayan region.

In the study site collected from altitude1700-1800m, 2100-2200m, 2500-2600m **La. /Long.:** 27° 34' 47.7'' N / 85° 35' 46" E. **Ecology:** shady places, mixed forest. **Voucher specimen**: **Collection Date:** 18/07/2075, **Col. No.: 009 (**TUCH**).**

Pteris terminalis Wall. *ex* J. Agardh

Plants extends up to 180 cm tall, rhizome erect, short, robust, to 2 cm in diam., woody, apex with black-brown scales, fronds clustered, stipe dark brown, upper part straw-colored, slightly lustrous, firm, robust, upper part glabrous, rachis straw-colored, pinnati partite, broadly triangular, pinnae alternate or sub-opposite, basal pinnae longest, upper pinnae, smaller sessile, sori marginal.

Distribution: reported from FW, like Darchula and Doti, CN like Baglung and Rasuwa and EN Tapljung.

In the study site: collected from altitude 2100-2200m **La. /Long.:** 27° 34' 59.7'' N / 85° 35' 43" E. **Ecology:** mesophytic, in open barren places, lower temperate forest. **Voucher specimen (V.S.)**: **Collection Date:** 18/07/2075, **Col. No.: 103(**TUCH**).**

Pteris biaurita L.

It is a large and robust compound species, stipe green becoming straminous on drying, occasionally becoming fairly extensively dark brown, lamina wide, herbaceous pale green, pinnae costate.

Distribution: reported from Ilam, Taplejjung, Tehrathum, Panchthar of EN and some part of central region.

In the study site collected from altitude 1700-1800m, 2100-2200m, **La. /Long.:** 27° 34' 47.7'' N / 85° 35' 46" E. **Ecology:** shady places, mixed forest. **Voucher specimen**: **Collection Date:** 28/06/2076, **Col. No.: 15(**TUCH**).**

Pteris stenophylla Wall. *ex* Hook. & Grev.

It is a medium dactylate *P*teris with few pinnae or segments; stipe crowded straminous; thin, lamina digitate with 3-5 segments, margins entire in both sterile and fertile fronds. **Distribution**: reported from Palpa, Parbat, Tanahu, Kathmandu central region.

In the study site collected from altitude 1500-1600m, 2100-2200m, **La. /Long.:** 27° 34' 47.7'' N / 85° 35' 46" E. **Ecology:** shady places, mixed forest. **V.S.**: **Collection Date:** 28/6/2076, **Col. No.: 13(**TUCH**).**

Coniogramme affinis Hieron.

It is long creeping species, somewhat thick underground rhizome, fronds up to 70 cm tall, stipe fairly robust, glabrous, and sori running along the veins in crowded, parallel lines from near the midrib.

Distribution: reported from Darchula of FW region, Dolkha of CN region and Dhankuta. Panchthar, Jhapa of eastern region.

In the study site collected from altitude 1500-1600 m, 1800-1900m, **La. /Long.:** 27° 34' 47.7'' N / 85° 35' 46" E. **Ecology:** shady places, mixed forest. **Voucher specimen**: **Collection Date:** 28/6/2076, **Col. No.: 12(**TUCH**).**

Coniogramme puberula Hieron.

It is large and distinctive species, robust stipe, deltate, dark green frond, widest at the base, sori exendusiate forming rather short lines along the veins.

Distribution: reported from Darchula of FW region, Dolkha of CN region and Dhankuta. Panchthar, Jhapa of eastern region.

In the study site collected from altitude 1500-1600 m, 1800-1900 m, **La. /Long.:** 27° 34' 47.7'' N / 85° 35' 46" E. **Ecology:** shady places, mixed forest. **Voucher specimen**: **Collection Date:** 28/6/2076, **Col. No.: 58 (**TUCH**).**

***Pteris* sp**.

Plants extends up to 180 cm tall, rhizome erect, short, robust, to 2 cm in diam., woody, apex with black-brown scales, fronds clustered, stipe dark brown, upper part straw-colored, slightly lustrous, firm, robust, upper part glabrous, rachis straw-colored, pinnati partite, broadly triangular, pinnae alternate or sub-opposite, basal pinnae longest, upper pinnae, smaller sessile, sori marginal.

Distribution (Dist.): reported from FW, like Darchula and Doti, CN like Baglung and Rasuwa and EN Tapljung.

In the study site: collected from altitude 2100-2200 m **La. /Long.:** 27° 34' 59.7'' N / 85° 35' 43" E. **Ecology:** mesophytic, in open barren places, lower temperate forest **Voucher specimen**: **Collection Date:** 18/07/2075, **Col. No.: 103(**TUCH**).**

13. Sellaginaceae

Sellaginella pallida Hook. & Grev**.**

Leaves become further apart towards the base of the stem, lateral leaves minutely denticulate acroscopically, sporophyll dimorphic, slightly apart megasporophylls forming a narrow central region.

Distribution: reported from FW Darchula, MW Jumla along with different parts central and eastern parts.

In the study site: almost in all quadrats, collected from 1600- 2100 m, **La. /Long.:** 28° 33' 59'' N / 82° 35' 15" E. **Ecology:** In the moist shady area, mixed forest from upper subtropical to upper temperate region. **V. S.**: **Coll. Date:** 18/07/2075, **Col. No.:**011**(**TUCH**).**

Sellaginella chrysocaulos (Hook. & Grev.) Spring

Delicate erect stems, growing from single small, basal tuberous bulbil, it is up to 5 cm long, leaves become further apart towards the base of the stem, lateral leaves minutely denticulate acroscopically, sporophyll dimorphic, slightly apart mega sporophylls forming a narrow central region.

Distribution: reported from FW Darchula, MW Jumla along with different parts central and Eastern parts.

In the study site: almost in all quadrats, **Alt.:** 1600-2600 m, **La. /Long.:** 28° 33' 59'' N / 82° 35' 15" E. **Ecology:** In the moist shady area, mixed forest from upper subtropical mto upper temperate region.**V. S.**: **Coll. Date:** 18/07/2075, **Col. No.:**107**(**TUCH**).**

Sellaginella subdiaphana (Wall. ex Hook. & Grev.) Spring

Stems 5–25 cm, evergreen or seasonally green, erect, with elongate tuber at base. Main stems branched from near base or from lower part upward, in basal part main stem 0.5–1 mm in diameter.

Distribution: reported from FW Darchula, MW Jumla along with different parts central and Eastern parts.

In the study site: almost in all quadrats, **Alt.:** 1600-2000 m, **La. /Long.:** 28° 33' 49'' N / 82° 36' 15" E. **Ecology:** Epiphyte, found on the Rhododendron tree, in moist area lowered tempered mixed forest. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Locality:** Phulchowki Hill, Lalitpur **Collector:** Anita Madhikarmi, **Col. No.:**104**(**TUCH**).**

14. Thelypteridaceae

Thelypteris dentate (Forssk.) E.P. St. John

Rhizome thick, shortest-creeping, often with slightly ascendant apex, fronds borne together at the apex, lamina varying from tapering below to more typically slightly shorter at its base, pinnae lobed to about their half depth, sori brown, linearly placed on the surface of pinnae. **In the study site:** collected from1700 -1900 m, **La. /Long.:** 28° 31' 24'' N / 82° 34' 50" E. **Ecology:** In the moist shady area, near water resources, mixed forest to temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 108 (**TUCH**).**

Thelypetris cana (J. Sm.) Ching

Rhizome thickish, long creeping, but sometimes becoming erect with a clump of tall rhizome, the next pinna up usually abruptly reduced down to short, bilobed flaps, pinnules narrow, slightly acute, sori sub marginal with hairy indusia.

In the study site: collected altitude 1500-1600 m**,** 1700 -1900 m, **La. /Long.:** 28° 31' 24'' N / 82° 34' 50" E. **Ecology:** In the moist shady area, near water resources, mixed forest to temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 005(**TUCH**).**

Thelypteris tyodes (Kunze) Ching

Rhizome thick, erect, with a loose basket of fronds; stipe long, with several alternate pairs, pinnae longest from the middle to base of the lamina, veins all free, sori medial or sometimes nearer the segment – midrib, indusiate.

In the study site: collected altitude 1500 – 1600 m**,** 1700 -1900 m, **La. /Long.:** 28° 31' 24'' N / 82° 34' 50" E. **Ecology:** In the moist shady area, near water resources, mixed forest to temperate region. **Voucher specimen**: **Coll. Date:** 18/07/2075, **Coll. No.: 017(**TUCH**).**

Community structure in three zones

The whole study side was site which includes sub tropical to temperate zone was resolved in three sub zones on the basis of elevation ranges.

Lower elevation zone (1500 - 1900 masl)

In this range *Dryopteris carolohopei* showed the highest frequency 81.82% and relative frequency 10.29%; followed by *Selaginella chrysocaulis* with 63.64% frequency and 8% relative frequency. The lowest frequency and relative frequency were 4.55% and 0.57% respectively (Appendix 3). Similarly, the importance value index (IVI) was found to be highest for *Selaginella chrysocaulas* (32.88) and followed by *Dryopteris carolohopei* (30.13), while the other species like *Aleuritopteris bicolar* and *Thelypteris dentata* showed least IVI 0.76 and 0.67 respectively (Appendix 3). In this range forest canopy was dominated *Schima wallichii*, *Castanopsis indica*, and *Alnus nepalensis* but sub-canopy was well dominated by *Melastoma malabaricum*, *Eurya acuminata* and *Symlocos* species. Altogether 28 pteridophyte species were recorded from this zone.

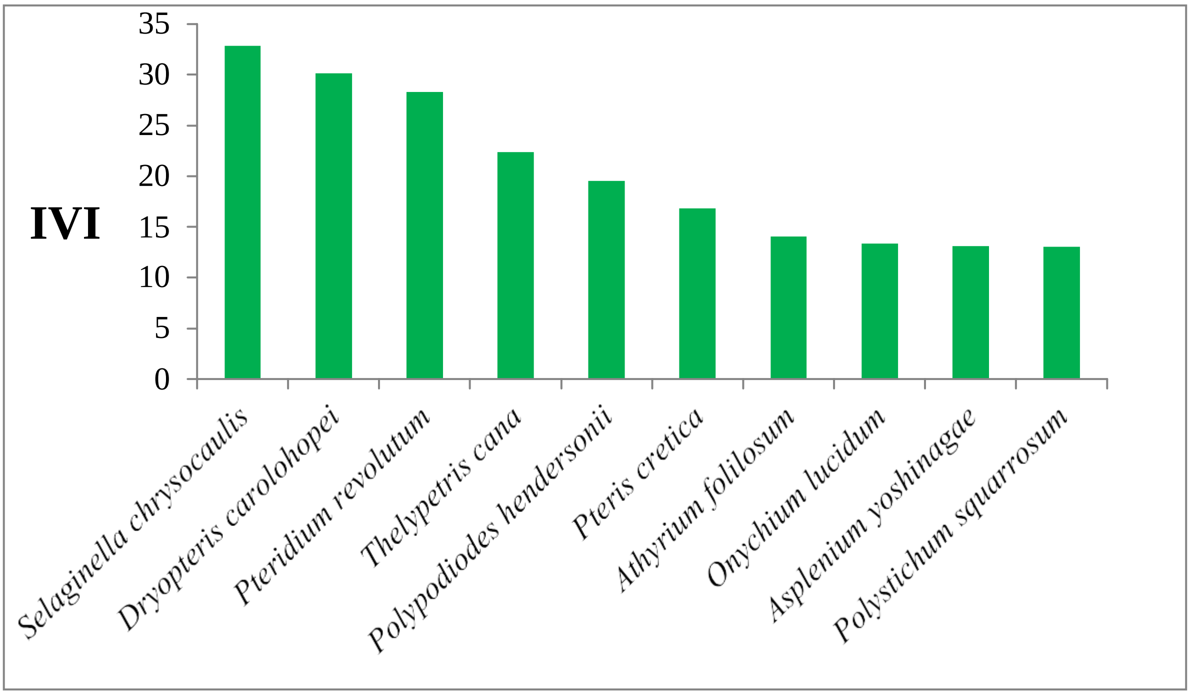

Figure 5: IVI of most dominant ten pteridophyte species at lower elevation zone.

Middle elevation zone (1900 - 2300 masl)

Polystichum squarrosum was the highest frequency was achieved as 93.10% and relative frequency 13.43%; followed by *Oleandra wallichii* and *Selaginella chrysocaulis* with similar value of frequency 65.52 and relative frequency 9.45 (Appendix 4). Similarly, the lowest frequency and relative frequency achieved as 3.45% and 0.5% respectively. Middle elevation zone is well dominated by *Polystichum squarrosum* with its highest IVI value 39.25 and co-dominated by *Drynaria mollis* (38.26) and the species such as *Thelypetris cana* and *Woodwardia unigemmata* showed very scanty presence with least IVI values 0.78 and 0.7 respectively (Appendix 4). In this zone *Quercus incana*, *Quercus glauca* and *Castanopsis tribuloides* formed the very well canopy up to 20 m. Consequently, *Crotalaria cytisoides*, *Osyris wightiana*, *Berberis aristata* made the sub canopy. Altogether 33 Pteridophytes species were recorded from this site.

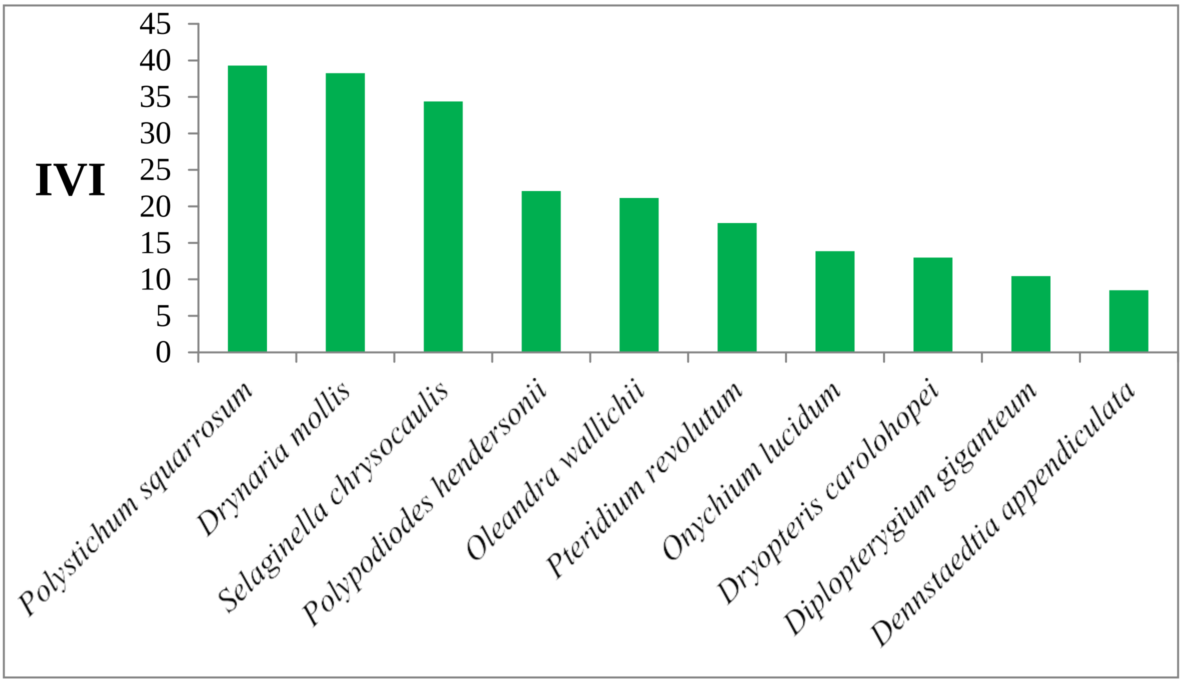

Figure 6: IVI of most dominant ten pteridophyte species in middle elevation zone.

Upper elevation zone (2300 - 2700 masl)

Polypodiodes hendersonii showed the highest frequency and relative frequency achieved as 75% and 14.15%. Likewise, the lowest frequency and relative frequency were 5% and 0.94% respectively were seen in *Onychium lucidum*. *Polypodiodes hendersonii* was well dominating species in this range with maximum IVI 68.08 and co-dominated by *Drynaria mollis* with IVI value 51.35 and *Pichisermollodes quasidivaricata* with IVI value 33.47 (Appendix 5). Other species like *Onychium lucidum*, *Pteris* sps and *Selaginella subdiaphana* showed scanty in distribution. In this site *Quercus semecarpifolia* was monodomianat canopy with plants up to 25 m high. Similarly, *Berberis asiatica, Rubus acuminatus, Arundinaria falcata* made the sub canopy, Altogether, 20 species of pteridophytes were recorded from this site.

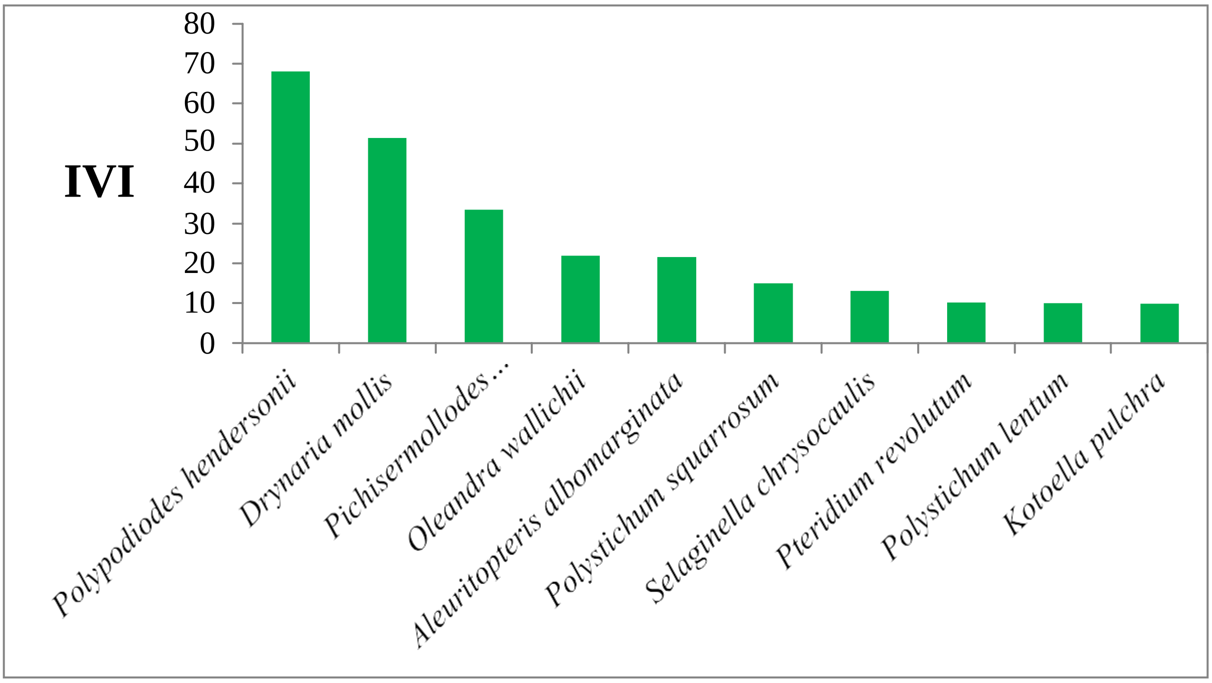

Figure 7: IVI of most dominant ten pteridophyte species in upper elevation zone.

Species Richness and Diversity Indices

Species richness of pteridophyte species was highest at middle elevation zone (33) and lowest at upper elevation zone (20) and lower elevation zone (20). Similarly, the Simpson's diversity index (D) was highest for stand upper elevation zone (0.174) followed by middle (0.118) and lower zone (0.077). Shanon-Weiner's index (H') was maximum for lower elevation zone (2.8) followed by middle (2.608) and upper zone (2.13). The evenness index value showed maximum value at lower elevation zone (0.84) followed by middle (0.746) and upper elevation zone (0.711) respectively (Table 1).

Table 1: Species richness (S), Shanon-weiner's index (H'), Simpson's Diversity index (D) and Evenness index (Ep) of three elevational zones.

Elevation Zone	Species richness (S)	Shannon Wiener diversity index (H')	Simpson's Diversity index (D)	Evenness index (Ep)
Lower	28	2.80	0.077	0.840
Middle	33	2.608	0.118	0.746
Upper	20	2.130	0.174	0.711

Similarity index between lower elevation zone & middle elevation zone was highest 59.016% while it was least between lower elevation zone and upper elevation zone 45.83% and 56.604% in between middle elevation and upper elevation zone (Table 2).

Table 2: Similarity index among three zones.

Index of Similarity (IS)	Middle elevation zone	Upper elevation zone
Lower elevation zone	59.016	45.83
Middle elevation zone		56.604

The highest level of diversity and species richness was recorded for middle elevation zone, followed by lower and upper elevation zone respectively (Table 3). Maximum value of species richness and Shannon Wiener diversity index was recorded in 2000-2100 masl (25 and 2.489), its value went on decreasing with the increasing in elevation 1600-1700 masl (19 and 2.441), 1700-1800 masl (16 and 2.427), 2100-2200 masl (19 and 2.255), and the least values were depicted at 2500-2600 masl (5 and 1.272). However, steady levels of species richness (12) were recorded at an altitudinal range of 1500-1600 masl and 1800 masl to 2000 masl respectively (Table 3). Evenness index was recorded with a maximum value of 0.888 at an elevation of 1800-1900 masl followed by 2600-2700 (0.884), 1700-1800 (0.875); Minimum value of Ep 0.561 was observed at elevation of 1900-2000 masl. Similarly, the maximum value for Simpson's diversity was recorded in elevation 1900-2000 masl (0.403). However, the values of Simpson's diversity indicated a uniform pattern (0.106 – 0.134) at an altitude of 1600 masl to 1900 masl, whereas a small peak in the values was observed at an altitude of 1900-2000 masl from where the values further fell (0.139 to 0.344). The minimum recorded value was 0.106 for lower elevation zone at an elevation of 1700-1800 masl (Table 3).

Table 3: Total species richness and diversity parameters of Pteridophyte along the elevational gradient.

Where, SR: Species Richness; D: Simpson's diversity index; H': Shannon-Weiner's diversity index and Ep: Evenness index.

Elevation Zone	Elevation (masl)	No. of Quadrats	SR	D	H'	Ep
Lower	1500-1600	5	12	**0.394**	1.48	0.595
	1600-1700	8	**19**	0.11	**2.441**	0.829
	1700-1800	5	16	0.106	2.427	0.875
	1800-1900	4	12	0.134	2.207	**0.888**
Middle	1900-2000	5	12	**0.403**	1.393	0.561
	2000-2100	8	**25**	0.139	**2.489**	0.773
	2100-2200	8	18	0.154	2.255	0.78
	2200-2300	8	12	0.166	2.045	**0.823**
Upper	2300-2400	5	**15**	0.214	2.025	0.748
	2400-2500	5	12	0.178	**2.042**	0.822
	2500-2600	5	5	**0.344**	1.272	0.79
	2600-2700	5	7	0.209	1.721	**0.884**

Species richness and diversity patterns of Pteridophyte species along increasing elevation

The results of Pteridophyte species richness showed a clear asymmetric hump-shaped relationship with elevation in the study area (Figure 8). Maximum pteridophyte species richness was recorded at the elevation of 2000-2100 masl (1639 individuals, 13 families, 19 genera, and 25 species), followed by that recorded at the elevation of 1600-1700 masl (1534 individuals, 7 families, 13 genera, and 19 species), 2100-2200 masl (1780 individuals, 11families, 17 genera, and 18 species) (Figure 8).

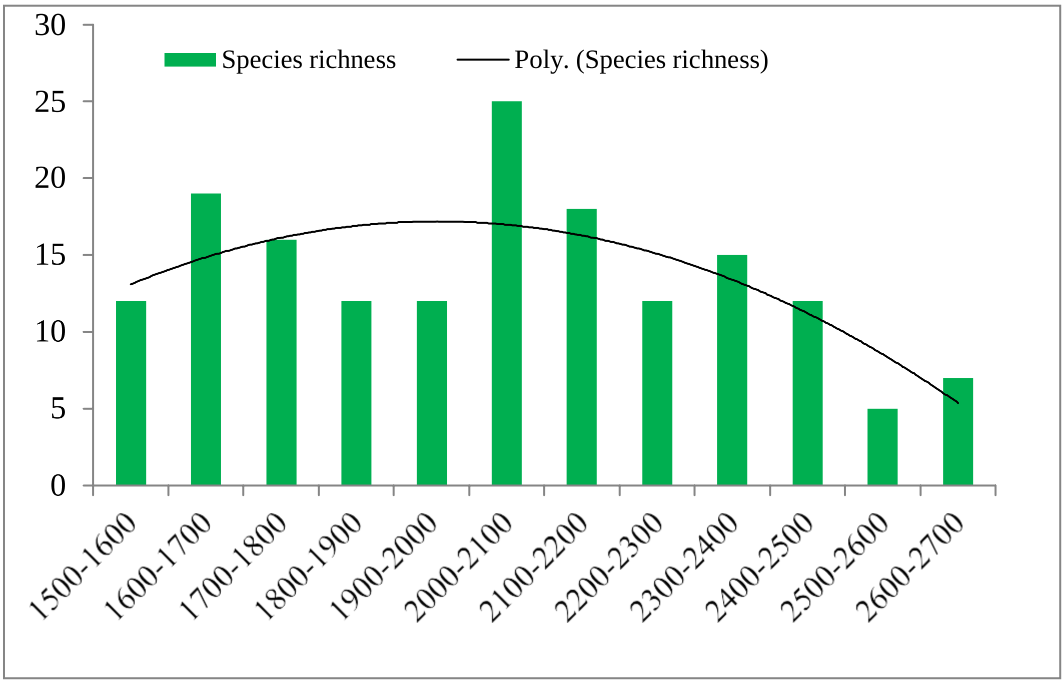

Figure 8: Relation of species richness along the elevational gradient.

Total species richness and diversity of pteridophyte followed an asymmetric hump-shaped pattern along the elevation gradient in all three elevation zone, and a fourth order polynomial regression showed the trend of the variation (Figure 9). Species richness and diversity were intermediate at lower elevations below 1900 masl, high between 1900 to 2300 masl in middle elevation zone, with the maximum value (25) observed at 2000-2100 masl. This value accounts for about 54.35 percent of the total number of plants found in studied area (Figure 8). Similarly, low value of species richness was observed in upper elevational zone (2300 - 2700 masl).

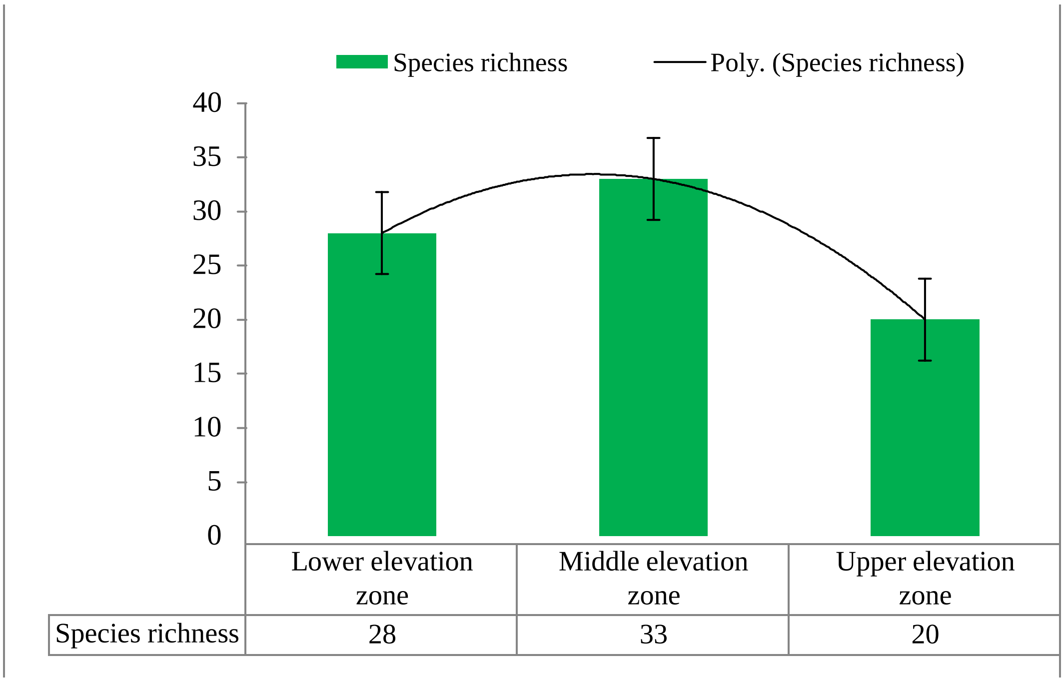

Figure 9: Species richness and distribution trend along the various levels of elevational zones of the study area.

Correlation analysis

Species were not normally distributed according to Shapiro-Wilk test for normality, so Spearman's correlation was done that showed elevation play an important role in regulating species richness. A negative relationship emerged when the richness of fern were related with the elevation through correlation analysis. The most significant relationship was species richness of pteridophytes that closely linked with Simpson's diversity index ($p < 0.01$ (Table 4). There was strong positive correlation of elevation with Simpson's index ($p < 0.01$) and significantly negative correlation with species richness ($p < 0.01$), and Shannon Weiner diversity index ($p < 0.01$) (Table 4). Similarly, Shannon Weiner diversity index and evenness index of pteridophytes also shows significantly negative correlation ($p < 0.01$) with Simpson's index. However, there was no any significant relationship between elevation and species richness with evenness index ($p > 0.01$) (Table 4).

Table 4: Spearman's correlation coefficient between different parameters

Abbreviations: SR=Species richness, D=Simpson's diversity index, H'=Shannon Wiener diversity index, EP=Evenness index.

		Elevation	SR	D	H'	Ep
Elevation	Correlation Coefficient	1.000				
	Sig. (2-tailed)					
	N	71				
SR	Correlation Coefficient	-.468**	1.000			
	Sig. (2-tailed)	0.000				
	N	71	71			
D	Correlation Coefficient	.325**	-.609**	1.000		
	Sig. (2-tailed)	0.006	0.000			
	N	71	71	71		
H'	Correlation Coefficient	-.371**	.739**	-.959**	1.000	
	Sig. (2-tailed)	0.001	0.000	0.000		
	N	71	71	71	71	
Ep	Correlation Coefficient	0.069	0.028	-.714**	.594**	1.000
	Sig. (2-tailed)	0.568	0.814	0.000	0.000	
	N	71	71	71	71	71

**. Correlation is significant at the 0.01 level (2-tailed).

CHAPTER - FIVE

DISCUSSION

Pteridophytes composition

Pteridophytes composition has been studied to enumerate and prepare the comprehensive description of the pteridophyte species along the elevational gradient of Phulchowki Hill of Central, Nepal. This study showed the variation in the diversity and distribution of pteridophytes with the variation in elevational range of the hill. Distributions of Pteridophytes in studied area were not homogenous which might be due to variation in geographic as well as light condition caused due to the changes in elevational gradients. Plant diversity patterns and their relationship with soil and climatic factors also show variation along elevational gradient (Bhattarai & Vetaas, 2003).

Three major habitats from different areas of Nepal for fern and fern allies have been reported by Bhattarai, (2013); Rajbhandary, (2013) and Rajbhandary, (2016). From the present study site, a total of 46 species were collected, the highest numbers of species were terrestrial 39 species followed by 7 epiphytic species. Thakur & Rajbhandari (2018) found 47 and 28 species of terrestrial and epiphytic pteridophytes respectively from Panchase Protected forest, Central Nepal. Out of the 46 species of pteridophytes, 28 genera and 14 families have been found in the study area. The result of the present study was much similar to 45 species of pteridophytes reported by Dudani *et al*., (2014) from wet evergreen forests of Sakleshpur in central Western Ghats, India but much less than that of 105 species from Nubri valley and its adjoining areas of Manaslu Conservation Area (MCA), Central Nepal (Bhattarai & Rajbhandary, 2017) and 98 species of Pteridophytes in Kolli Hills of the Eastern Ghats, India reported by Jeyalatchagan *et al*., (2019). However, the species richness of pteridophytes in this study is much greater than that of 11 species of ferns and fern allies from Daman and the adjoining areas of Makawanpur district, Central Nepal (Chalise *et al.,* 2020) and 15 pteridophyte species from Chameli Community Forest, Bhaktapur, Nepal (Chaulagain & Shrestha-Malla, 2017).

Ecological Parameters

The IVI of different pteridophytes species in different elevation gradients indicated considerable sharing of importance by number of species. This study showed a mixed type of pteridophytes distribution along the hill. In the lower elevation, based on IVI values *Selaginella chrysocaulas* was dominant species followed by *Dryopteris carolohopei* and *Pteridium revolutum*. The maximum values of pteridophytes densities were also recorded for *Selaginella chrysocaulas* followed by *Dryopteris carolohopei* and *Pteridium revolutum* (Appendix 3). Sagar *et al*., (2008) have suggested that species richness decreases with an increase in species dominance. Similarly, at middle elevation, *Polystichum squarrosum* (39.25) was found to be dominant with IVI value followed by *Drynaris moliis* (38.26) and *Selagineela chrysocaulas* (34.39). The maximum value of frequency and coverage was recorded for *Polystichum squarrosum*; while, the highest density value was recorded for *Drynaris moliis* (39.25) (Appendix 4). However, in upper elevation *Polypodiode hendersonii* an epiphytic species was dominant species with highest value of IVI (68.08**)**. The maximum frequency and coverage were also recorded in *Polypodiode hendersonii* (Appendix 5) as upper forest is dominated by *Quercus* forest this might be due to the favourable habitat for epiphytic fern. Salazar *et al.,* (2013) and Nettesheim *et al.*, (2014), reported that various growth factors, moisture, light incidence, slope orientation and nutrients are responsible for the community differentiation pattern which makes variation in species diversity.

Spearman's correlation was used to observe the relationship between the diversity parameter and the environmental gradients. The result showed that elevational gradient significantly ($p < 0.01$) affected all diversity parameters of study sites except evenness index (0.069) (Table 4). Similar result of present study was also observed by Naud *et al*., (2019). Dorji *et al*., (2014) found that the patterns of species richness and evenness were significantly associated with elevation. Elevational gradient has many effects on a plant species; it influences the wind velocity, sun light and soil moisture which might have a combined effect on tree canopy cover, temperature, decreasing distance from snow melt water sources, high litter accumulation and organic matter that decrease soil pH (Biswas & Mukherjee, 1994).

Species richness and diversity parameters

In the present study, the values of Shannon-Weaver diversity index and Simpson's diversity index did not show any increasing or decreasing tendency of values as the elevational gradient increased (Table 3). Similar result was been observed by Rascón-Ayala *et al.*,(2018) in an elevational gradient of the Sierra La Laguna Biosphere Reserve, Mexico; however Vetaas & Grytnes, (2002) reported a decreasing of species and diversity richness as the increasing elevational gradient. The pteridophyte species richness of the vegetation in the present study followed the trend as middle elevational zone > lower elevational zone > upper elevational zone (Figure 9). This is similar to that reported by Austrheim, (2002) from semi-natural grasslands along an elevational gradient in southern Norway. On contrary Wiafe, (2014) reported the trend as low, mid and upper elevational zone. The maximum species diversity was observed for middle elevational zone at an elevational range of 2000-2100 m, where in maximum value of Shannon Wiener index was recorded for lower elevation zone (2.80) followed by middle elevation zone (2.608) and upper elevation zone (2.13) respectively (Table 1). Manhas & Raina (2018) found the value of Shannon diversity index (H') ranging between 0.47-2.33 in different forest types of Jammu and Kasmir, India. In the present study its H' value ranged from 1.272-2.489 within different elevational level (Table 3). The uniform decreasing pattern of species diversity and Shannon Weaver's diversity index was encountered in the elevational range of 1600-2000 masl with Shannon Wiener's index varying in between 2.441-1.393 (Table 3). However, the Shannon Wiener's diversity observed peaks at 2000-2100 (2.489) and decrease gradually up to range of 2600-2700 with minimum value (1.272) at 2500-2600 masl (Table 3). Higher species diversity is an indication of maturity in the ecosystem (Marglef, 1963) and low species diversity is a result of incorporation of some other species through competition.

Simpson's diversity index values were observed minimum values at lower elevational zone (0.077). These values of Simpson’s index (0.077-0.174) (Table 1) were ranged in between 0.06-0.2 that observed in three elevational zones of the Bambouto Mountains, West Cameroon (Taffo *et al*., 2017). In the present study the values of Simpson index ranges from 0.11 to 0.394 and decreased with increasing diversity i.e. highest in 1900-2000 masl (0.394) and lowest in 1700-1800 masl (0.11) (Table 3). Usually the value of Simpson index decreases with increasing diversity (Simpson, 1949). The lower diversity and consequently greater Simpson value in the upper elevation (0.174) could be due to lower rate of evolution and diversification of communities and severity of environment (Sharma *et al*., 2009). The values of Simpson index were more or less similar to the earlier reported values for the different forests such as 0.15-0.59 of Jammu and Kasmir (Manhas & Raina, 2018).

Species evenness decreased with increasing soil moisture at higher elevations, whereas it increased with soil moisture at lower elevations (Dorji *et al*., 2014). Maximum value of evenness in lower elevation zone (0.84) represented homogeneous communities having similar species distribution. Low evenness values of pteridophyte communities in upper elevation zone (0.711) and middle elevation zone (0.746) indicates that one or a few species were highly dominant, while others were present with few individuals (Table 1). The maximum value of evenness index (Ep) (0.888) was found at lower elevational zone at 1800-1900 masl. The uniform increasing pattern of Ep was found from lower to higher elevational range (1500-1900 masl) and the values ranges in between (0.561- 0.888), respectively (Table 3). Sorensen's floristic similarity coefficient 59.016%, 45.83%, and 56.604% respectively in the lower zone-mid-zone, lower zone-upper zone and mid-zone-upper zone were nearly more than 50% and confirmed that the three zones belonged to nearly similar plants communities (Table 2). This attested the great homogeneity of ecological niches when one moves from lower elevation to upper elevation areas along this slope of the Phulchowki Hills. However, similarity indexes with value less than 50% were observed by Taffo *et al*., (2017) in three altitudinal zones of the Bambouto Mountains, West Cameroon.

Species richness pattern

Most of the species richness studies suggest that the highest species richness appears at the mid-altitudinal zones forming a unimodal pattern (Grytnes & Vetaas, 2002; Bhattarai & Vetaas, 2003; Carpenter, 2005; Oommen & Shanker, 2005) however, monotonic decrease in species richness with increasing elevation is not uncommon (Stevens, 1992). This study showed that pteridophytes species richness in the Phulchowki Hills follows asymmetric hump-shaped elevational pattern across a broad altitudinal gradient with highest values at about 2000 masl for all species in general, as well as for terrestrial and epiphytic species. The pattern observed here was similar with a pattern observed by Tanaka & Sato, (2014) and Jeyalatchagan *et al*., (2019). Most of the elevation gradient studies on plants especially on fern species showed a hump-shaped pattern by several author from different part of the world (Aldasoro *et al*., 2004; Watkins *et al*., 2006; Kluge *et al.,* 2008; Marini *et al*., 2011; Salazar *et al*., 2013).

The mid altitudinal ranges have been reported to have higher species richness which decreased towards upper as well as lower altitudes (Chawla *et al*., 2008, Arshad *et al*., 2013). In the present study also, overall pteridophytes species richness has been recorded higher in the middle ranges following an asymmetric hump-shaped elevational pattern with highest species numbers per plot at mid-elevations between 1900-2000 masl and a marked decline towards both low and high elevations (Figure 3). Similar result was also observed in fern richness patterns along an elevational gradient of Sierra de Juárez, Oaxaca, Mexico by Hernandez *et al*., (2018).

This study shows that altitude controlled the diversity and distribution of pteridophytes. Along with altitude pteridophytes species composition was affected by aspect, canopy cover, forest types and tree fork number. They were also affected by interactions between tree types and forest types (Adhikari *et al*., 2017). Dispersal might play a vital role in the broader distribution of epiphytes as well as terrestrial pteridophytes, because spores released in the forest canopy are likely to disperse greater distances (Peck *et al*., 1990). Additionally, epiphytic and terrestrial niches operate at largely different scales: whereas terrestrial microhabitats change due different factors such as soil nutrients, soil moisture, and topographic parameters over distances of several dozen meters (Jones *et al*., 2011; Cicuzza *et al*., 2013) and epiphytic niche differentiation is driven by small-scale features due to tree crown architecture (Kro¨mer *et al*., 2007). The environmental variables in particular, topography, light, temperature, snow cover, soil moisture, soil pH, have been correlated with species richness at both regional and local scales (Walker, 1995; Gould & Walker, 1999). Similarly, interpolation of species presence between the lower and the upper extremes of recorded altitudinal ranges used in this study might also be a factor for creating the hump-shaped pattern for interpolated empirical richness (e.g. Sanders, 2002; Vetaas & Grytnes, 2002). The Mid domain effect (MDE) due to geometric constraints (physical and biological boundaries) for species distributions is another possible cause for such hump-shaped curves (Colwell & Lees, 2000; Colwell *et al*., 2004). Based on a null model analysis, Grytnes & Vetaas (2002) advocated that MDE was a contributor to the relationship between plant species richness and elevation in Nepalese Himalayan Mountains. Similarly, present results indicated that MDE predictions of the null models fitted the empirical patterns well.

CHAPTER – SIX

CONCLUSION AND RECOMMENDATIONS

Conclusion

The study reveals that pteridophytes found along the Phulchowki Hill exhibited varying patterns of distribution along different elevational gradients.

Altogether 46 species, with 14 families and 28 genera were recorded from the study site.

Among total species, 39 species were recorded from terrestrial habitat and 7 species from epiphytic habitat. The Polypodiaceae and the Pteridiaceae families were the most frequent, the most abundant and the richest in all elevational zones.

Each zone is characterised by floristic richness and diversity that are under influence by edaphic, climatic and anthropogenic conditions. The overall species richness showed asymmetric hump shaped pattern due to different biotic and abiotic factors that influences the mountainous forest. The study clearly revealed the negative and significant relationship of species richness with elevational gradients and the patterns were basically asymmetric hump shaped. The elevation gradient also plays significant role for changing the species composition due to change in humidity, sunlight and temperature of the plots. In the heterogeneous habitat the pteridophyte species showed complete turnover and high diversity.

The pteridophyte species richness was found highest in middle elevational zone with maximum peak in between 1900 - 2000 masl of the study site followed by lower and upper elevational zone; thus showing asymmetric hump shaped pattern.

The density of pteridophyte species were higher in middle elevational zone followed by lower and upper elevational zone.

From the above result it has been concluded that in Phulchowki Hill, with different elevational gradients, climatic conditions and environmental as well as biotic and abiotic factors favors the diversity and distribution of pteridophytes species.

Recommendations

- This study was only focused along road side and foot trails of Phulchowki Hill forests it needs to be extended in other part too in order to understand the pteridophytes diversity in different forest types in Central Nepal.
- Detailed distribution map of major pteridophytes need to be prepared so that management can be focused to the most problematic areas and future monitoring would be possible.
- Local communities should be educated to make them able to identify pteridophyte species, understand their long term impacts and benefits on biodiversity and environment.

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APPENDICES

Appendix 1: List of Pteridophyte species found in Phulchowki Hill Forest.

S.N	Local name	Family
1	*Adiantum capillus* veneris L.	Pteridiaceae
2	*Adiantum philippense* L. subsp. Philippense	Pteridiaceae
3	*Adiantum venustum* D.Don	Pteridiaceae
4	*Aleuritopteris albomarginata* (C.B.Clarke) Ching	Pteridiaceae
5	*Aleuritopteris bicolor* (Roxb.) Fraser-Jenk.	Pteridiaceae
6	*Asplenium yoshinagae* Makino sub sp. indicum *(Sledge) Fraser-Jenk*	Aspleniaceae
7	*Athyrium foliolosum* T. Moore ex R. Sim	Athyriaceae
8	*Botrychium lanuginosum* Wall. ex Hook. & Grev.	Ophioglossaceae
9	*Coniogramme affinis* Hieron.	Pteridiaceae
10	*Coniogramme puberula* Hieron.	Pteridiaceae
11	*Denstaedtia appendiculata* (Wall. ex Hook.) J. Sm.	Dennstaedtiaceae
12	*Dicranopteris lanigera* (D. Don) Fraser-Jenk	Gleicheniaceae
13	*Diplazium subspectabile* (Ching & W. M. Chu) Z. R. He	Athyriaceae
14	*Diploterygium giganteum* (Wallich ex Hook. & Bauer) Nakai	Gleicheniaceae
15	*Drynaria mollis* Bedd.	Polypodiaceae
16	*Dryopteris carolihopei* Fraser-Jenk	Dryopteridaceae
17	*Dryopteris juxtaposita* Christ	Dryopteridaceae
18	*Dryopteris* sp.	Dryopteridaceae
19	*Goniophlebium argutum* (Wall. ex Hook) Bedd.	Polypodiaceae
20	*Kotoella pulchra* (D. Don) Fraser-Jenk, Kandel & Pariyar	Davallaceae
21	*Lindsaea odorata* Roxb.	Lindsaeaceae
22	*Loxogramme involuta* (D. Don) C. Presl	Polypodiaceae
23	*Microlepia platyphyllla* (D. Don) J. Sm.	Dennstaedtiaceae

24	*Odontosoria chinensis* (L.) J. Sm.	Lindsaeaceae
25	*Oleandra wallichii* (Hook.) C. Presl	Oleandraceae
26	*Onychium lucidum* (D. Don) Spreng	Pteridiaceae
27	*Pichisermollodes quasidivaricata* (Hayata) Fraser-Jenk.	Polypodiaceae
28	*Polypoides hendersonii* (Bedd.) Fraser-Jenk	Polypodiaceae
29	*Polystichum discretum* (D. Don)	Dryopteridaceae
30	*Polystichum lentum* (D. Don) T. Moore	Dryopteridaceae
31	*Polystichum obliquum* (D. Don) T. Moore	Dryopteridaceae
32	*Polystichum squarrosum* (D. Don) Fée	Dryopteridaceae
33	*Pteridium revolutum* (Blume) Nakai	Dennstaedtiaceae
34	*Pteris aspericaulis* Wall. ex J. Agardh	Pteridiaceae
35	*Pteris biaurita* L.	Pteridiaceae
36	*Pteris cretica* sub spcretica L.	Pteridiaceae
37	*Pteris sp.*	Pteridiaceae
38	*Pteris stenophylla* Wall. ex Hook. & Grev.	Pteridiaceae
39	*Pteris terminalis* Wall. ex J. Agardh	Pteridiaceae
40	*Sellaginella chrysoocaulos* (Hook. & Grev.) Spring	Selaginellaceae
41	*Sellaginella pallida* Hook. & Grev.	Selaginellaceae
42	*Selaginella subdiaphana* (Wall. ex Hook. & Grev.) Spring	Selaginellaceae
43	*Thelypetris cana* (J. Sm.) Ching	Thelypteridiaceae
44	*Thelypteris dentate* (Forssk.) E. P. St. John	Thelypteridiaceae
45	*Thelypteris tyodes* (Kunze) Ching	Thelypteridiaceae
46	*Woodwardia unigemmata* (Makino) Nakai	Blechnaceae

Appendix 2: Family, genera and species composition of Pteridophytes in the Phulchowki Hill forest.

S.N	Family	Genus	Species
1	Aspleniaceae	1	1
2	Athyriaceae	2	2
3	Blechnaceae	1	1
4	Davillaceae	1	1
5	Dennstaedtiaceae	2	2
6	Dryopteridaceae	2	7
7	Gleicheniaceae	2	2
8	Lindsaeaceae	2	2
9	Oleandraceae	1	1
10	Ophioglossaceae	1	1
11	Polypodiaceae	6	6
12	Pteridiaceae	5	**14**
13	Selaginellaceae	1	3
14	Thelypteridiaceae	1	3
		28	**46**

Appendix 3: Family, Epiphytic and Terresterial species composition of Pteridophytes in the Phulchowki Hill forest.

S.N	Family	Terresterial	Epiphytic
1	Aspleniaceae	0	1
2	Athyriaceae	2	0
3	Blechnaceae	1	0
4	Davillaceae	1	0
5	Dennstaedtiaceae	3	0
6	Dryopteridaceae	7	0
7	Gleicheniaceae	2	0
8	Lindsaeaceae	2	0
9	Oleandraceae	0	1
10	Ophioglossaceae	1	0
11	Polypodiaceae	1	4
12	Pteridiaceae	**14**	**0**
13	Selaginellaceae	2	1
14	Thelypteridiaceae	3	0
		39	**7**

Appendix 4: Shows Frequency (F%), Relative Frequency (RF), Density (D), Relative Density (RD), Coverage (C), Relative Coverage (RC) and Importance Value Index (IVI) of Pteridophyte species in lower elevation zone.

S.N	Species name	Density (D)	RD	Frequency (F)	RF	Coverage (C)	RC	IVI
1	*Adiantum capillus*	0.698	6.27	18.18	2.29	1.64	2.22	10.78
2	*Adiantum venustum*	0.073	0.65	4.55	0.57	0.14	0.19	1.41
3	*Aleuritopteris bicolar*	0.007	0.07	4.55	0.57	0.09	0.12	0.76
4	*Asplenium yoshinagae*	0.609	5.47	40.91	5.14	1.83	2.48	13.09
5	*Athyrium folilosum*	0.345	3.10	31.82	4.00	5.14	6.98	14.08
6	*Coniogramme affinis*	0.198	1.78	13.64	1.71	2.41	3.27	6.77
7	*Coniogramme puberula*	0.042	0.38	9.09	1.14	0.41	0.56	2.07
8	*Dennstaedtia appendiculata*	0.344	3.08	36.36	4.57	3.77	5.13	12.78
9	*Dicranopteris lanigera*	0.013	0.11	4.55	0.57	0.36	0.49	1.18
10	*Drynaria mollis*	0.960	8.62	18.18	2.29	1.27	1.73	12.63
11	*Dryopteris carolohopei*	0.615	5.52	**81.82**	10.29	10.55	14.33	30.13
12	*Loxogramme involuta*	0.158	1.42	13.64	1.71	0.36	0.49	3.63
13	*Microlepia platyphylla*	0.149	1.34	22.73	2.86	4.32	5.87	10.06
14	*Onychium lucidum*	0.942	8.45	27.27	3.43	1.09	1.48	13.37
15	*Polypodiodes hendersonii*	0.884	7.93	45.45	5.71	4.36	5.93	19.58
16	*Polystichum discretum*	0.060	0.54	18.18	2.29	1.23	1.67	4.49
17	*Polystichum lentum*	0.025	0.23	9.09	1.14	0.28	0.38	1.75

18	*Polystichum squarrosum*	0.289	2.60	45.45	5.71	3.50	4.76	13.07
19	*Pteridium revolutum*	0.418	3.75	59.09	7.43	12.64	17.17	28.35
20	*Pteris aspericaulis*	0.122	1.09	31.82	4.00	1.09	1.48	6.58
21	*Pteris biaurita*	0.345	3.10	27.27	3.43	1.55	2.10	8.63
22	*Pteris cretica*	0.695	6.23	59.09	7.43	2.34	3.18	16.84
23	*Pteris stenophylla*	0.015	0.13	13.64	1.71	0.23	0.32	2.16
24	*Pteris terminalis*	0.045	0.41	13.64	1.71	0.73	0.99	3.11
25	*Selaginella chrysocaulis*	1.822	16.35	63.64	8.00	6.27	8.52	**32.88**
26	*Selaginella pallid*	0.193	1.73	22.73	2.86	1.59	2.16	6.75
27	*Thelypetris cana*	1.071	9.61	54.55	6.86	4.36	5.93	22.40
28	*Thelypteris dentate*	0.004	0.03	4.55	0.57	0.05	0.06	0.67
		11.140		795.45		73.59		

Appendix 5: Shows Frequency (F%), Relative Frequency (RF), Density (D), Relative Density (RD), Coverage (C), Relative Coverage (RC) and Importance Value Index (IVI) of Pteridophyte species in middle elevation zone.

S.N	Species name	Density (D)	RD	Frequency (F)	RF	Coverage (C)	RC	IVI
1	*Adiantum philippense*	0.06	0.46	17.24	2.49	0.72	1.39	4.33
2	*Aleuritopteris albomarginata*	0.04	0.33	10.34	1.49	0.28	0.53	2.35
3	*Aleuritopteris bicolar*	0.13	1.06	10.34	1.49	0.69	1.32	3.87
4	*Asplenium yoshinagae*	0.03	0.26	3.45	0.50	0.14	0.26	1.02
5	*Athyrium folilosum*	0.40	3.19	17.24	2.49	1.48	2.84	8.51
6	*Dennstaedtia appendiculata*	0.37	2.97	20.69	2.99	1.34	2.57	8.53
7	*Diplazium subspectabile*	0.02	0.20	3.45	0.50	0.83	1.58	2.28
8	*Diplopterygium giganteum*	0.13	1.08	24.14	3.48	3.07	5.87	10.43
9	*Drynaria mollis*	**3.29**	26.49	34.48	4.98	3.55	6.79	38.26
10	*Dryopteris carolohopei*	0.91	7.31	13.79	1.99	1.93	3.69	13.00
11	*Dryopteris juxtaposita*	0.01	0.08	3.45	0.50	0.28	0.53	1.10
12	*Dryopteris sps*	0.17	1.33	10.34	1.49	0.48	0.92	3.75
13	*Goniophlebium argutum*	0.02	0.13	6.90	1.00	0.17	0.33	1.46
14	*Kotoella pulchra*	0.08	0.63	17.24	2.49	0.55	1.06	4.18
15	*Lindsaea odorota*	0.26	2.10	13.79	1.99	0.55	1.06	5.15
16	*Loxogramme involuta*	0.17	1.34	17.24	2.49	0.66	1.25	5.09

17	*Odontosoria chinensis*	0.08	0.61	13.79	1.99	0.83	1.58	4.18
18	*Oleandra wallichii*	0.70	5.62	65.52	9.45	3.17	6.07	21.15
19	*Onychium lucidum*	0.47	3.80	31.03	4.48	2.90	5.54	13.82
20	*Pichisermollodes quasi divaricata*	0.19	1.54	24.14	3.48	0.72	1.39	6.41
21	*Polypodiodes hendersonii*	0.88	7.08	34.48	4.98	5.24	10.03	22.08
22	*Polystichum discretum*	0.08	0.66	20.69	2.99	0.90	1.72	5.36
23	*Polystichum lentum*	0.06	0.47	17.24	2.49	0.66	1.25	4.21
24	*Polystichum obliquum*	0.01	0.07	3.45	0.50	0.31	0.59	1.16
25	*Polystichum squarrosum*	1.16	9.33	93.10	13.43	8.62	16.49	**39.25**
26	*Pteridium revolutum*	0.48	3.85	55.17	7.96	3.07	5.87	17.68
27	*Pteris aspericaulis*	0.06	0.48	10.34	1.49	0.90	1.72	3.69
28	*Pteris cretica*	0.04	0.33	10.34	1.49	0.24	0.46	2.29
29	*Pteris terminalis*	0.09	0.71	10.34	1.49	0.79	1.52	3.72
30	*Selaginella chrysocaulis*	1.70	13.66	65.52	9.45	5.90	11.28	34.39
31	*Thelypetris cana*	0.01	0.09	3.45	0.50	0.10	0.20	0.78
32	*Thelypteris tyodes*	0.34	2.71	6.90	1.00	1.14	2.18	5.88
33	*Woodwardia unigemmata*	0.01	0.07	3.45	0.50	0.07	0.13	0.70
		12.41		693.10		52.28		

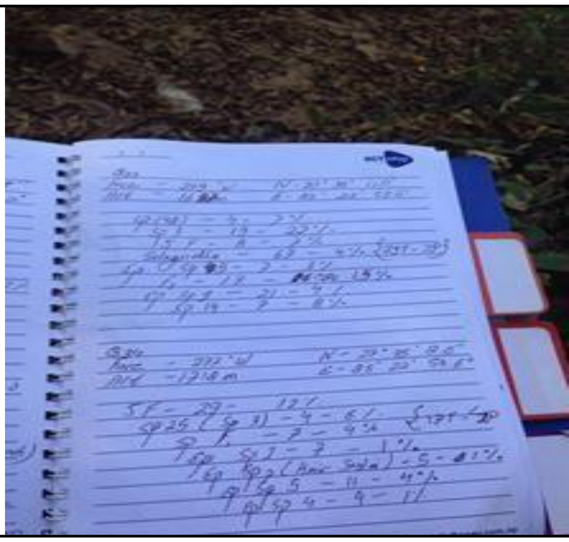
Appendix 6: Shows Frequency (F%), Relative Frequency (RF), Density (D), Relative Density (RD), Coverage (C), Relative Coverage (RC) and Importance Value Index (IVI) of Pteridophyte species in upper elevation zone.

S.N	Species name	Density (D)	RD	Frequency (F)	RF	Coverage (C)	RC	IVI
1	*Aleuritopteris albomarginata*	0.90	7.94	45.00	8.49	2.65	5.20	21.64
2	*Botrychium luunaginosum*	0.04	0.39	10.00	1.89	0.50	0.98	3.26
3	*Dicranopteris lanigera*	0.18	1.63	25.00	4.72	1.80	3.53	9.88
4	*Diplopterygium giganteum*	0.10	0.89	10.00	1.89	0.90	1.77	4.54
5	*Drynaria mollis*	3.17	28.12	55.00	10.38	6.55	12.86	51.35
6	*Kotoella pulchra*	0.14	1.21	30.00	5.66	1.55	3.04	9.91
7	*Oleandra wallichii*	0.85	7.50	40.00	7.55	3.50	6.87	21.92
8	*Onychium lucidum*	0.02	0.14	5.00	0.94	0.15	0.29	1.38
9	*Pichisermollodes quasidivaricata*	1.29	11.44	45.00	8.49	6.90	13.54	33.47
10	*Polypodiodes hendersonii*	2.91	25.76	75.00	14.15	14.35	28.16	**68.08**
11	*Polystichum discretum*	0.08	0.73	25.00	4.72	1.95	3.83	9.27
12	*Polystichum lentum*	0.20	1.77	25.00	4.72	1.85	3.63	10.12
13	*Polystichum obliquum*	0.03	0.28	10.00	1.89	0.25	0.49	2.66
14	*Polystichum squarrosum*	0.30	2.66	35.00	6.60	2.90	5.69	14.96
15	*Pteridium revolutum*	0.18	1.61	30.00	5.66	1.50	2.94	10.22
16	*Pteris sps*	0.04	0.39	5.00	0.94	0.20	0.39	1.73
17	*Pteris terminalis*	0.07	0.66	10.00	1.89	0.60	1.18	3.72
18	*Selaginella chrysocaulis*	0.48	4.22	30.00	5.66	1.65	3.24	13.12
19	*Selaginella pallida*	0.23	2.02	15.00	2.83	1.00	1.96	6.81
20	*Selaginella subdiaphana*	0.08	0.67	5.00	0.94	0.20	0.39	2.01
		11.28		530.00		50.95		

PHOTOPLATES

Dryopteris juxtaposita *Loxogramme involuta*

General observation of studied sites

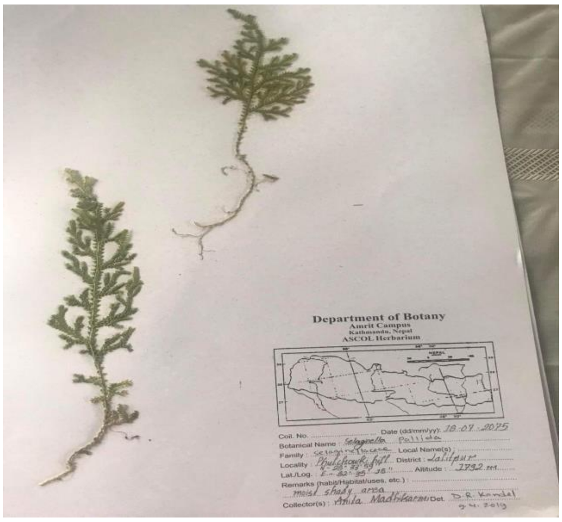


Recording the plot characteristics

Diploterygium giganteum

Oleandra wallichii

Drynaria mollis



Sellaginella pallida

Microlepia platyphylla

Polystichum squarrosum

Collection and preparation of herbarium