STUDY OF VARIATION IN LEAF TRAIT AND SOIL NUTRIENTS IN *SCHIMA WALLICHII* AND *QUERCUS LEUCOTRICHOPHORA* AT SHIVAPURI NAGARJUN NATIONAL PARK, NEPAL

A THESIS

SUBMITTED FOR THE PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE MASTER'S DEGREE IN BOTANY

BY

SUMITRA DAHAL

Symbol Number: 455/ 073

TU Registration No. 5-2-37-1247-2011

DEPARTMENT OF BOTANY

AMRIT CAMPUS

INSTITUTE OF SCIENCE AND TECHNOLOGY

TRIBHUVAN UNIVERSITY

KATHMANDU, NEPAL

April 2023

DECLARATION

I, Sumitra Dahal, hereby declare that the thesis entitled **"Study of variation in leaf trait and soil nutrients in *Schima wallichii* and *Quercus leucotrichophora* at Shivapuri Nagarjun National Park, Nepal"** is a genuine work done by me and has not been published elsewhere for the award of any degree. All the information cited in this piece of work are specifically acknowledged and credited to the respective authors or institutions as references.

Sumitra Dahal

Department of Botany

Amrit Campus

Kathmandu, Nepal

Date: April, 2023

Tribhuvan University
Institute of Science & Technology
AMRIT CAMPUS
P. O. Box No. 102, Thamel, Kathmandu, Nepal.
E-mail : amritcampus@ntc.net.np
☎ 4411637
4410408

Institute of Science & Technology
Amrit Campus

Ref No.:

Date:

12 April, 2023

RECOMMENDATION LETTER

This is to certify that Ms. Sumitra Dahal has completed the Master's thesis entitled **"Study of varition in leaf trait and soil nutrients in *Schima wallichii* and *Quercus leucotrichophora* at Shivapuri Nagarjun National Park, Nepal"** under my supervision. The entire work is based on the results of her own field work and laboratory work and has not been submitted in any other academic degree to the best of my knowledge. I, therefore, recommended this thesis work to be accepted for partial fulfillment of Master's Degree in Botany from Amrit Campus, Tribhuvan University.

....	....
Prof. Dr. Kanta Poudyal	**Dr. Biva Aryal**
Supervisor	Co- supervisor
Department of Botany	Department of Botany
Amrit Campus	Amrit Campus
Tribhuvan University Kathmandu, Nepal	Tribhuvan University Kathmandu, Nepal

Tribhuvan University
Institute of Science & Technology
AMRIT CAMPUS
P. O. Box No. 102, Thamel, Kathmandu, Nepal.
E-mail : amritcampus@ntc.net.np
4411637
4410408

Ref No.: Date:

LETTER OF APPROVAL

This thesis work entitled **"Study of varition in leaf trait and soil nutrients in *Schima wallichii* and *Quercus leucotrichophora* at Shivapuri Nagarjun National Park, Nepal"** submitted by Sumitra Dahal has been accepted for the examination and submitted to Amrit Campus, Tribhuvan University for partial fulfillment of the requirements for Master's Degree in Botany (Ecology).

EXPERT COMMITTEE

Supervisor
Prof. Dr. Kanta Poudyal
Department of Botany, Amrit Campus
Tribhuvan University, Kathmandu, Nepal

Co- supervisor
Dr. Biva Aryal
Department of Botany,Amrit Campus
Tribhuvan University, Kathmandu, Nepal

External examiner
Assoc. Prof. Dr. Giri Prasad Joshi
Central Department of Botany
Tribhuvan University, Kirtipur, Kathmandu Nepal

Internal Examiner
Prof. Dr. Mukesh Kumar Chettri
Department of Botany, Amrit Campus
Tribhuvan University, Kathmandu Nepal

M. Sc. Coordinator
Assoc. Prof Dr. Laxmi Joshi Shrestha
Department of Botany, Amrit Campus
Tribhuvan University, Kathmandu, Nepal

Head of Department
Assoc. Prof. Dr. Shila Singh
Department of Botany, Amrit Campus
Tribhuvan University, Kathmandu, Nepal

Date of oral Examination : April 10, 2023

ACKNOWLEDGEMENTS

This thesis has been completed with the help, support and encouragement of following people to whom I would like to heartily acknowledge. I would like to express my deep sense of gratitude towards my Supervisor Prof. Dr. Kanta Poudyal and Co- supervisor Dr. Biva Aryal for their continuous support and guidance throughout my thesis work.

I am highly thankful to the Coordinator of Department of Botany Dr. Laxmi Joshi Shrestha and head of department Dr. Shila Singh for the facilities provided and sincere cooperation during the study.

I am indebted to the teaching and laboratory faculty of Department of environmental science, Kritipur and Department of Botany Amrit Campus for their concern and support.

My special thank goes to my classmate Bishal Subedi, Hasina Shrestha, Pooja Prasai, Pramoda Niraula, Samrita Budhathoki, Sujan Deshar and Yagyaraj Bhatta helped me during my field visits and laboratory work.

Last but not least, I am very much thankful to my family members and my husband for encouragement and continuous support during my thesis work completion.

Sumitra Dahal

ABSTRACT

Leaf trait analysis is a useful tool in ecology and has played an important role in theories related to the plant growth, plant plasticity, species co-existence and ecosystem levels processes. Soil factors are essential factors that influence plant species' spatial distribution and functional traits. In the present research, relationships between soil nutrient status and nutrient-related leaf traits (leaf N and P concentration and resorption) was studied in *Schima wallichii* and *Quercus leucotricophora*, as most of the leaf traits, including leaf length, width,area and biomass (dry weight) quantifies the relationships with soil features. Furthermore, Specific Leaf Area (SLA) is an integrative parameter of leaf area and leaf dry weight, and increasing SLA may be one of the strategies adopted by the plants to adapt to changing environments by maximizing their photosynthetic rate. Species adapted to low-nutrient soils tend to develop strategies that enhance nutrient acquisition. This study aimed to explore the relationship between functional leaf traits (morphological and chemical constitution) and soil nutrients in *Schima wallichii* and *Quercus leucotricophora* in two aspects of forest i.e., northern and southern. The methods used in this study were data collection by quadrat method for leaf and soil collection, soil test and data analysis.

The seasonal(leaf flushing, leaf maturation and leaf senescence) study of SLA between two species (*Quercus leucotrichophora* and *Schima wallichii*) showed the significant difference in the distribution. In two sampled species, the relation between leaf parameter and soil attributes showed significant relationship. In northern slope, soil nitrogen was weakly correlated with leaf nitrogen and leaf phosphorus. But soil nitrogen had positive correlation with leaf carbon. Soil phosphorus was positively correlated with both leaf phosphorus and leaf carbon but negatively correlated with leaf nitrogen. Soil carbon was negatively correlated with leaf phosphorus, while soil carbon had positive correlation with leaf nitrogen**.** But in the southern slope, soil nitrogen was positively correlated with leaf nitrogen. But soil nitrogen was weakly correlated with leaf carbon and leaf phosphorus. Soil phosphorus had a positive correlation with leaf phosphorus, leaf nitrogen and leaf carbon. Soil carbon was negatively correlated with leaf carbon while soil carbon had positive correlation with leaf phosphorus and leaf nitrogen. The fluctuation of leaf and soil parameters might be due to changing environmental conditions as well as microbial activities. The Important Value Index (IVI) of tree species is positively correlated with soil phosphorus and Potassium but had negative correlations with soil nitrogen in the southern aspect, but Tree IVI was positively correlated with all soil parameters (NPK) in the Northern aspect. This study concluded that leaf Nutrients was normally affected by change in soil nutrient in northern and southern aspects.

Keywords: attribute, microbial, SLA, Leaf trait leaf nutrient parameters, IVI

TABLE OF CONTENT

Contents

LIST OF FIGURE

LIST OF TABLE

Acronyms and abbreviation

IUCN	-	International Union for Conservation of Nature
P	-	Phosphorus
N	-	Nitrogen
C	-	Carbon
LNC	-	Leaf Nitrogen Content
LPC	-	Leaf Phosphorus Content
SLA	-	Specific Leaf Area
PFAF	-	Plants for A Future
KMTNC	-	King Mahendra Trust for Nature Conservation.
ha	-	hector
ICIMOD	-	International Centre for Intregrated Mountain Development
ºC	-	Degree Celcius
Max	-	Maximum
Min	-	Minimum
T	-	Temperature
mm	-	millimeter
CO_2	-	Carbondioxide
i.e.	-	That means
LA	-	Leaf Area
cm^2	-	centimeter square
GPS	-	Global Positioning System
km^2	-	kilometer square
m	-	Meter
conc.	-	Concentrated

H_2So_4	-	Sulphuric Acid
SPSS	-	Statistical Package for Social Science
TIA	-	Tribhuvan International Airport
SD	-	Standard Deviation
OM	-	Organic matter
ATP	-	Adenosine Triphosphate
RuBisCO	-	Ribulose-1,5-biphosphate carboxylase-oxygenase
IPCC	-	Inter govermental panel on climate change

Chapter I

1.1 Introduction

The essential part of a plant's photosynthetic apparatus, the leaves, are essential to plant function and long-term environmental adaptation. Specific leaf area and leaf dry mass content were said to be attributes commonly employed to predict growth patterns and the response to environmental changes. They also show the balance between investing in growth or storage. So, in order to forecast functions and processes at the community or ecosystem level, it is imperative to understand leaf physiology (functional features) (Daneshgar et al. 2012). The interaction between leaf characteristics and soil nutrient contents shows the trade-off between nutrient conservation and growth. Soil nutrient quality, climate, phenology, and leaf characteristic values may all be crucial factors in figuring out the species makeup of plant communities. Conceptual models of long-term ecosystem development have tended to focus on the negative covariation between the availability of Phosphorus (P) and Nitrogen (N) in soils, with the highest productivity at intermediate N: P ratios (Vitousek, 2004).

Leaf traits are generally considered good predictors of plant performance. Variation within the leaves' structure, shapes, stomata structure, thickness, etc., among the plants and their uptake of carbon dioxide ratio, sun energy, and photorespiration has directed their significant roles to withstand them in an environment. The significant dimension of variation among plant species, the evolution of plant traits, trait relationships, and the determining of these by climate, nutrients, gradients of altitude, latitude, and other edaphic factors are said to be revealed by quantifying leaf trait relationships between various plant species and habitats (Wright et al. 2001; Lamont et al. 2002; Westoby et al. 2002). One of the most important elements is the availability of soil nutrients. Through nutrient cycles, different plants have species-specific effects on the nutrients that are available in the soil. Hence, plant functional features and phenological strategies may be influenced by the nutritional state of the soil. Large volumes of litter are produced by plants that thrive in nutrient-rich situations, releasing a lot of nutrients and maintaining high soil fertility levels. In contrast, plants in nutrient-poor environment generate little litter and store resources in tough, long-lasting tissues, which helps to maintain the sterility of the environment (Ordoez et al. 2009). Although foliar morphology has a genetic base, it is subject to strong environmental selection pressure, resulting in a variety of shapes and foliar sizes. This kind of data offers a framework for analyzing more in-depth investigations of leaf function, as well as input for models that predict changes in vegetation, carbon fluxation (C), nitrogen fluxation (N), and climate change (Moorcroft et al. 2001; Berry and Roderick, 2002; Bohan et al. 2002).

The relationship between plant nutrients and soil nutrients has been extensively explored (Aerts and Chapin, 2000), although research on phenotypic responses across different plant. In contrast, plants in nutrient-poor environments produce small amounts of litter and preserve nutrients in long-lived and recalcitrant tissues, thus reinforcing the sterile environment (Ordoñez *et al.* 2009). However, foliar morphology is determined on a genetic basis, but it is exposed to intense selection pressure in the environments, expressing different forms, and foliar-size species are still scarce at large spatial ranges (Lavorel and Garnier, 2002). This information is crucial in light of continuous environmental changes and is urgently required to increase our understanding of how ecosystems work (Grime, 2006; McGill et al., 2006). One of the most difficult aspects of making future climate change forecasts is calculating how changes in nutrient availability will affect plant productivity (Hungate *et al.,* 2003).

The total amounts of N and P per unit dry leaf mass, expressed in mg^{-1}, are referred to as leaf nitrogen concentrations (LNC) and leaf phosphorus concentrations (LPC). It is claimed that LPC and LNC interspecific rankings were frequently co-relate. For all species, LNC and Mass-based photosynthetic rates tend to be tightly connected. In food webs, strong LNC and LPC are typically correlated with good nutritional quality for the consumer. Yet, the availability of phosphate and nitrogen in the soil tends to have a considerable impact on LNC and LPC of a specific species. The LNC: LPC (N: P) ratio is used to determine whether the availability of nitrogen or Phosphorus is more restricting for the ecosystem's carbon cycle process. An illustration would be that LNC or LPC of the entire leaf (including the petiole and rachis) may be of interest (connection with SLA; allometric relationship), or the average LNC and LPC of Leaf in cohorts made of evergreen leaves in various years may be a measure of the nutritional quality of the entire plant. The soil's supply of nitrogen and Phosphorus can have a significant impact on LNC and LPC.

The interaction of variables present when the samples are taken for analysis is reflected in the composition of the vegetal tissue. So, first, it's important to rule out any biotic or abiotic factors that might interfere with plant nutrient concentrations. Among these are pests and diseases, wind, hot or low temperatures, dry or wet conditions, compacted or improperly plowed soils, mechanical harm, and herbicide toxicity(G.I.(2008). These elements could result in deficient symptoms by inhibiting nutrient absorption and transport in the plant. In this instance, the only way to get rid of the stress factors is to get rid of the deficient symptoms.

The physiological components of nitrogen (N), Phosphorus (P), Potassium (K), calcium (Ca), and magnesium (Mg) are necessary to maintain functioning activity (Taiz and Zeigar 2006). According to research (Guiz et al. 2016; Hartmann et al. 2009), different plant species may have distinct resource needs and growth patterns, and these variations may impact plant nutrient uptake.

It is claimed that species variety in terrestrial ecosystems may also impact the plant nutrient concentrations of specific species (Borer et al. 2015; Guiz et al. 2016). Several studies revealed that when growing in mixtures, certain plant species declined, while others showed enrichment in the leaf N and P contents (Borer et al., 2015; Guiz et al., 2016). Plant nutrient concentrations may be impacted by community rivalry over resource use and plant species variety (Novotny et al. 2007; Deyn et al. 2009; Abbas et al. 2013). Legumes' presence in plants resulted in higher plant N concentrations in the local environment (Novotny et al. 2007). The relationship between plant species diversity and plant nutrient concentration in terrestrial ecosystems is demonstrated in this study.

1.2 Justification

while the plant–soil nutrient status has been studied extensively (Aerts and Chapin, 2000), quantification of the leaf trait responses across various spatial scales is still limited (Lavorel and Garnier, 2002). Such quantitative knowledge is urgently needed to advance our understanding of ecosystem function (Grime, 2006; McGill *et al*., 2006) and is paramount in the face of ongoing environmental changes. Predicting the effects of changes in the quality of soil and nutrient availability to plants is one of the highest worries of future climate change predictions (Hungate *et al*. 2003). A broad quantification of the leaf trait responses across various spatial scales in woody species of Nepal has not been done so far. Leaf traits and soil nutrients could contribute to a better understanding of the plant community.

1.3 Research Question

What are the most individually important soil variables explaining variation in these leaf traits at Northern and Southern aspect of Shivapuri Nagarjuna National Park?

1.4 Research Objectives

1.4.1 General objective

- To study the species diversity at northern and southern aspect of Shivapuri Nagarjuna National Park.To analyze the leaf trait variation and soil nutrient status in northern and southern aspects of Shivapuri Nagarjun National Park.

1.4.2 Specific objectives

- Enumeration of associated tree species to know the status of diversity and vegetation composition.
- To measure the specific leaf area(SLA).
- Estimation ofLeaf carbon, nitrogen and phosphorus content.
- Estimation of Soil Nitrogen, Phosphorus, Potassium, Soil pH, and Soil organic carbon.
- To study the stomatal density of *Q.Leucotrichophora* and *Schima wallichii*.

Chapter II

Literature Review and Research Gaps

Specific leaf area (SLA) is an important trait of plant functional ecology. The most accepted research finding is that species with greater SLA more efficiently capture a limited light resource. SLA reflects the expected return on previously captured resources, and high-SLA leaves are productive (Klinka *et al*. 1992). Still, they are necessarily also short-lived and vulnerable to herbivores. These phenomena, therefore, work best in resource-rich environments. In contrast, low SLA leaves work better in resource-poor environments where retention of captured resources is a higher priority. Because stronger leaf reinforcement is required to ensure longer life, low SLA leaves often have longer leaf lifespans. Plant species with high SLA, high CO2 and N uptake rates per unit leaf and root mass, and high rates of photosynthesis per unit leaf N are characterized by high nitrogen concentrations (Lambers and Poorter, 1992). These creatures have evolved to acquire resources at a rapid rate.

The plant species with low SLA generally have high values for dry matter content, high concentrations of cell walls and secondary compounds, and greater leaf and root longevity. These species seem to be adapted for the conservation of acquired resources. The specific leaf area (SLA) of deciduous species was higher than evergreen species in central Himalayan (Negi, 1996). Elevation and canopy show a significant effect on the SLA. For instance, Luo *et al*. (2005) showed that as elevation increased, the mean SLA of species and stand decreased from their maximum. Similarly, Lambers and Poorter, 1992 concluded that more shade-tolerant species (understories) develop more SLA by decreasing leaf thickness. When growing in open areas, these understory species increase leaf thickness and decrease specific leaf area. Klinka *et al*. (1992) reported that more shade-tolerant species generally have a high capacity to change their leaf structure according to environmental conditions. Stem diameter determines the leaf number and total leaf area of plants. Westoby and Wright (2003) found that, the total leaf area of species was strongly correlated with twig cross section area but within sites the leaf and twig size was negatively correlated with SLA.

Kearney (2006) defined Leaf functional trait analysis is a useful tool in plant ecology and has played an important role in theories related to plant growth, plasticity, species co-existence, and ecosystem-level. The interplay between temperature and photoperiod (i.e. day-length) affects phenological processes such as flowering time, budburst, seasonal stem growth, leaf senescence and dormancy (Zohner and Renner 2016; Luo *et al*. 2018; Tylewicz*et al*. 2018).

Patterns of plant functional trait variation inform not only on community structure but also on population dynamics and the mechanisms affecting ecosystem functioning. Shifts in plant functional traits within or between sites and/or species across environmental gradients may also reflect deterministic processes of community organization (Silva and Batalha, 2009).

Nutrient reabsorption, the withdrawal of nutrients from aging tissues for transport to and re-use in developing tissues, play a vital role in community functioning and nutrient cycling (Aerts 1999). According to a prior statement, species in low-nutrient soils rely more on reabsorption than species in higher-nutrient soils; however, they may or may not exhibit any discernible variation in proportionate reabsorption efficiency (Wright and Westoby 2003). Net primary production and community dynamics are impacted by phosphorus and nitrogen constraints in the soil (Lambers *et al*. 1992; Menge *et al.* 2012). As a component of all proteins and nucleic acids, nitrogen is an essential plant resource and, necessary to plant health. (Epstein and Bloom 2005).

According to research, nitrogen is the mineral nutrient that plants require in the highest proportions, and a lack of it can have disastrous effects on plant growth (Epstein and Bloom 2005). It revealed that Phosphorus is the most limiting nutrient for plant growth. Crucial components include nucleic acids, phospholipids, and adenosine triphosphate contains Phosphorus, which is also involved in metabolic pathway management and important enzyme activities. Phosphorus is frequently cited as being at least as productively limiting as nitrogen on old soils (Vitousek *et al*. 1995).

TIn comparison to relationships between leaf traits and resource/climate distributions at the species level, responses of leaf traits to soil resources within species are less accurate. Studies on other features have revealed a decline in nutrient resorption proficiency and an increase in nutrient concentrations in living leaves when soil resource availability increased . According to Cordell *et al.* (2001) and Richardson *et a*l. (2010), there have been reports of both decreases and increases in leaf longevity, are variable responses. However, the study of some features, like the longevity of leaves, is lacking. Many research are controlled experiments with nutrient amendment or drought treatments that may affect the relative flexibility of traits because the majority of studies only look at one to a few traits, which prevents judgments about this. he responses of leaf traits to soil resources within species are less precise than species-level associations between leaf traits and resource/climate distributions. For other traits, studies have shown that increasing soil resource availability led to increasing nutrient concentrations in live leaves and decreased in nutrient resorption proficiency. Variable responses for leaf lifespan have been reported, such as decrease and increase (Cordell et al. 2001 and Richardson et al. 2010) respectively. However, some traits e.g. leaf lifespan are understudied. Most studies examine one to few traits, which precludes conclusions regarding relative plasticity among traits; and many studies are controlled experiments (Poorter *et al.* 2009) that have nutrient amendment or drought treatments that may or may not try to replicate variations in the availability of soil resources. Species growing in nutrient-poor soils exhibit traits that enhance resource conservation, including the use of physically robust (scleromorphic), long-lived leaves and the drawing of nutrients down to deficient levels before leaf fall. These traits have direct implications for extending nutrient residence time in biomass and reducing reliance on soil-derived nutrients.

(Borer et al., 2015; Guiz et al., 2016) showed that increasing ecosystem N availability can affect plant nutrient concentrations via mechanisms like altering the microbe-mediated N transformation process and decreasing P availability through Phosphorus binding to metal ions. It was concluded that High N availability might contribute to nutrient imbalances because the increase does not match the increase in the uptake of N in the uptake of other nutrients, e.g., K, Ca, and Mg (Li *et al.* 2011). According to studies (Moles *et al.* 2014), base cation depletion and soil acidification could cause N deposition to reduce plant K, Ca, and Mg concentrations across a variety of terrestrial ecosystems. In contrast, research revealed that the N supply increased plant K and Mg concentrations. The effects of plant species diversity on plants' nutrient concentrations (e.g., N, P, K) remain unclear. Due to the coupling relationship of elements in biogeochemical cycles, it is essential to determine the responses of multiple plant elements to plant species diversity in ecosystems with high N availability.

This research aims to study the relationships between soil nutrient status and nutrient-related leaf traits in an evergreen species, *Quercus leucotrichophora; and Schima wallichii* in temperate forest, in terms of leaf N and P concentration and reabsorption, knowing the relationships among them with other key leaf traits, and with soil features.

Chapter III

Materials And Methods

3.1 Description of Study Area

Shivapuri Nagarjun National Park is located in the country's mid-hills on the northern fringe of the Kathmandu valley and lies about 12 km. away from the center of the capital city. It covers an area of 159km^2 in the districts of Kathmandu Nuwakot and Sindhupalchowk, with 29 adjoining VDCs from the district. In the west, the protected area extends to the Dhadhing District (KMTNC, 2004). The Shivapuri Nagarjun National Park is one of Kathmandu Valley's main drinking water sources. According to the SHNP Management Plan from 2004, the park's elevation spans from 1350 m to 2732 m at Shivapuri summit. The majority of the park's land is, however, located between 1,600 m and 2,500 m above sea level..

Geographically, Shivapuri is located between 27°45" to 27°52" N and 85°16" to 85°45"E, and Nagarjuna is located between 27°43" to 27°46" N and 85°13" to 85°18" E. The area was gazetted as a national park in 2002. According to the 2011 SHNP Management Plan, the area was first designated as the Shivapuri Watershed Reserve in 1976 and the Shivapuri Watershed and Wildlife Reserve in 1984. According to the National Park and Wildlife Conservation Act of 1973 and the National Park and Wildlife Conservation Regulation of 1974, it was designated as the ninth National Park in the nation. It adopted the IUCN Management Category II of Protected area, covering an area of roughly 144 km2 in the Central Development Region districts of Kathmandu, Nuwakot, and Sindhupalchowk. Most precipitation falls between June and September during the monsoon season, which begins in June. The highest amount of annual precipitation, 3335.2 mm, was registered in 2011.

Shivapuri is plagued by land slides, gullies, sheet erosion on the sloping terraces, and stream bank erosion. Three major factors that contribute to these dangers are (a) the building of a road on the steep southern and northern slopes, (b) overgrazing, and (c) abandoned agricultural land that is vulnerable to overgrazing and has not been maintained with terraces. At an altitude of 1641 meters, this investigation was carried out in Shivapuri Nagarjun National Park's northern and southern regions..

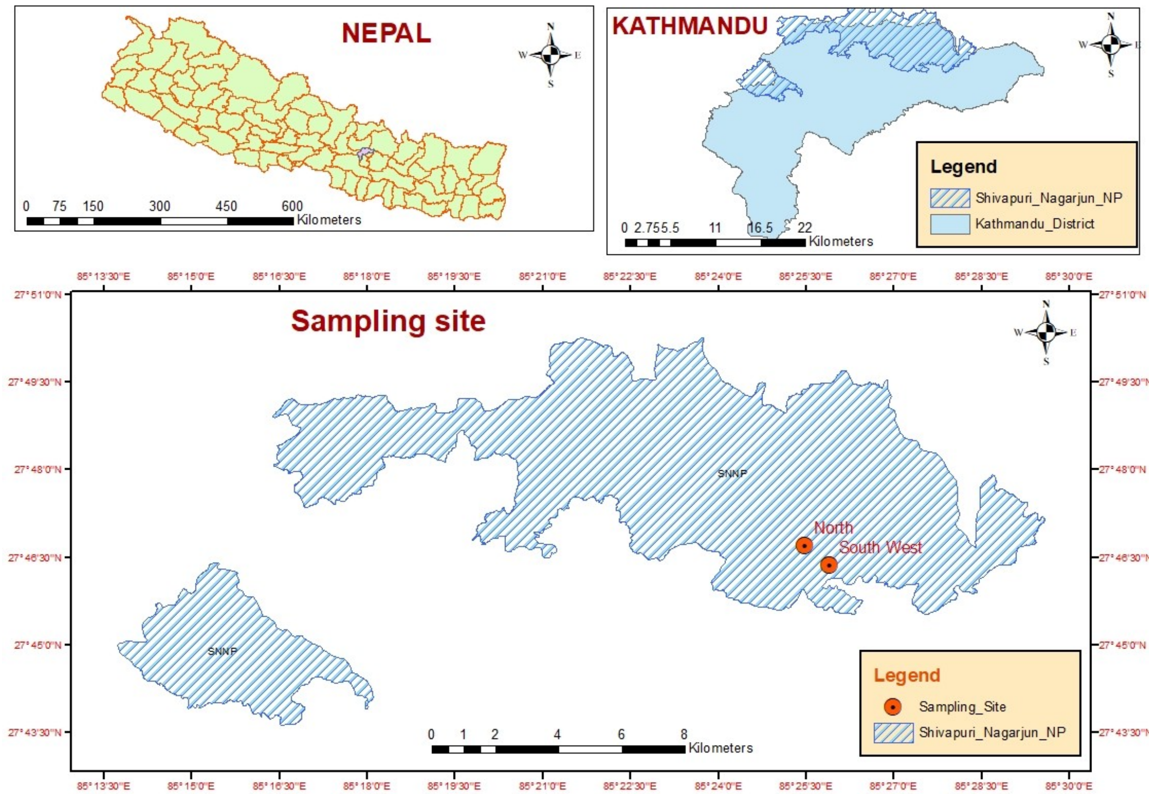


Figure 1: Map of the study area

3.2. Soil Properties of Shivapuri Nagarjun National park

It was found that Soils contain metamorphic rocks such as phyllite, limestone and dolomite, gneiss, and ingratiate, which are loamy on the northern aspect and sandy on the southern aspect. Gneiss and magmatite are among the most common rocks, along with mica schist and pegmatic granite. The soils in the area range from sandy loam on the southern slope to loamy sand on the northern side. Almost 50% of the park's land has steep slopes of above 30%, with mountains making up the majority of the topography. According to Shrestha, 1993, the runoff rate is usually low and the soil is highly nutrient-rich in most park regions because of the dense vegetation covering. In contrast, degraded forest regions had relatively high runoff ratesof runoff and soil erosion. The soil in Shivapuri Nagarjun National Park falls into the following categories: overused soil (1122 ha), soil that needs treatment (10,090 ha), soil that is being used to the best of its ability (6,491 ha), seriously used soil (9491 ha), and underused soil (2,350 ha) (KMTNC, 2004). There are three distinct seasons in this area: a wet (monsoon) season (June to September), a mild, dry winter, and a hot, dry summer (March to May).

3.3 Climate and Weather

Subtropical to warm temperate type of climate was found in Shivapuri Nagarjun National park. Hence, there is a high variation in annual temperature and precipitation. Nepal falls under the Indian sub-continent with rainy summer and dry winter seasons. Temperature and precipitation data within nine years (2010-2019) of the nearest meteorological station i.e., Kathmandu station, have been presented, where mean maximum temperature, mean minimum temperature, and average annual precipitation were recorded, respectively.

The maximum temperature recorded in 2010 ranged from 25o C-28 o C and the minimum temperature recorded in 2012 ranged from 10^{o} C -10.5^{o} C. Annual rainfall was maximum in 2013 with 1800mm and minimum rainfall recorded in 2017 with 1000 mm. In the year 2019 maximum temperature recorded was 26^{o} C and the minimum temperature recorded was 19^{o} C.

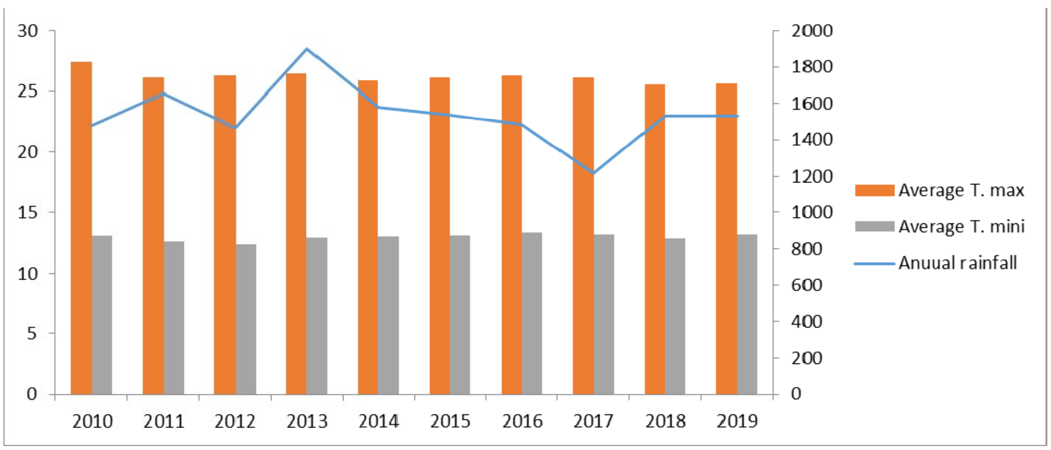


Figure2 Temperature and precipitation records of Kathmandu station of nine years (2010-2019).

(**Source: Department of Hydrology and Meteorology/ Government of Nepal.**

3.5 Vegetation of Shivapuri Nagarjun National Park

There are various environmental factors such as elevation slope, aspect, moisture, temperature, soil properties that determines the plants diversity. In the forest, the tree canopy determines the amount of light available on the ground surface. High tree canopy means low availability of light on the ground which is less favorable for the naturalized species. Disturbance leads to the destruction of resident biomass which results in the increase of resource availability and less competition for invaders from residents which facilitate the invasion process.

According to Stainton's (1972) list of plant species, floristic investigation revealed that Shivapuri's flora has both eastern and western species. In Shivapuri Nagarjun National Park, *Schima wallichii* and *castanopsis indica* are the two most prevalent species. *Alnus nepalensis* predominated in the damp, shaded sections of this belt, whereas pine forests may be found in the open, arid areas. *Pinus wallichiana* and *Pinus roxburghii* were the two most common trees. There were mixed oak forests in the middle belt (2000 m to 2300 m). In this belt, *Quercus lanata, Rhododendron arboreum,* and *Cyclobalanopsis glauc*a were the three most common trees (*Quercus glauca*). Oak forest are prevalent in the higher belt (2300 m to 2732 m). *Rhododendron arboreum, Quercus semecarpifolia*, and *Quercus lanata* were the three most common trees in this belt. Here the stems of *Quercus semecarpifolia* were thickened and the bifurcation of stem was distinct.

Shivapuri Nagarjuna National Park lies in a transition between subtropical and temperate climates. It supports rich flora and fauna diversity with the number of protected, threatened and endemic species of mammals, birds and plants. It harbors a total of 1250 plant species, including rhododendron, pine, and oak etc., with 16 endemic flowering plants, and 129 species of mushroom. KMTNC, 2004 reported that 16 endemic plant species found in this park are *Aechmanthera claudiae*, *Pteracanthus rotundifolius*, *Impatiens insignis*, *Impatiens leptoceras*, *Begonia flagellaris*, *Maharanga wallichiana*, *Silene pseudocashmeriana*, *Eriocaulon kathmanduense*, *Homalium napaulense*, *Ormosia glauca*, *Rotala rubra*, *Rubus hibiscifolius*, *Pedicularis wallichii*, *Carum diversifolium*, *Peucedanum nepalense*, *Pleurospermum rotundatum*.

At the Shivapuri National Park, 428 species of vascular plants from 112 families and 323 genera were recorded, according to Singh (2014). There are 50 species of pteridophytes, 3 species of gymnosperms, and 375 species of angiosperms among them (Dicotyledons 285 species and Monocotyledons 90 species). According to a floristic analysis, dicotyledons make up 65.9% of plant species, monocotyledons 21.5%, gymnosperms 0.7%, and pteridophytes 11.9%. Compositae (34 species), Gramineae (33 species), Leguminosae (17 species), Orchidaceae (16 species), Labiatae (14 species), Rosaceae (14 species), Rubiaceae (13 species), Cyperaceae (12 species), Polygonaceae (10 species), and Zingiberaceae are the ten largest families in the previous study with the highest number of species (9 species).

3.6 Species characters

3.6.1 Schima wallichii

Schima wallichii is an evergreen Schima tree called Needle wood Tree. *S.wallichii* belongs to the tea family, Theaceae. *S. wallichii* is a familiar tree that can grow in various climates, habitats and soils. It can grow in moderate light. It often occurs companionably in primary lowland to montane forests, but is particularly common in disturbed as well as secondary forests, grassland, and even in areas inundated with salty water. It was found that *Schima wallichii* is found chiefly up to 2400 (max. 3900) m, Mean annual temperature: of 0-5 to 37-45 deg. C, Mean annual rainfall: 1400-5000 mm. *S. wallichii* can grow in a wide range of soils. It usually prefers well-drained soils but has been observed in swamps and along rivers and is not choosy about soil texture or fertility. It is a valuable tree for reforestation and planting for water conservation in catchment areas.

3.6.2 Quercus leucotrichophora

Quercus leucotrichophora A. Camus An evergreen oak tree native to Asia, primarily in the Central Himalayas. The ideal places to grow Quercus leucotrichophora were in humid, temperate climates. In elevations ranging from 1500 to 2400 meters above sea level, the banj oak can be found. It does not grow on sandy, acidic soils; only loamy and clayey soils do. It thrives on soils with pH levels between neutral and basic (alkaline soils). While older trees need more sunshine, young trees thrive in the shade. The banj oak tree thrives primarily in damp soils. It can withstand heavy gusts but not exposure to the sea. The banj oak is appropriate for Himalayan Silvi-horticultural systems. The growth of oak forests boosted the soil organic matter content of abandoned denuded land.

3.7 Sample collection

Quadrat method was used in the field for the collection of leaf sample. All total thirty circular plots of 10 m radii were laid in each aspect(north and south). Leaf sample collection was carried out in three different stages i.e. early Leaf flushing time(Apr/May 2019), leaf maturation time(Sep/Oct 2019) and leaf senescence time(Dec/Jan 2019/2020). Twenty healthy leaves of selected species were collected from the every plot of the study site in both aspects. Leaves were collected from five fixed selected tree up to the height 2m from the ground level in every season in every plot for the equivalent result of the study. Leaves from healthy plants of each species that lies within the quadrat were taken for stomata observation and analysis. The altitude of each aspect was determined using GPS and the slope using clinometer. The dry weight of leaf was taken after drying in an oven at 60°c for 72 hours. The specific leaf area (cm^2/g) was calculated as a relation of leaf area (LA) / dry weight of leaf. Soil sampling was also conducted in three different seasons. Soil samples have been collected from 5 different places (i.e. 4 corners and center of the plot) of each quadrat up to 15 cm depth in field and put into the polythene bag for the laboratory analysis of soil organic matter, Nitrogen, Phosphorus, Potassium and Soil pH.

3.7.1 Vegetation analysis

Vegetation sampling was done using circular plots of radius 10m radii for trees at southern and northern aspect of Shivapuri Nagarjuna National Park. In each sample plot, the woody plant species(only tree) were recorded along with following structural attributes(DBH greater than 10cm, height greater than 20cm). All dominant species and associated species in each plot was observed and recorded. Most of the plant species were identified during field survey. Local name of the plants was identified with consultation of local people. Plants samples were made for unidentified species in field. These plants were then identified by consultation with experts nad using books by Polunin and stainton (1984), Staiton (1998) and Ghimire *et al.,* (2008). The quantitative data were used for the analysis of density and relative density; frequency and relative frequency; abundance and relative abundance, species richness and diversity index according to Zobel et al., (1987).

The formulae which were used for the calculation of these attributes are given below:

$$\textbf{Density of plants (D)} = \frac{\text{Total no. of species occured}}{\text{total no. of quadrat studied} * \text{area of quadrat}}$$

$$\textbf{Relative Density (RD)} = \frac{\text{Density of individual species} \;\; *100\%}{\text{Total density of all species}}$$

$$\textbf{Frequency (F)} = \frac{\text{Number of quadrat in which species occured} \;\; *100\%}{\text{Total no.of quadrat studied}}$$

$$\textbf{Relative Frequency (RF)} = \frac{\text{Frequency of individual species} \;\; *100\%}{\text{Total frequency of all species}}$$

$$\textbf{Abundance (A)} = \frac{\text{Total no.of individual species}}{\text{Total no. of quadrat in which species occured}}$$

$$\textbf{Relative Abundance (RA)} = \frac{\text{Abundance of individual Species} \quad *100\%}{\text{Total abundance of all species}}$$

Importance value index (IVI) = RD+ RF+RA

The sum of species richness and species evenness is referred to as species diversity. The number of species per sample unit is referred to as species richness, while the distribution of individual species within the specified sampling units is referred to as species evenness. when each species in the sample areas has an equal or nearly equal number of individuals There will be optimum evenness. The diversity of the species is reflected by a single index number. Because it is more susceptible to the most prevalent species than the unusual species, Simpson's index (C) represents the dominance. Following relations were utilized to generate Simpson's and Shannon-Weiner indices.

$$Simpson's\ Index(D) = \frac{\sum n(n-1)}{N(N-1)}$$

Simpson's index of diversity = 1-D

Shannon-Wiener diversity index (H) = -Σ Pi (Ln Pi)

$$\text{Evenness} = \frac{\text{Shanon diversity Index (H)}}{\text{Maximum Possible Value of H (Hmax)}}$$

Hmax = Ln (species richness)

Where, Pi = Proportion of individual species

3.7.2 Leaf analysis

3.7.2.1 Specific leaf Area(SLA)

Leaf length was measured by scale excluding the petiole, and breadth was measured in the widest part of the leaf. The estimated leaf area was calculated by multiplying the length and breadth of the leaves of every species, and the leaf area of the species was calculated by multiplying the leaf area and the coefficient factor of the Leaf (Poudyal *et al*. 2004). Then the specific leaf area was calculated by using the formula; **Leaf area/ dry weight of the leaf**, dry weight of the leaf was obtained from the oven dry weight of leaf at 60-70℃ up to 72 hours.

3.7.2.2 Leaf Nitrogen Concentration (LNC)

Leaves nitrogen was estimated by micro-Kjeldahl method (Karla, 1998) which helps the conversion of organic nitrogen into ammonia by boiling with conc. H2SO4; the ammonia was subsequently liberated from its sulphate by distillation in presence of an alkali, which was titrated against HCl. It had three predecessors. Digestion, Distillation and Titration.

Digestion: 0.2 gram of dry and sieved leaves, 2 gm. of digestion mixture and 10ml of conc. H_2SO_4 were taken in the digestion flask and the sample was digested in low heat until the frothing was stopped. Temperature was raised about 400°c taking care that the acid condenses at about one third the way up the neck of digestion flask. The flask was swirl at until the carbonaceous particle was present and the hue turned greenish blue at regular intervals. Before the mixture crystallizes, 40 ml of distilled water is added to the digested mixture after it has been cooled to room temperature. The digestion flask was washed with 3–4 lots of small amounts of the solution before being placed into a 100 ml volumetric flask to the mixture with gentle shaking. Then 20 ml. of 4%boric acid in 125 ml. Erlenmeyer flask was taken and 4 drops of mixed indicator was added and was placed under the condenser.

Distillation: The Kjeldahl distillation flask with digested materials was assembled on distillation chamber. 20 ml. of 40% sodium hydroxide solution was poured down the neck holding the flask at 45° angle so that it turns to the bottom of the flask without mixing. Now the flask was attached quickly to the distillation unit and swirl to mix. Then the distillation flask was heated to boiling but avoided sucking back of boric acid. Distillation was continued till the distillate is about 75 ml. Again the nitrogen was determined by titrating the distillate with 0.05 HCl. The color of the mixed indicator just changes from blue to reddish at the end point.

Calculation:

$$\% N = \frac{(S - B) \times n \times 14 \times 100 \times 100}{W \times 1000 \times 20} = \frac{(S - B) \times n \times 7}{w}$$

Where,

S = volume of standard acid (ml) used up by sample

B = volume of standard acid (ml) used up by blank

n = Normality of the standard acid.

W = oven dry weight of sample

14 = equivalent weight of nitrogen

20 = Aliquot

3.7.2.3 Available Leaf Phosphorus

Available leaves phosphorus was estimated by Vanadomolybdo- Phosphoric system method. Besides simplicity, it has greater tolerance to the interfering elements than any other methods. The acid concentration in the determination is not so critical however final concentration of 0.3N to 0.8N acidity is recommended. The sensitivity varies along 10 fold between the wave lengths 400 and 400µu with the higher sensitivity at the low wavelength. Therefore, for the determination of yellow color of Phosphorus, the 420µu wavelength is recommended.

Dry ash extract: 5 ml aliquot of extract solution was taken in 50 ml volumetric flask and was diluted to 35 ml. Now 10 ml of vanadomolybdate reagent and was diluted to 50 ml. with distilled water and was mixed. At that, the yellow color was measured after 20 min. at 420µu and as compared with that of the phosphorus standards.

Calculation:

$$\textbf{Ppm P in plant} = \frac{\textbf{ppm P in solution}}{\textbf{W}} \times \textbf{10}$$

Where,

W = oven dry weight of plant sample and 5 ml aliquot is taken from 50 ml dry ashing extract.

% P in plant = ppm P in plant x 100/ 10^6

Wet digestion extract: 10 ml. aliquot of the wet digestion extract was pipetted in 100 ml. of beaker and evaporate to dryness. The residue was dissolved in 5 ml. of 2N HNO3 warming if necessary. Now it was transferred to 25 ml. volumetric flask with distilled water and make up the volume. 10 ml. aliquot of the distilled solution was taken in the 50 ml. volumetric flask and proceeded to determine Phosphorus by vanadomolybdate phosphoric yellow methods as dry ashing extract.

Ppm P in plant= $\frac{\textbf{ppm P in solution} \times 10}{\textbf{W}}$

Where,

W = oven dry weight of plant sample and 10 ml aliquot is being used to controlthe acidity and 10 ml. aliquot was taken for color development.

% P in plant = ppm P in plant x 100/ 10^6

3.2.2.4 Leaf Carbon

Carbon content of leaves for each site was derived through the multiplication of biomass with 0.47, a carbon fraction in the dry biomass (IPCC, 2006).

3.2.3 Soil analysis

3.2.3.1 Soil pH

Soil pH was determined electronically on a direct-reading pH meter, using a glass electrode with a saturated potassium chloride (KCl)-calomel reference electrode. A 1:2.5 soil water ratio was used to prepare soil solution.

3.2.3.2 Soil Organic matter

Soil Organic Carbon was determined by Walkley and Black's rapid titration method (Walkley and Black, 1934).

Reagents:

- Standard 1N potassium dichromate
- 0.5N ferrous ammonium sulphate
- Diphenylamine indicator
- Concentrated sulphuric acid
- Sodium fluoride

Method:

1.0 g of soil was taken in a 500 mL conical flask and 10 mL of 1N $K_2Cr_20_7$ was added and swirled gently. Then 20 mL of H2SO4 was added and swirled gently again. The flask was allowed to stand for 30 minutes and then added 200 mL of distilled water. 0.5 g sodium fluoride and few drops of diphenylamine indicator were added. The contents were titrated with 0.5 N ferrous ammonium sulphate solutions till the color changed from blue-violet to green. Simultaneously, a blank was run without soil.

Calculations:

Carbon (%) = (1 - ......) (3.951 .....)Where,

B = Volume of ferrous ammonium sulphate used up for blank titration (ml)

S = Volume of ferrous ammonium sulphateused up for sample titration (ml)

W = Weight of soil sample taken (gm.)

3.2.3.3 Total Nitrogen was determined by Kjeldahl method.

Reagents:

- Digestion Mixture: 10 gm. of grinded copper sulphate with 200 gm. of sodium sulphate.
- Concentrated Sulphuric acid
- Sodium Hydroxide (40%)
- Mixed Indicator: 0.5 gm.Bromo cresol green and 0.1 gm. methyl red dissolved in 100 ml of 95% ethanol
- Boric acid (4%)
- 0.1N HCl
- Phenolphthalein Indicator

Method:

2 gm. soil was taken in a 50 ml kjeldhal Digestion flask. 2 gm. catalyst digestion mixture and 10 ml concentrated sulphuric acid were added. The solution was then swirled and gradually heated by increasing heat for several minutes till the sample turned turquoise. The solution was then allowed to cool for few minutes. Then distilled water was gradually added to the solution with swirling and made up to the volume. The solution was then transferred to a 100 ml volumetric flask, leaving the sand in the digestion flask and made up to the volume

20 ml aliquot with 20 ml of 40% NaOH was added to the distilling flask and distilled, collecting the liberated gas in 50 ml of 4% Boric acid solution containing few drops of mixed indicator. The final solution was then titrated with 0.01N HCl. A blank was run without soil.

Calculation:

Soil N (%) = 14 ×N × S−B ×100

Where,

N = Normality of HCl

S = Volume of HCl consumed with sample (ml)

B = Volume of HCl consumed with blank (ml)

M = Mass of soil taken (mg)

3.2.3.4 Available Phosphorus was determined by Olsen's Bicarbonate Method.

Reagents:

- Sodium bicarbonate ($NaHCO_3$) 0.5 M extracting solution
- Darco-G-60 or equivalent grade phosphorus free charcoal
- Ammonium molybdate solution
- Ascorbic acid solution
- Antimony potassium tartrate solution
- Sulphuric acid 2.5 M
- Using the above reagents, preparation of the Murphy-Riley color developing solution; In a 500 mL volumetric flask, 250 mL of 2.5 M H_2SO_4 was added, followed by 75 mL of ammonium molybdatesolution, 50 mL of ascorbic acid solution, and 25 mL of antimony potassium tartrate solution. Then 100 mL of distilled water was added and mixed on a magnetic stirrer.
- P- nitrophenol indicator
- Standard stock P solution preparation: After one hour of drying at 600 C in an oven and one hour of cooling in a desiccator, precisely 0.439 g of potassium dihydrogen orthophosphate (KH_2PO_4) of A.R. grade was dissolved in 500 mL of distilled water. The volume of the solution was increased by 25 mL by adding 7 N H_2SO_4, and 1 Liter by adding distilled water. From this, 5 mL of the solution was taken in a 100 mL volumetric flask and made up to the volume, yielding a 100 ppm stock solution of P (100 gP L-1). Thus, 5 ppm P solution (5 g P L-1) was produced.

Preparation of standard curve:

In order to prepare standard curve of P, 1, 2, 3, 4, and 5 mL of 5 ppm P solution were taken in 50 ml volumetric flasks. The extracting solution ($NaHCO_3$) (5 mL) was then added to them. Then 10 ml of distilled water and one drop of p-nitrophenol indicator were added. Then, drop by drop, 2.5 M H_2SO_4 was added until the solution was clear. The ideal pH (5.0) for color development was reached when the yellow color of the indicator vanished. If the end-point exceeded through addition of excessive acid, the pH could be brought back up again by adding NaOH.

To each flask 8 mL of the Murphy-Riley solution was added and the volume was made 50 mL with distilled water and blended. The P concentrations in these standards were 0.1, 0.2, 0.3, 0.4, and 0.5 g P mL-1. Using $NaHCO_3$ solution, distilled water, and Murphy-Riley reagent, a blank was created. The intensity of the blue color was measured at 730 nm after waiting for 15 minutes. To create a standard curve between absorbance values and the concentration of P in standards, absorbance values (readings) for the standards having 0, 0.1, 0.2, 0.3, 0.4, and 0.5 g P mL-1 were employed.

.**Method:**

- 2.5 g sample of air dried soil (ground to less than 2 mm) was taken in a 125 mL Erlenmeyer flask.
- A little of Phosphorus free Darco-G-60 or activated charcoal was added.
- To each flask 50 mL of $NaHCO_3$ solution at 250 C was added.
- Then shaken at 120 strokes per minute for 30 minutes on a reciprocating shaker.
- An uncontaminated blank was also run in a similar manner.
- Using Whatman No. 40 filter paper, the extract was purified. The filtrate was required to be refiltered if it was hazy.
  - A 50 mL volumetric flask was filled with a 10 mL aliquot of the extract, 10 mL of distilled water, and one drop of p-nitrophenol indicator. By gradually adding 2.5 M H_2SO_4 until the color vanished, the content was then acidified to pH.
  - After bringing the volume up to 50 mL with distilled water, 8 mL of the Murphy-Riley solution was added. After waiting for 15 minutes, the intensity of blue color was read on spectrophotometer at 730 nm (as in case of standard).

Calculation:

Available P (Kg ha-1) = C ×............ × 2.24 ......Where,

C = μg P in the aliquot (obtained from standard curve)

3.4.5 Available Potassium was determined by Flame Photometer method (Gupta, 2000).

Equipments and Reagents

- Flame photometer
- Centrifuge or shaker
- Erlenmeyer flask
- Neutral normal ammonium acetate solution
- Standard KCl solution

2.0 g of air dried soil was taken in a 125 ml conical flask and 20 ml of 1N ammonium acetate at pH 7 was added. The solution was shaken in a mechanical shaker for 5 minutes and then filtered through Whatman No 42 filter paper. A standard curve was drawn from the flame photometer readings of 0, 5, 10, 15, 20 and 25 ppm K standard solutions and potassium content in the soil was calculated by comparing the Flame photometer reading of soil solution with the standard curve.

Calculations

ppm K = R × 20/2

ppm K2O = R × 20/2 × 1.2 = R × 12

(K2O (kg/ha) = R × 12 × 2.24 = R × 26.88

2.24=kg/ha)

Where,

R = Potassium of soil extract in ppm from the standard curve.

20 = Volume of extraction solution taken.

2 = Wt. of soil taken. (1.2 = ppm K to K_2O)

3.2.3 Stomatal characterstics

Fresh leaves with fully matured leaf samples were collected from *Schima wallichii* and *Quercus leucotricophora* plants species and brought in the laboratory of Amrit Campus. In the laboratory, first of all the loose dust particles accumulated on leaf surface was cleaned by removing it with fine brush. A transparent imprint of 1cm^2 was prepared from a healthy leaf of average size by applying nail police on the abaxial surface at both sides of the main vein to a 1 cm^2 patch on the both sides of the main vein on the Leaf abaxial surface to make a transparent imprint of the leaf surface. After drying, the nail police was removed with pincers, and mounted it on a microscope slide. Stomatal density (SD) was estimated by counting the number of stomata fromtwo different slopes by using ocular scale micrometer of view on each leaf sample at 40 X 15 magnifications. From each of these images, the guard cell length and breadth of five randomly selected stomata were taken. Therefore, for each species, the stomatal density was calculated and the length of guard cells was measured.

3.2.5 Statistical analysis

Statistical analyses were statistically analyzed by using SPSS version 25.0 software packages. Data obtained was presented as mean ± standard deviation to understand the spread of important variables such as specific leaf area, leaf carbon content, leaf nitrogen content, leaf phosphorus content and soil parameter along with the aspect. Correlation coefficient analysis of the data was done between independent variables and dependent variable, that is, specific leaf area, carbon, nitrogen, Phosphorus and soil parameters. Generalized linear regression model analysis was applied for the inter-comparison of the parameters with using the value of R^2 (Coefficient of determination).

Chapter IV

4.1 Results

4.1.1 Important Value Index (IVI):

The important value index provides a quantitative basis for the claasification of community at northern and southern aspect of Shivapuri Nagarjuna National Park.

At Both aspect, highest IVI was recored for *Quercus leucotrichophora* followed by *Schima wallichii* and lowest IVI was recorded for *Myrica esculenta* at southern aspect and *Myrsine semiserrata* at northern aspect.

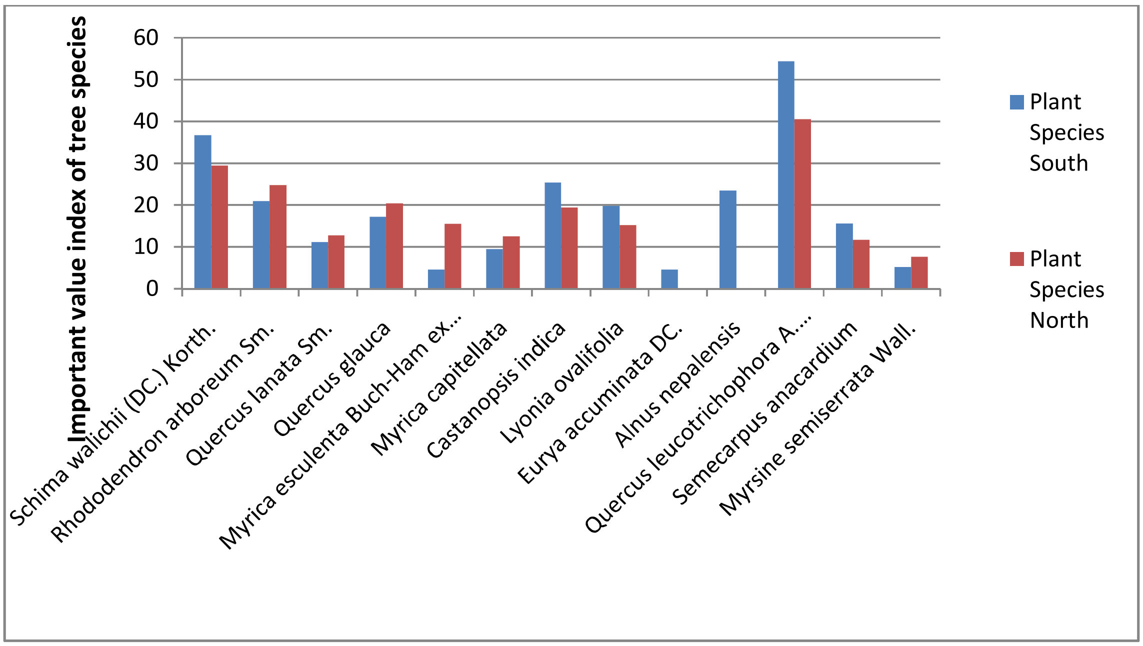


Figure 3: Importants Value Index for the studied plots in the Shivapuri Forest

The total number of tree species was highest in Southern aspect (Annex 2). The major associated tree species were *Rhododendron arborium, Quercus lanata, Quercus gluaca, Myrica esculenta, Myrica capitellata, castanopsis indica, Lyonia ovalifolia, Semecarpus anacardium and Myrsine semiserrata* at northren aspect, at southern aspect, *Alnus nepalensis*, and Eurya *accuminata* were most associated species recorded. At both aspect *Schima wallichii, Quercus leucotrichophora, Rhododendron arboreum, Castanopsis indica, Quercus glauca and Lyonia ovalifolia* were most frequent and dominant species.

Simpsons index for tree species was 0.24 and Shanon Wiener Index of species diversity was 2.64 while the evenness was 0.92 for Northern aspect. Similarly, Simpsons index for tree species was 0.76 and Shanon Wiener Index of species diversity was 3.13 while the evenness was 0.89 for Southern aspect.

Table 1: Species diversiy index of tree species along with aspect

	North Aspect	South Aspect
Simpson's diversity index(C)	0.2421	0.7613
Shanon's diversity index(H)	2.6434	3.143
Evenness	0.92	0.89

4.1.2 Specific leaf area(SLA)

Table 2: Showing mean specific leaf area(Mean value of SLA±S.D) of the species in northern and southern slope at different stage of leaf formation.

Stage	Slope	SLA(Q. leucotrichophora)	SLA(S.wallichii)
1(leaf flushing)	North	117.26± 25.38b	186.38± 30.83c
2(leaf maturation)	North	101.66± 20.87ab	152.44±41.16b
3(leaf senescence)	North	109.54± 16.46a	142.37±24.99ab

same alphabet in the row and coloumn after mean ± standard deviation do not differ significantly at $P < 0.05$, using one way Anova followed by Duncan multiple range test.

Stage	Slope	SLA(Q. leucotrichophora)	SLA(S.wallichii)
1	South	106.68± 21.65ab	171.51±29.49c
2	South	108.90± 17.51b	142.99±28.10ab
3	South	115.85± 31.15b	131.33±24.04a

same alphabet in the row and coloumn after mean ± standard deviation do not differ significantly at $P < 0.05$, using one way Anova followed by Duncan multiple range test.

From this study, while comparing the data of *Quercus leucotrichophora* species in Northern and Southern slope, the value of SLA was insignificant during Season 1(leaf flushing) and 2(leaf maturation) but there was significant change in Season 3(leaf senescence). Likewise comparing the seasonal data of SLA in *Schima wallichii* significant change was observed in season 1 and 2 of northern slope and in southern slope significant change was observed in season 1 and season 2 and also in Season 1 and season 3 as shown in figure below.

Table 3: The seasonal study of SLA between two species(*Quercus leucotrichophora* and *Schima wallichii*) showed the significant difference in the distribution.

Species vsAvg SLA

Total N	360
Mann-Whitney U	28145
Test Statistic	28145
Standard Error	987.2688968
Standardized Test Statistic	12.09903405
Asymptotic Sig.(2-sided test)	0

Since the p -value was less than 0.05, reject H_0, that means there was significant difference in distribution of average SLA between two species.

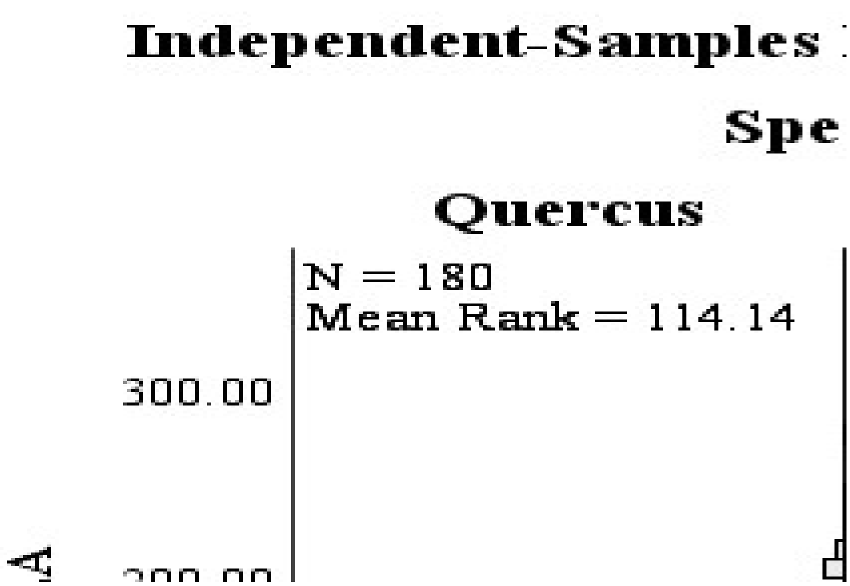


Figure 4: Showing variation in SLA between sampled species.

The result obtained from the analysis showed that the Specific Leaf Area (SLA) of the two species showed a significant different of both northern and southern aspect.

4.1.3 Correlation

4.1.3.1 Leaf trait variation and soil nutrients status of Q. leucotrichophora leaves in Northern aspects

Soil Nitrogen was weakly correlated with leaf Nitrogen and leaf Phosphorus. But soil Nitrogen had positive correlation with leaf carbon as shown in table 4.

Soil phosphorus was positively correlated with both leaf phosphorus and leaf carbon but negatively correlated with leaf nitrogen.

Soil carbon was negatively correlated with leaf phosphorus while soil carbon had positive correlation with leaf nitrogen *Q.leucotrichophora* and soil parameter.

Table 4: Relationship between soil and leaf parameter of *Q.leucotrichophora* at Northern Slope.

Northern soil parameter	**Leaf parameter of Quercus at Northern aspects**					
	Nitrogen		**Phosphorus**		**Carbon**	
	Corr. Coeff.(r)	**p-value**	**Corr. Coeff.(r)**	**p-value**	**Corr. Coeff.(r)**	**p-value**
Nitrogen	-0.521	0.150	-0.202	0.603	0.351	0.354
Phosphorus	-0.334	0.379	0.736	0.024	0.008	0.984
Organic matter	0.466	0.206	-0.471	0.201	-0.148	0.705

4.1.3.2 Leaf trait variation and soil nutrients status of Q. leucotrichophora leaves in Southern aspects

Soil Nitrogen was positively correlated with leaf Nitrogen. But soil Nitrogen was weakly correlated with leaf carbon and leaf Phosphorus. Soil phosphorus had positive correlation with leaf phosphorus, leaf nitrogen and leaf carbon. Soil carbon was negatively correlated with leaf carbon while soil carbon had positive correlation with leaf phosphorus and leaf nitrogen.

Table 5: Relationship between leaf parameter and soil parameter of *Q.leucotrichophora* at Southern slope

South soil parameter	Leaf parameter of Quercus at Southern aspects					
	Nitrogen		Phosphorus		Carbon	
	Corr. Coeff.(r)	p-value	Corr. Coeff.(r)	p-value	Corr. Coeff.(r)	p-value
Nitrogen	0.071	0.856	-0.149	0.703	-0.038	0.923
Phosphorus	0.567	0.112	0.299	0.435	0.024	0.951
Organic matter	0.652	0.057	0.707	0.033	-0.066	0.865

4.1.3.3 Leaf trait variation and soil nutrients status of S. wallichii leaves in Northern aspects

Soil Nitrogen had positive correlation with leaf Nitrogen. But soil Nitrogen was weakly correlated with leaf carbon and leaf phosphorus. Soil phosphorus was positively correlated with leaf phosphorus, leaf carbon and leaf nitrogen. Soil carbon was negatively correlated with leaf phosphorus, leaf nitrogen and leaf carbon.

Table 6 : Relationship between soil and leaf parameter of *Schima wallichii* at Northern Slope

North soil parameter	Leaf parameter of Schima at Northern aspects					
	Nitrogen		Phosphorus		Carbon	
	Corr. Coeff.(r)	p-value	Corr. Coeff.(r)	p-value	Corr. Coeff.(r)	p-value
Nitrogen	0.444	0.231	-0.189	0.626	-0.076	0.847
Phosphorus	-0.046	0.907	-0.518	0.153	0.164	0.673
Organic matter	-0.111	0.776	0.464	0.209	0.068	0.863

4.1.3.4 Leaf trait variation and soil nutrients status of S. wallichii leaves in Southern aspects

Soil Nitrogen was positively correlated with leaf Nitrogen. But soil Nitrogen was weakly correlated with leaf carbon and leaf Phosphorus. Soil phosphorus was negatively correlated with both leaf phosphorus and leaf nitrogen but positively correlated with leaf carbon. Soil carbon was negatively correlated with leaf nitrogen while soil carbon had positive correlation with leaf phosphorus and leaf carbon.

Table 7: Relationship between soil and leaf parameter of *Schima wallichii* at Southern Slope

South soil parameter	**Leaf parameter of Schima at Southern aspects**					
	Nitrogen		**Phosphorus**		**Carbon**	
	Corr. Coeff.(r)	**p-value**	**Corr. Coeff.(r)**	**p-value**	**Corr. Coeff.(r)**	**p-value**
Nitrogen	0.316	0.408	-0.148	0.704	-0.152	0.696
Phosphorus	0.201	0.604	0.538	0.135	0.143	0.713
Organic matter	-0.422	0.258	-0.077	0.843	-0.179	0.645

4.1.4 Stomata Analysis

Table 8: Stomatal density of selected plant species

S.N	**Stomatal Density of *Schima wallichii***	**Stomatal Density of *Quercus leucotrichophora***
1	521.52	417.22
2	563.25	354.64
3	458.94	438.08
4	542.39	396.36
5	584.11	312.91
6	417.22	479.80
7	479.80	271.19

8	625.83	375.50
9	438.08	458.94
10	604.97	521.52
Mean	**523.61**	**402.62**
Standard error	**22.947**	**24.302**

There was a marked variation in the density of stomata in the plant leaves of *Schima wallichii* and *Q. leucotrichophora* (Table: 9). The density of stomata was found higher in all the plant leaves of *Schima wallichii* than in *Q. leucotrichophora.*

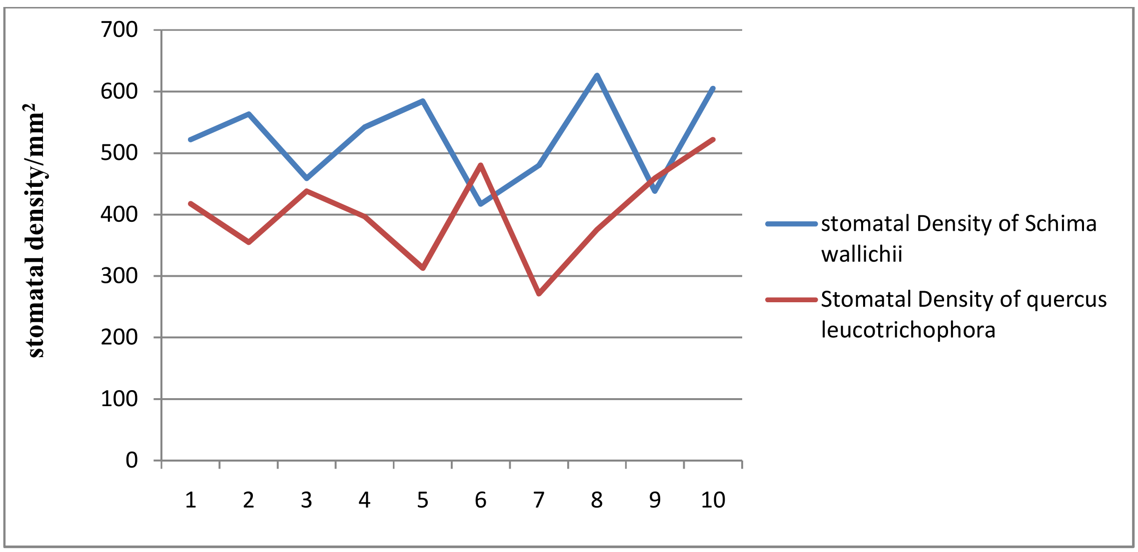


Figure 5: variation of stomatal density between the species.

4.1.5 Regression analysis between leaf and soil parameter

Here, Soil nitrogen significantly decreased with increasing leaf nitrogen of *Quercus* plant (R^2= 0.008) as shown in figure 6.

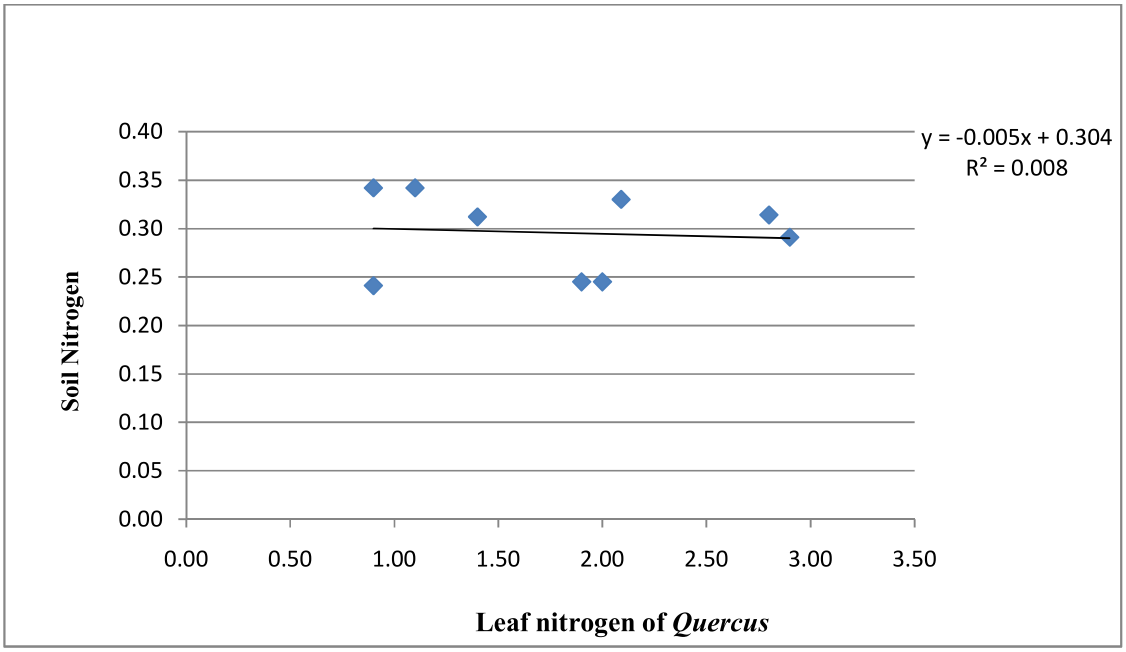


Figure 6: Relationship between Soil Nitrogen and Leaf Nitrogen of *Quercus leucotricophora*

Here, soil phosphorus slightly decreased with increasing leaf phosphorus of *Quercus leucotricophora*(R^2=0.134) as shown in figure 7.

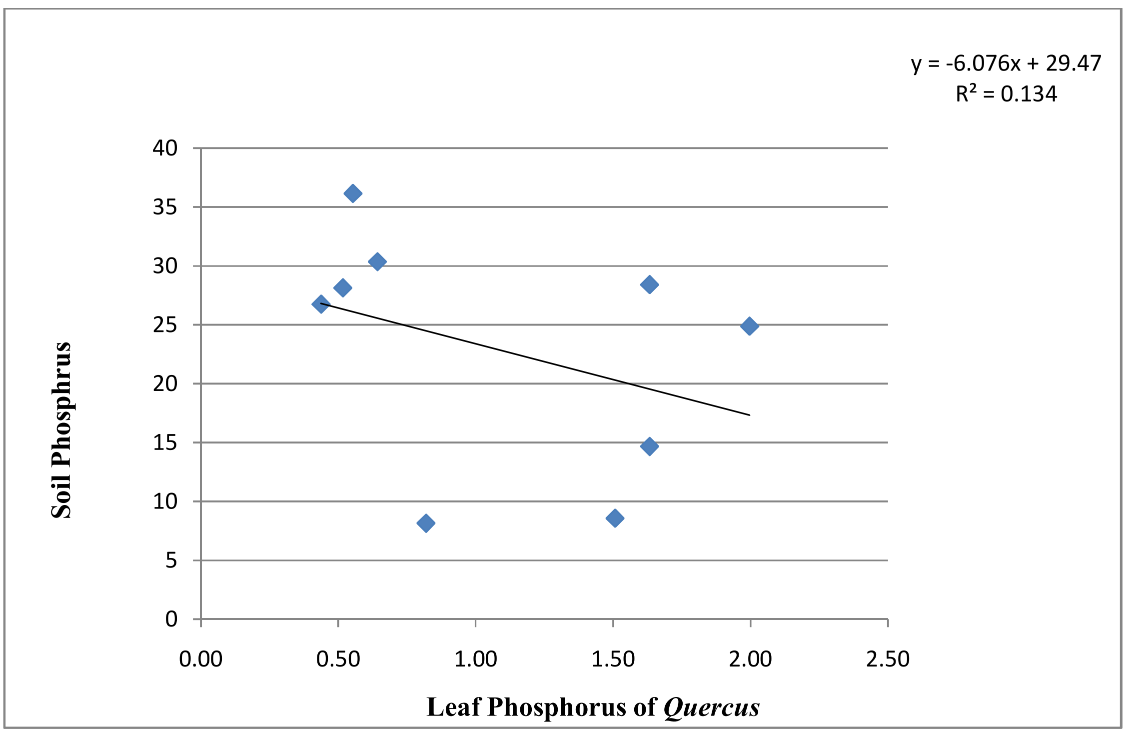


Figure 7: Relationship between Soil phosphorus and Leaf phosphorus of *Quercus leucotricophora*

Here, soil nitrogen was significantly increasing with increasing leaf nitrogen of *Schima wallichii* (R^2=0.203) as shown in figure 8.

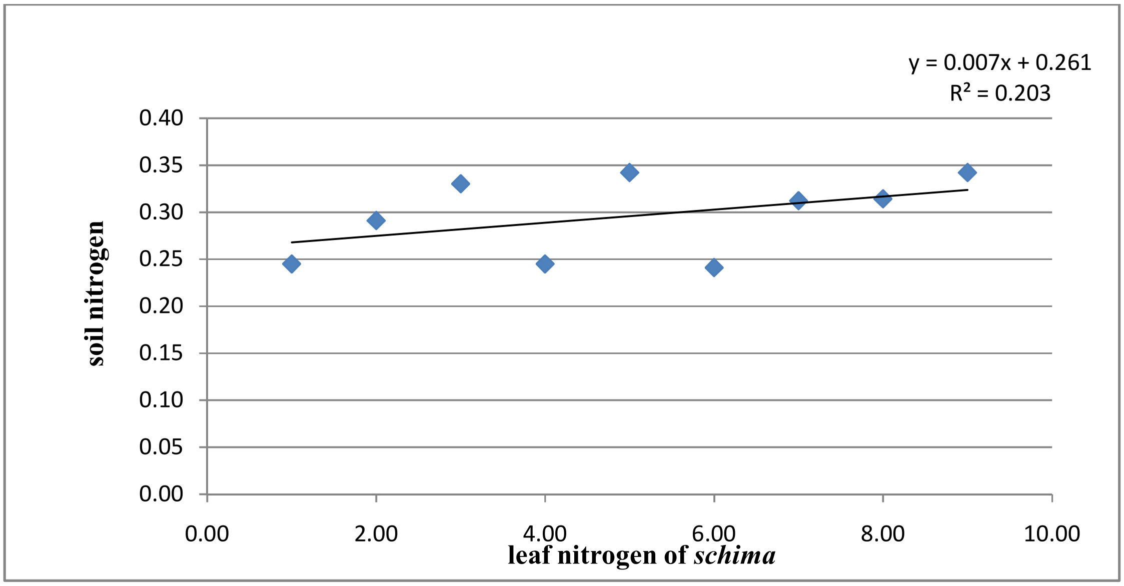


Figure 8: Relationship between Soil Nitrogen and Leaf Nitrogen of *Schima wallichii*

Here, soil phosphorus decreased with increasing leaf phosphorus of *Schima wallichi i*(R^2=0.043) as shown in figure 9.

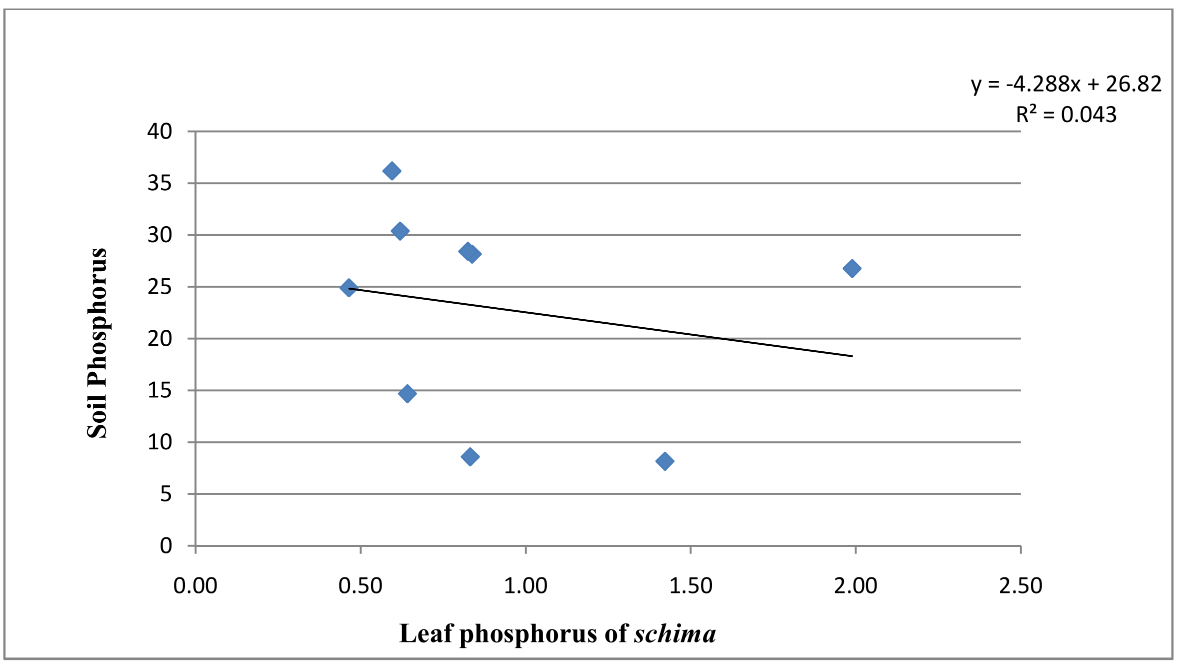


Figure 9: Relationship between Soil Phosphorus and leaf phosphorus of Schima *wallichii*

Here, Soil Nitrogen significantly increased with increasing soil pH in northern aspect (R^2=0.267) as shown in figure 10.

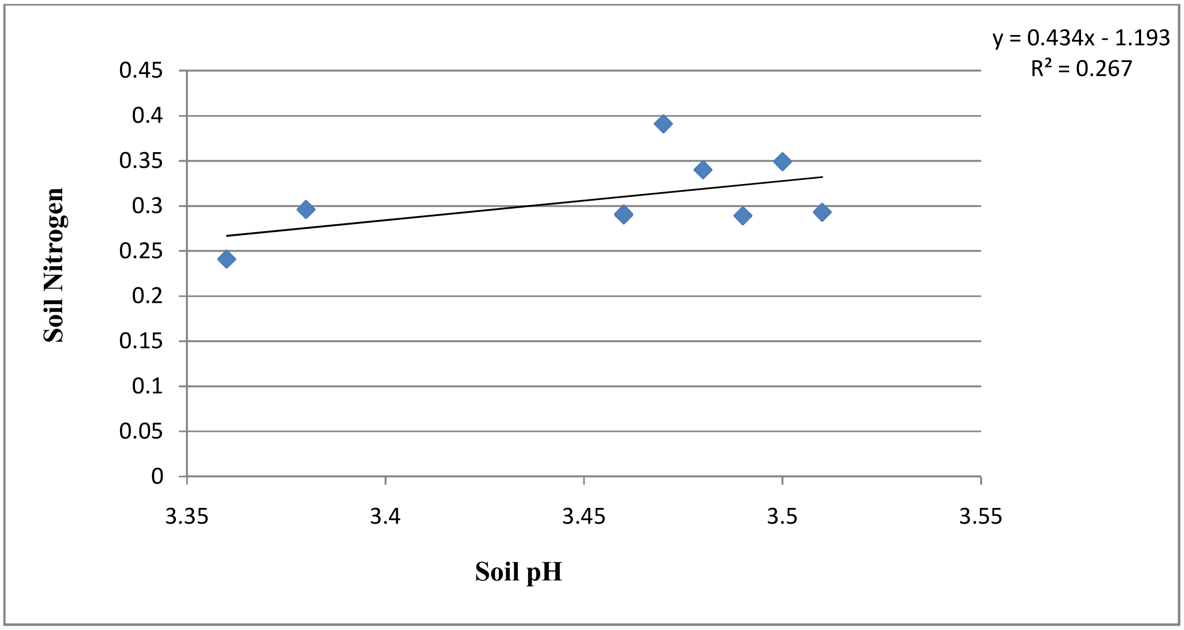


Figure 10: Relationship between soil Nitrogen and soil pH in northern aspect.

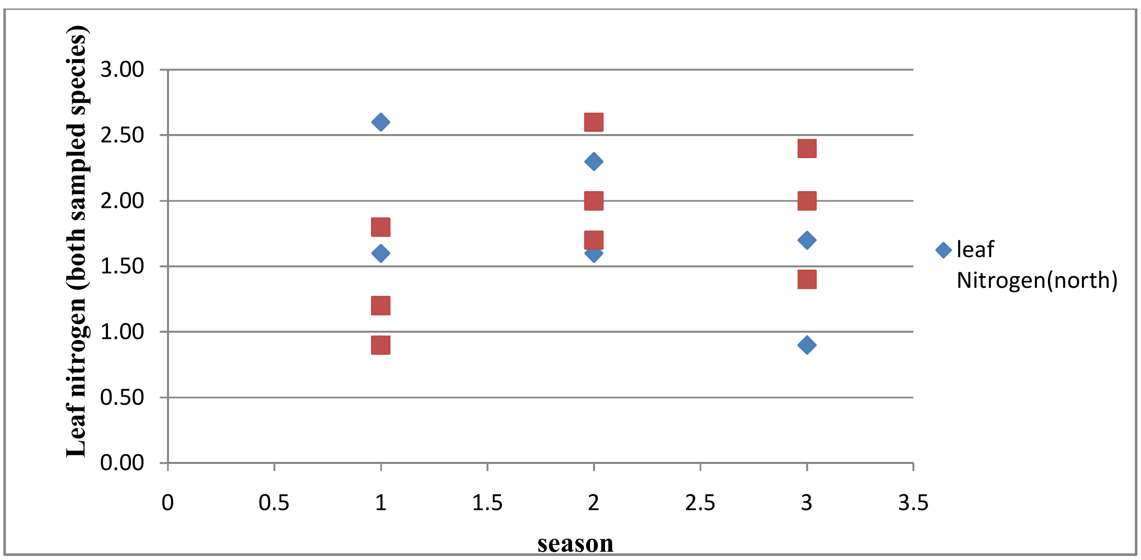


Figure 11: Distribution of leaf nitrogen in both aspects

Leaf Nitrogen concentration(%) was found to be higher in leaf maturation stage compare to leaf flushing and leaf senescence stage shown in figure 11. Leaf Maturation stage, the physiological and developmental growth of plant can take place however the SLA of Plant leaf was also found to be higher in that stage. That's why the number of photosynthetic tissue was found to be higher and the leaf nitrogen of both sample species was found to be higher.

4.1.6 Relationship between Important Value Index of Tree species and Soil Nutrients

Table 9: Relationship between Important value index of trees and south soil nutrient

		IVI of Plant	Phosphorus	Potassium	Nitrogen
Pearson Correlation	IVI of Plant	1.000	0.581	0.287	-0.327
	Phosphorus	0.581	1.000	0.256	0.150
	Potassium	0.287	0.256	1.000	-0.253
	Nitrogen	-0.327	0.150	-0.253	1.000

Table 10: Relationship between Important value index of trees and North soil nutrient

		IVI	potassium	nitrogen	phosphorus
Pearson Correlation	IVI	1.000	0.441	0.369	0.395
	potassium	0.441	1.000	0.624	0.765
	nitrogen	0.369	0.624	1.000	0.753
	phosphorus	0.395	0.765	0.753	1.000

The Important Value Index (IVI)of tree species is positively correlated with soil phosphorus and Potassium but had negative correaltion with soil nitrogen in southern aspect but Tree IVI is positively correlated with all soil parameter (NPK) in Northern aspect.

Chapter V

5.1 Discussion

According to research, plant relative growth rates, leaf carbon assimilation rates, and energy supply are all positively correlated with leaf traits like SLA, LNC, and LPC (Lambers and Poorter, 1992: Lavorel and Garneir 2002:, Niklas et al. 2005). It should also be emphasized that plants supplied particular response on soil nutrients and effects on soil nutrient availability (Booth et al. 2005). Plant response patterns and feedback on soil nutrient supply reflect a nutrient exchange in plant growth and development and reflect some plant functions. SLA is highly used in ecological studies and can explain plant productivity (Madani et al. 2017). SLA reveals significant significance in influencing plant productivity, as changes in Leaf SLA reflect changes to the structure and nutritional content of leaves. However, because of practical and logistical constraints, studies of SLA mainly provided data on differences among only a few species or species from a limited geographical area (Fonseca et al. 2000).

5.1.1 Vegetation Analysis

The patterns of distribution of plant species was not uniform along with aspect due to various micro climate. The highest number of species was found in southern aspect than in northern aspect. Generally, the north slope aspect of hills in Nepal is moist, and the south is drier, Accoding to Panthi *et al*., 2007, higher species richness in the north slope aspect than the south in Manang valley. The growth rate of plants in the south-facing slope aspect may be less than the North aspect due to high solar radiation and less moisture. Kutiel and Lavee 1999 shows that water plays a deterministic role in the composition, structure, and density of plant communities. It confirms that water and solar radiation play a leading role in species richness and species distribution in different aspects of any landscape or all continents or countries.

5.1.2 Specific leaf area

In the seasonal study of SLA, there was a significant difference between two species viz. *Schima wallichii* and *Quercus leucotrichophora*. In the present study, the SLA of Schima wallichii was higher in Leaf flushing stage than in the other two (leaf maturation and leaf senescence stage) in both geographical aspects (north and south). In the immature stage leaf was very thin and density of leaf was low, whereas in mature stage of Leaf SLA decreased as a result of increasing leaf thickness and density of the leaf. This increment might result from cuticle thickening and secondary cell wall development in the leaves after expansion ceases(Pieters, 1974). Decreases in SLA on leaves ageing might also be associated with retention of current photosynthate in mature leaves(Isebrands *et al*., 1983), adsorption and retention of calcium and other mineral elements(Zelawski and Walker 1976), shrinkage(Hackett, 1973) or continued cambial development in mature leaf petiole(Isebrands and Larson, 1977).

Similarly, In SLA of *Quercus leucotrichophora*, slight different has been occurred in all three stages i.e. leaf flushing, leaf maturation and leaf senescence period in both geographical aspects whereas in leaf flushing stage, SLA of *Quercus leucotrichophora* was high at northern aspect than at southern aspect. In leaf maturation stage and leaf senescence period ,SLA of *Quercus leucotrichophora* was found to be higher in southern aspect than at Northern aspect. Northern aspect was always moist due to lack of sunlight, so the leaf area of the leaf was less by using low amount sunlight. But in southern aspect, sunlight was always present. Therefore the leaf of the plant species used excess amount of sunlight for their livelihood. Using excess water and sunlight, leaf area of the species would be increased. But in leaf flushing stage, SLA of *Quercus leucotrichophora* was found to be higher in northern aspect than in southern aspect. This might be due to excess amount of soil moisture during leaf flushing stage. Both specific leaf area and leaf nitrogen have a close relationship with water-use efficiency. Increasing leaf nitrogen can enhance a plant cell's photosynthetic capacity and osmotic pressure, facilitating the conservation of water inside the plant. Low specific leaf area can limit the amount of water and carbon-dioxide reaching the chloroplasts, and also further limit the photosynthesis rate (Li *et al.* 2005).

Analysis of species traits and distributions shows that the trend towards smaller leaves on exposed slopes was due to a reduction in minimum leaf size, not an overall shift from larger to smaller leaves. Large-leaved species were seen all along the slope, but small-leaved species mainly were found on south-facing slopes at the high exposure end. The change in mean leaf size with exposure is commonly interpreted in terms of the advantages of small leaves for maintaining leaf temperatures in hot environments. The distribution seen here, however, indicated that the change in mean leaf size was brought on by the absence of small-leaved plants on slopes that faced north. The small-leaved species on south-facing slopes included drought-tolerant sclerophylls dominating these community portions. The lack of small-leaved species On less exposed, north-facing slopes might reflect greater competition for light and the lower efficiency of small leaves for light capture and shading of neighbors.

5.1.3 Relationship Between soil parameter and leaf parameter

5.1.3.1 Relationship Between soil parameter and leaf parameter of Schima wallichii

In Southern slope, Soil Nitrogen had positive correlation with leaf Nitrogen. But soil Nitrogen was weakly correlated with leaf carbon and leaf phosphorus. Soil phosphorus was positively correlated with leaf phosphorus, leaf carbon and leaf nitrogen. Soil carbon was negatively correlated with leaf phosphorus, leaf nitrogen and leaf carbon. But in Northen slope, Soil Nitrogen was positively correlated with leaf Nitrogen. But soil Nitrogen was weakly correlated with leaf carbon and leaf Phosphorus. Soil phosphorus was negatively correlated with both leaf phosphorus and leaf nitrogen but positively correlated with leaf carbon. Soil carbon was negatively correlated with leaf nitrogen while soil carbon had positive correlation with leaf phosphorus and leaf carbon.

5.1.3.2 Relationship Between soil parameter and leaf parameter of Quercus leucotrichophora

In Northen Slope, Soil Nitrogen was weakly correlated with leaf Nitrogen and leaf Phosphorus. But soil Nitrogen had positive correlation with leaf carbon. Soil phosphorus was positively correlated with both leaf phosphorus and leaf carbon but negatively correlated with leaf nitrogen. Soil carbon was negatively correlated with leaf phosphorus while soil carbon had positive correlation with leaf nitrogen**.** But in Southern slope, Soil Nitrogen was positively correlated with leaf Nitrogen. But soil Nitrogen was weakly correlated with leaf carbon and leaf Phosphorus. Soil phosphorus had positive correlation with leaf phosphorus, leaf nitrogen and leaf carbon. Soil carbon was negatively correlated with leaf carbon while soil carbon had positive correlation with leaf phosphorus and leaf nitrogen.

Variation in community scale leaf traits could also influence geographic patterns in nitrogen and Phosphorus. If climate variation alters leaf life span or leaf mass per area, these changes could affect leaf nitrogen and Phosphorus was given the generally close association of these leaf attributes(Reich *et al.* 1991, 1997). Several studies from regional to global scale found that leaf phosphorus for various plant group and different geographical region can be more variable and more strongly related to the climatic condition and soil nutrients compared to leaf nitrogen(Mingzhu *et al*. 2014).

Different plants form dominant species distributions due to differences in climate (Ordonez et al. 2009; Moles et al. 2014; Athokpam and Garkoti, 2015). Nitrogen and Phosphorus are consequently closely related and crucial growth factors, as research has repeatedly demonstrated. Fast-growing plant typically needing a Phosphorus rich environment to support the synthesis of proteins and molecules such as ribosomes, ATP and RuBisCo. Nitrogen and Phosphorus are common limiting factors for plant growth. According to earlier research, soil phosphorus and nitrogen are derived from different sources because, while the decomposition of organic matter largely produces nitrogen, Phosphorus is primarily derived from rock weathering and reflects the physical and chemical characteristics of the rock (Hedin, 2004). That's why leaf phosphorus is highly susceptible to environmental influences

(Huang *et al*. 2019). There was a significant impact between leaf and soil phosphorus, increasing soil phosphorus decreasing the leaf phosphorus content.

5.1.4 Stomatal Density

There was no significant relationship between leaf area or any of the stomatal variables with aspect but was significant between the selected plant species. Leaf morphological traits, including stomatal density and distribution, and epidermal features may affect gas exchange quite remarkably and their relationships with key environmental factors such as light, water status, and CO_2 levels (Woodward, 1987; Nilson and Assmann, 2007). Variation in size and density of stomata may arise due to genetic factors and/or growth under different environmental condition.

5.1.5 Leaf Nitrogen(LN)

In *Schima* species, leaf nitrogen was higher in leaf maturation stage and in *Quercus* species leaf nitrogen was higher in leaf flushing stage(before rainy season) in northern slope. In both species Leaf nitrogen was found to be higher in leaf maturation(after rainy season) stage in southern slope. Ruizang *et al.*(2018) *c*oncluded that high nitrogen content may be a result of the moist weather, which increased the activity of microorganisms that fix nitrogen. In the moderate altitude of my study region, the soil was drier than at higher altitudes. The reduced nitrogen value was brought on by erosion and leaching losses. Though nitrates are highly soluble in water, it is lost during the rainy season. Also, as the growing season is the wet season, the majority of the total mineral intake and incorporation was finished before the rapid rise in Mass started. Increased nitrogen content during the dry season was caused by biological fixation of nitrogen, a slower rate of leaching, and increased nitrogen-fixing bacterial activity. Another region of the country's nitrogen content trend was also noted.

5.1.6 Leaf Phosphorus (P)

In *Schima* species leaf phosphorus was found to be higher in leaf flushing stage and in *Quercus* species leaf phosphorus was found to be higher in leaf senescence stage in northern stage. In *Schima* species leaf phosphorus was found to be higher in leaf maturation stage and in *Quercus* species leaf phosphorus was found to be higher in leaf flushing stage in southern stage. Due to varying climates, many plants create dominant species distributions (Ordonez et al. 2009; Moles et al. 2014; Athokpam and Garkoti, 2015). Because of this close relationship and significance to growth, research has repeatedly proven that Phosphorus and nitrogen are interrelated. There was a substantial relationship between the phosphorus content of the soil and the leaves; as soil phosphorus increased, leaf phosphorus content decreased. The quick consumption of Phosphorus by massive trees and regenerated plants may be to blame for the low concentration. Iron and aluminum phosphate formation contributed to the low value of Phosphorus.

5.1.7 Leaf carbon

Large individual trees account more carbon proportion(Mwakisunga *et. al.* (2012). In *Schima* species leaf carbon was found to be higher in leaf senescence stage and lower in leaf flushing stage in both slopes. In *Quercus* species leaf carbon was found to be higher in leaf maturation stage in both slopes and lower in leaf flushing stage. The carbon storage was observed low at leaf flushing stage. The reason might be related with the absence of more productive stem density in the first growing phase than in other stages. An aspect plays a key role in both aboveground and belowground carbon storage and can be influenced by different factors such as natural factors, environmental factors, environmental variables i.e. altitude, physical factors and human disturbances (Sheikh *et al*. 2009). This study had shown variation on carbon storage and the reason might be the area was affected by environmental variables i.e. season followed by canopy cover, species diversity.

5.1.8 Soil pH

It was discovered that the soil in the Shivapuri forest was acidic. The pH scale ranged from (3.5 – 3.6. in south and 3.3-3.6 in north). The pH of the soil in the study region fluctuated throughout all stages and ranged from 3.3 to 3.6 during leaf flushing, leaf maturation and leaf senescence. The dry season had a higher pH than the wet. High levels of microbial activity during the rainy season might be to responsible for the production of $CO2$, humic acid, fulvic acid, and other inorganic acids.

5.1.9 Organic Matter (OM)

At both the southern slope and the northern slope, leaf maturation time corresponded to higher soil organic matter levels. In North, the OM ranged from 4.5% to 12%, and in the South, it was 7.5% to 14%. The primary source of minerals returning to soil is organic matter (OM), which is made up of soil-dwelling micro- and macroorganisms as well as the dead corpses of plants and animals. The average OM content was high in all leaf maturation time. This study's results were remarkably similar to those from a previous one conducted in Shivapuri (Singh 2014).

5.1.10. Relationship between Important value index of tree species and soil parameter

The Important Value Index (IVI)of tree species is positive correlated with soil phosphorus and Potassium but had negative corealtion with soil nitrogen in southern aspect but Tree IVI is positively corelated with all soil parameter(NPK) in Northern aspect a shown in table 10 and 11.

The forest structure attributes are closely related to many soil parameters. soil nitrogen, available P and K are the main factors affecting the variation in species richness in degraded forest(Lui *et al*., 2011).Summarized explanation of forest structure and soil properties correlation results could be that soil conditions differs between the forest types. It should be pointed out, that forest composition not only affects soil but that soil properties also govern forest composition and diversity (Wardle *et al.,* 2004). The relationships between forest vegetation and edaphic factors established here may be utilized to conserve preferred species. In this study, the result should be affected by litter deposition, light intensity and soil type that found in forest area as well as adaptaion featutre of tree species in that area.

Chapter VI

Conclusion

Both sampled species showed significant relationship between leaf parameter and soil parameter. The study showed that aspect as well as different life stages (leaf flushing, leaf maturation and leaf senescence) of *S.wallichii andQ. leucotrichophora* leaves were significantly influenced and showed effect on specific leaf area, leaf nitrogen content, leaf carbon content, and leaf phosphorus content as the value continually changed.

The seasonal study of SLA between two species(*Quercus leucotrichophora* and *Schima wallichii*) showed the significant difference in the distribution in both aspects whereas the relationship between leaf nitrogen, leaf phosphorus and soil nitrogen, soil phosphorus showed a fluctuating value in all developing stages of leaf in both aspects. Leaf phosphorus for various plant groups and different geographical regions could be more variable and more strongly related to climate condition and more strongly related to climate condition and soil nutrients compared to leaf nitrogen. Soil of study area was found to be acidic but northern aspect was less acidic than southern aspect. Soil organic matter was highly deposited in northern aspect due to low microbial activity.

This study concluded that the leaf nutrients were significantly fluctuated with some soil nutrients but most of the leaf nutrient did not show any fluctuation with soil parameter .The most fluctuating leaf parameters(nutrients)were leaf nitrogen with Soil Nitrogen.

REFERENCES:

A gren, G. I. (2008). Stoichiometry and nutrition of plant growth in natural communities. Annual Review of Ecology, Evolution, and Systematics, 39, 153–170.

Abbas, M., Ebeling, A., Oelmann, Y., *et al*. (2013). Biodiversity effects on plant stoichiometry. Plos One, 8, e58179.

Aerts, R. (1999) Interspecific competition in natural plant communities: mechanisms, trade-offs and plant-soil feedbacks. *Journal of Experimental Botany*, **50**, 29–37.

Aerts, R. and Chapin, F.S (2000). The mineral nutrition of wild plants revisited: a re-evaluation of processes and patterns. *Advances in Ecological Research*, **30**, 1–67.

Athokpam, F.D. and Garkoti. S. C. (2015).Dynamics of foliar nitrogen of evergreen and deciduous species in a wet tropical forest South Assam, India. *Plant Ecology*, **216**, 1117-1135.

Berry, S. L. and Roderick, M. L. (2002). Estimating mixture of Leaf functional types using continental- scale satellite and climatic data. *Global Ecology and Biogeography Letters*, **11**, 23-29.

Bist, M.S., Adhikari, M.K. and Rajbhandari, K.R 2001. *Flowering plant of Nepal(Phanerogames*). Department of Plant Resources, Kathmandu, Nepal.

Bohan, G. B., Levis, S. Kergoat, L. and Oleason, K. W. (2002). Landscape as patches of plant functional types: an intregating concept for climate and ecosystem models. *Global Biogeochemical Cycles,* **16**, 1021.

Booth, M. S., Stark, J. M. and Rastetter, E. (2005).Controls on nitrogen cycling in terrestrial ecosystems: a synthetic analysis of literature data *Ecology Monograph*., **75**, 139-157.

Borer, E. T., Lind, E. M., Ogdahl, E. J. (2015). Food - web composition and plant diversity control foliar nutrient content and stoichiometry. Journal of Ecology, **103,** 1432–1441.

Cleland, P.B., Walters, M. B. and Ellsworth, D.S. (2007). Leaf lifespan in relation to leaf, plant, and stand characteristics among diverse ecosystems. *Ecological Monographs*, **62**, 365–392.

Cordell, S., Goldstein, G., Meinzer, F.C. & Vitousek, P.M. (2001) Morphological and physiological adjustment to N and P fertilization in nutrient-limited

Metrosideros polymorpha canopy trees in Hawaii. *Tree Physiology*, **21**, 43–50.

Daneshgar, P.P., Polley, H. W. and Wilsey, B.J. (2012). Simple plant traits explain functional group diversity decline in novel grassland communities of Texas. *Plant Ecology,* **214,** 231–241.

Daniel, P. Schachtment, Robert, J., Reid, S.M., Alying. (1998). Phosphorus uptake by plants from soil to cell .*American society of plant physiologists,* **116**, 447-453.

Daniel, P., Schachtman, Reid, R.J. and Alying, S.M. (1998). Phosphorus uptake by plant; from soil to cell .*Plant physiology,* **116 (2),**447-453.

Deyn, G. B. D., Quirk, H., Yi, Z. (2009). Vegetation composition promotes carbon and nitrogen storage in model grassland communities of contrasting soil fertility. *Journal of Ecology,* **97,** 864–875.

Epstein, E. and Bloom, A.J. (2005). Mineral Nutrition of Plants: Principles and Perspectives. 2nd Edition, *Sinauer Associates*, Sunderland.

F Stuart Chapin, 1980. The Mineral Nutrition of Wild Plants. *Institute of Artic Biology,* University of Alaska, Fairbanks. 99-701.

F Stuart Chapin, 2003. Effect of Plant Trait on Ecosystem and Regional Process; Conceptual Framework for Predicting the Consequences of Global Change. *Annalas of Botany,* **91**, 455-463.

Fonseca, C.R., Overton, J. M., Collins, B., Westoby, M. (2000).Shifts in trait-combinations alongrainfall and phosphorus gradients. *Journal. Ecology*. **88**, 964e977.

Ghimire suresh, Indu Bikal Sapkota, Bhesh Oli, Rudriskhya Rai Parajuli (2008). Non-Timber Forest Products of nepal Himalaya: Database of some important species found in the Mountain Protected areas and surroundings Regions. WWF Nepal.

Grime, J.P. (2006). Trait convergence and trait divergence in herbaceous plant communities: mechanisms and consequences. *Journal of Vegetation Science*, **17**, 255–260

Guiz, J., Hillebrand, H., Borer, E. T., *et al.* (2016). Long - term effects of plant diversity and composition on plant stoichiometry. *Oikos,* **125,** 613–621.

Guo, Z. W., Hu, J. J., Chen, S. L., Yang, Q. P., Li, Y. C. and Cai, H. J. (2017). Nitrogen addition and clonal integration alleviate water stress of dependent ramets of *Indo calamusdecorus* under heterogeneous soil water environment. *Scientific. Report,* 7:44524. **10**.1038/srep 44524

Gupta, P. K. (2000). *Methodsin Environmental Analysis Water, Soil and Air.* AGROBIOS, India.

Hackett, C. (1973). An exploration of the carbon economy of the tobacco plant *I. Inferences* from a simulation. *Austrian Journal Biology Science*, **26**:1057–107.

Hartmann, A., Schmid, M., Tuinen, D. V., *et al*. (2009). Plant driven selection of microbes. *Plant and Soil*, **321**, 235–257.

Hedin, L. O.(2004). Global organization of terrestrial plant-nutrient interactions. Proc. Natl. Acad. Sci. Unit. States Am. **101**, 10849-10850.

Huang, W., Su, X., Ratkowsky, D.A., Niklas, K. J., Gielis, J. and Shi, P.(2019). The scaling relationship of leaf biomass vs. leaf surface area of 12 bamboo species. *Global Ecological Conservation*, **20**, e00793.

Hungate, B.A., Dukes, J.S., Shaw, M.R., Luo, Y. Q. and Field, C.B. (2003). Nitrogen and climate change. *Science*, **302**, 1512–1513.

IPCC. (2006). Good Practice Guidance for National Greenhouse Gas Inventories. **Volume 4**: Agriculture, Forestry and Other Land uses (AFOLU). Geneva, Switzerland: Inter goverenmental Panel on Climate Change. https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html.(Accessed February 2017).

Isebrands, J. G., Nelson, N. D., Dickmann, D. I. and Michael, D. A. (1983). Yield physiology of short rotation intensively cultured poplars. In: Hansen, Edward A., ed. Intensive plantation culture: 12 years research. Gen. Tech. Rep. NC-**91.** St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 77-93.

Isebrands, J.G. and Larson, P. R.(1977). Organization and ontogeny of the vascular cambium in the petiole of eastern cottonwood. *American Journal of Botany***.** **64**,65–77.

Jackson, S.D. (2009).Plant responses to photoperiod. *New Phytologist,* **181**, 517–531.

K€orner, C. (2012).Alpine Tree lines: Functional Ecology of the Global High Elevation Tree Limits. Springer-Verlag, New York.

Karla, Y.P. (1998). Reference Method For Plant Analysis. Tylor and Francis Group. Bacaraton, Washington Dc. Pp 76-80.

Kearney, M. (2006). Habitat, environment and niches, what are we modeling? *Okios,* **115,** 186-191.

King Mahendra Trust for Nature Conservation Nepal (KMTNC) (2004). Departments of National Parks and Wildlife Conservation, Kathmandu, Nepal

Kjeldahl, J.(1883). A New Method for the Determination of Nitrogen in Organic Matter. *Zeitchrift fur Analytische Chemie*, **22**, 366-382.

Klinka, K., Meidinger, D. and Mackinnon, A. (1992). Use of the Biologioclimatic ecosystem classification system in British Columbia. *Forestry Chronicle,* **68.**

Knops, J.M. H. and Reinhart, K. (2000). Specific leafarea along a nitrogen fertilization gradient. *American Midland Naturalist*, **144**, 265–272.

Körner, C., Basler, D., Hoch, G., Kollas, C., Lenz, A., Randin, C. F. and Zimmermann, N.E. (2016). Where, why and how? Explaining the low-temperature range limits of temperate tree species. *Journal of Ecology,* **104**, 1076–1088.

Korner, J. M. and Basler, W.G. (2010). Covariation in leaf and root traits for native and non-native grasses along an altitudinal gradient in New Zealand. *Oecologia*, **134**, 471–478.

Kumar, S., Kumar, M. and Sheikh, M. A. (2013).Carbon stock variation of *Pinusroxburghii* Sarg. Forest along altitudes of Garhwal Himalaya, India. *Russian Journal of Ecol*ogy, **44,** 131–136 .

Lambers, H. and Poorter, H. (1992). Inherent variation in growth rate between higher plants: a search for physiological causes and ecological - consequences. *Advances in Ecological Research*, **23**, 187-261.

Lamont, B. B., Groom, P.K. and Cowling, R. M. (2002). High leaf mass per area of related species assemblages may reflect low rainfall and carbon isotope discrimination rather than low Phosphorus and nitrogen concentration. *Functional Ecology,* **16**, 403-412.

Lavorel, S. and Garnier, E. (2002).Predicting changes in community composition and ecosystem functioning from plant traits: revisiting the Holy Grail. *Functional Ecology*, **16**, 545–556.

Li, Y. H., Luo, T. X., Lu ,Q., Tian, X. Y., Wu, B. and Yang, H. H. (2005). Comparisons of leaf traits among 17 major plant species in Shazhuyu Sand Control Experimental Station of Qinghai province. *Acta Ecol Sin*, **25**(5), 994–999.

Liu X, Lu Y, Zhou Y, Lei X, Meng J(2011). The influence of soil conditions on regenerations establishment for degraded secondary forest restoration, Southern China. Forest Ecology Manage 261: 1771-1780.

Luo, F. L., Huang, L., Lei, T., Xue, W., Yu, F. H., Li, H. L.(2018). Responses of performance and morphological traits to experimental submergence predict field distribution pattern of wetland plants. *J. Veg. Sci.* **27,** 340-351.

M.P. Panthi, R.P. Chaudhary 2002. Angiospermic flora of Arghakhanchi district and adjoining areas, west Nepal. *Natural History Museum*, *TU, Kathmandu*, Nepal, **21**. pp. 7-21

Madani, N., Kimball, J. S. and Running, S. W.(2017). Improving global gross primary productivity estimates by computing optimum light use efficiencies using fluxtower data. J. Geophys. Res.: *Biogeosciences*, **122**, 2939e2951.

McGill, B.J., Enquist, B. J., Weiher, E. and Westoby, M. (2006).Rebuilding community ecology from functional traits. *Trends in Ecology and Evolution, **21***, 178–185.

Menge, D.N.L, Hedin, L. O. and Pacala, S. W. (2012). Nitrogen and phosphorus limitation over long-term ecosystem development in terrestrial. *PLoS ONE,* **7(8),** e42-45.

Mingzhu, H., Feike, A., Dijkstra, Ke, Z., Li, X., Tan, H. and Yanhong, G. and Gang, L.(2014). Leaf Nitrogen and Phosphorus of temperate desert plants in response to climate and soil nutrient availability. *Scientific Reports,* **4**, 6932; DOI: 10.1038/srep06932 (2014).

Moles, A.T., Perkins, S.E., Laffan ,S. W., Flores-Moreno, H., Awasthy, M., Tndal, M. L., Sac, L., Pitman, A., Kattge, J. and Aassen, L.W. (2014). Which is a better predictor of plant traits, temperature or precipitation? *Vegetation Science*, **25**, 1167-1180.

Moorcroft, P. R., Hurtt, G. C. and Pacala, S. W. (2001). A method for scaling vegetation dynamics: the ecosystem demography model (ED). *Ecological monographs,* **71**, 557-585.

Mwakisunga, B. and Majule, A. (2012).The influence of altitude and management on carbon stock quantities in Rungwe forest, southern highland of Tanzania. *Open Journal of Ecology***, 2**, pp. 1-8.

Negi, G.C.S. (1996). Phenology, leaf and twig growth pattern and leaf nitrogen dynamics of some multipurpose tree species of Himalaya: Implications towards agroforestry practice. *Journal of Sustainable Agriculture,* **6(4),** 43-60.

Niklas, K.J., Owens, T., Reich, P. B. and Cobb, E.D. (2005). Nitrogen/phosphorus leaf stoichiometry and the scaling of plant growth. *Ecology Letters,* **8,** 636-642.

Nilson, S. E. and Assmann, S. M. (2007).The control of transpiration. Insights from Arabidopsis, *Plant Physiology*, vol. **143,** 19-27.

Novotny, A. M., Schade, J. D., Hobbie, S. E*., et al.* (2007). Stoichiometric response of nitrogen-fixing and non-fixing dicots to manipulations of CO2, nitrogen, and diversity. *Oecologia*, **151,** 687–696.

Ordonez, S. C., Van Bodegam, P. M., Writte, I. J., Reich, P. B. and Aerts, R.(2009). A global study of relationship between leaf trait, climate, and soil measures of nutrient fertility. Global *Ecology Biogeography*, **18**, 137-149.

Ordoñez, J. C., Bodegom, P. M., Witte, M., Wright, I., Reich, P. and Aerts, R. (2009). A global study of relationships between leaf traits, climate and soil measures of nutrient fertility. *Global Ecology and Biogeography,* **18**, 137-149.

P. Kutiel, H. Lavee 1999. Effect of slope aspect on soil and vegetation properties along an aridity transect. *Israel Journal of Plant Science*, **47**, pp. 169-178,

Pieters, G.A. (1974). The growth of sun and shade leaves of *Populus euramericana* 'Robusta' in relation to age, light intensity and temperature. *Medeterrian Land bouwhogesch Wageningen,* **74**, 1-107.

Polunin. O, and Stainton, A., 1984. Flowers of the Himalya. Oxford University Press. India.

Polunin. O, and Stainton, A., 1984. *Flowers of the Himalayas*. Oxford University Press. India.

Poorter, H. and Garnier, E. (1999).Ecological significance of inherent variation in relative growth rate and its components. Handbook of functional plant ecology (ed. by F.I. Pugnaire and F. Valladares), 81-120. Marcel Dekker, Inc., New York.

Pooter, H., Ninemets, U., Pooter, L., Wright, I.J., and villar, R.(2009). Causes and consequences of variation in leaf mass per area (LMA): a meta analyis. *New Phytologist,* **182(3),** 565-588.

Poudyal, K., Jha, P.K., Zobel, D. B. and Thapa, C.B. (2004).Patterns of leaf conductance and water potential of Himalayan tree species, *Tree Physiology,* **24**, 689-699.

Reich, P.B., Walters, M. B. and Ellsworth, D.S. (1991). Leaf life-spanin relation to leaf, plant, and stand characteristics among diverse ecosystems. *Ecological Monographs*, **62,** 365-392.

Reich, P.B., Walters, M. B. and Ellsworth, D.S. (1997). From tropicsto tundra: global convergence in plant functioning. *Proceedings of the National Academy of Sciences USA*, **94,** 13730-13734.

Richardson, A.D. and Berlyn, G. P. (2010). Spectral Reflectance and Photosynthetic Properties of *Betulapapyrifera* (Betulaceae) Leaves along an Elevational Gradient on Mt. Mansfield, Vermont, USA. *American Journal of Botany* ,**89**, 88-94.

Rui, Z., Hongwei, P., Biting, H., Huanwei, C. and Zhichun, Z.(2018). Nitrogen and phosphorus Stoichoimetry of *Schima superba* under nitrogen deposition; Scientific reports(2018).

Sheikh Mehraj A, Munesh kumar and Rainer W Bussmann (2009). Altitudinal variation in soil organic carbon stock in coniferous subtropical and broadleaf temperate forests in Garhwal Himalaya. *Carbon balance and management* volume **4,** Article number: 6.

Silva, L. V. and Batalha, G.R. (2009).Feedback-limited photosynthesis and regulation of sucrose-starch accumulation during cold acclimation and low-temperature stress in a spring and winter wheat. *Planta,* **201**, 18-26.

Singh Sabina, (2014). A Thesis Submitted on Floristic study and Vegetation analysis of Shivapuri Nagarjuna National Park, Central Nepal. Central Department of Botany, Kathmandu, Nepal.

Singh, G., andRawat, G. S. (2012). Quantitative analysis of tree species diversity in different oak (*Quercus* spp.) dominated forests in Garhwal Himalaya, India. *Notulae Scientia Biologicae*, **4(4),** 132-140.

Singh, J. S. and Singh, S. P. (1992).Forest of Himalaya, Structure, Functioning and impact of Man. *Gyanodaya Prakashan*, Nainital, India.

Stainton, JDA. (1972). *Forest of Nepal.* John Murray Ltd., London.

Taiz, L. and Zeigar, E. (2006). Plant Physiology (4th ed.). Sunderland: Sinauer Associates Inc.

Tylewicz, S., Petterle, A., Marttila, S., Miskolcz,i P., Azeez, A., Singh, R.K., Bhalerao, R.P. (2018). Photoperiodic control of seasonal growth is mediated by ABA acting on cell-cell communication. *Science,* **360**, 212-215.

Vitousek, P.M., Turner, D. R. and Kitayama, K. (2004).Foliar nutrients during long-term soil development in Hawaiian montane rain forest. *Ecology*, **76**, 712-720.

Walkley, A. and Black, I. A.(1934).An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science,* **32**: 181-194.

Wang, H., Wang, S.P., Harrison, P.I., Colin, Y., Yang, F.,Bai, H.F. and Togashi. (2017). traits for land plants The China plant trait database: towards a comprehensive regional compilation of functional Ecology, 99.

Wardle DA, Bardgett R.D., Klironomos RN(2004). Ecological Linkages between aboveground and belowground biota. Science 304: 1629-1633.

Westoby M., FlasterDS., Moler AT., Vesk PA., Wright I.J. (2002). Plant ecological stratagies: same leading dimensions of variations between species. *Annual review of ecology and systematic,* **33**.125-159.

Westoby, M. and Wright, I. J..(2003). Leaves at low versus high rainfall: Co-ordination of surface lifespan and Physiology. *New phytologist*, **155**, 403-416.

Woodward, F. I. (1987). Stomatal numbers are sensitive to increases in CO_2 from pre-industrial levels, *Nature*, vol. **327,** 617-618.

Wright, I. J., Reich, P.B., and Westoby, M. (2004).The worldwide leaf economics spectrum. *Nature,* **428**, 821-827.

Zelawski, W. and Walker, R. B.(1976). Photosynthesis, respiration, and dry matter production. In Modern Methods of Forest Genetics. *Ed. J.P. Miksche. Springer-Verlag, New York*, pp 89-119.

Zeng, D., Hu, J., Dong, G., Liu, J., Zeng, L., Zhang, G., Guo, L., Zhou, Y. and Qian, Q. (2015). Quantitative trait loci mapping of flag-leaf ligule length in rice and alignment with ZmLG1 Gene. *JIntegr Plant Biology,* **51**, 360-366.

Zobel, D.B., Jha, P.K., Behan, M.J. and Yadav, U.K.R., (1987). *A Practical Mannual for Ecology*. Ratna Pustak Distributors, Kathmandu, Nepal.

Zohner, C.M., Benito, B.M., Svenning, J. C. and Renner, S.S. (2016). Day length unlikely to constrain climate-driven shifts in leaf-out times of northern woody plants. *Nature Climate Change,* **6**, 1120-1123.

Annex 1

Table 1: Minimum and Maximum Temperature of the year 2010 to 2019

2010	**Tribhuvan international Airport**			**2011**	**Tribhuvan international Airport**		
Month	**T(max)C**	**T(min)C**	**Mean T°C**	**Month**	**T(max)C**	**T(min)C**	**Mean T°C**
Jan	22.3	3.1	12.7	Jan	19.6	2.4	11
Feb	23.2	4.8	14	Feb	23.8	5.3	14.55
Mar	29.2	10.9	20.05	Mar	27	8.8	17.9
Apr	31.9	13.9	22.9	Apr	28.7	11.9	20.3
May	30.3	16.8	23.55	May	28.9	16.2	22.55
Jun	31.1	19.5	25.3	Jun	29.4	19	24.2
Jul	29.5	20.6	25.05	Jul	28.6	20.5	24.55
Aug	29.2	20.6	24.9	Aug	29.5	20	24.75
Sep	28.6	19.2	23.9	Sep	28.4	19.1	23.75
Oct	28	14.9	21.45	Oct	28.1	14.2	21.15
Nov	24.8	9.9	17.35	Nov	22.4	9.5	15.95
Dec	20.8	2.9	11.85	Dec	18.9	4.1	11.5
Mean	**27.41**	**13.09**	**20.25**	**Mean**	**26.11**	**12.58**	**19.35**

2012	Tribhuvan international Airport			2013	Tribhuvan international Airport		
Month	**T(max)^{o}C**	**T(min)^{o}C**	**Mean T^{o}C**	**Month**	**T(max)^{o}C**	**T(min)^{o}C**	**Mean T^{o}C**
Jan	17.5	2.7	10.1	Jan	18.9	1.6	10.25
Feb	22.8	5.2	14	Feb	23.8	6.1	14.95
Mar	26.6	8.4	17.5	Mar	28.1	10.1	19.1
Apr	28.7	13	20.85	Apr	29.3	12.4	20.85
May	31.4	16	23.7	May	30	17.1	23.55
Jun	31.2	20.1	25.65	Jun	30	20.1	25.05
Jul	28.8	20.6	24.7	Jul	29.4	20.4	24.9
Aug	29.5	20.2	24.85	Aug	29.6	20.2	24.9
Sep	29.4	19	24.2	Sep	29.8	18.9	24.35
Oct	27.3	12.7	20	Oct	26.6	15.9	21.25
Nov	22.5	6.5	14.5	Nov	22.6	7.7	15.15
Dec	19.3	4	11.65	Dec	18.8	4.8	11.8
Mean	**26.25**	**12.37**	**19.31**	**Mean**	**26.41**	**12.94**	**19.68**

2014	Tribhuvan international Airport			2015	Tribhuvan international Airport		
Month	**T(max)°C**	**T(min)°C**	**Mean T°C**	**Month**	**T(max)°C**	**T(min)°C**	**Mean T°C**
Jan	18.6	3.9	11.25	Jan	20.2	4.4	12.3
Feb	20.9	5.6	13.25	Feb	22.2	7	14.6
Mar	25.8	9.1	17.45	Mar	24.7	9.9	17.3
Apr	29.6	11.9	20.75	Apr	26.4	12.6	19.5
May	29.7	16.4	23.05	May	30.6	16.6	23.6
Jun	30.5	20.1	25.3	Jun	31.4	19.7	25.55
Jul	29.6	20.9	25.25	Jul	29.5	19.8	24.65
Aug	29.3	20.6	24.95	Aug	29.1	20.1	24.6
Sep	28.4	19	23.7	Sep	29.4	18.9	24.15
Oct	26.5	13.7	20.1	Oct	27.2	13.7	20.45
Nov	21.9	10.1	16	Nov	23.6	9.5	16.55
Dec	20.1	4.8	12.45	Dec	18.8	4.3	11.55
Mean	**25.91**	**13.01**	**19.46**	**Mean**	**26.09**	**13.04**	**19.57**

2016	**Tribhuvan international Airport**			**2017**	**Tribhuvan international Airport**		
Month	**T(max)C**	**T(min)C**	**Mean T^{o}C**	**Month**	**T(max)C**	**T(min)C**	**Mean T^{o}C**
Jan	18.3	4	11.15	Jan	19.3	3.2	11.25
Feb	23.4	6.3	14.85	Feb	23.7	6.8	15.25
Mar	27	10.3	18.65	Mar	24.1	9.4	16.75
Apr	31.2	14.2	22.7	Apr	28.2	13.4	20.8
May	28.9	16.2	22.55	May	28.2	16	22.1
Jun	29.2	19.5	24.35	Jun	29.9	19.6	24.75
Jul	28.1	20.4	24.25	Jul	29.3	20.4	24.85
Aug	30	20.1	25.05	Aug	29.2	20.4	24.8
Sep	27.9	19.3	23.6	Sep	29.7	19.3	24.5
Oct	27.4	15.5	21.45	Oct	28	15.4	21.7
Nov	23.5	8.5	16	Nov	23.6	9	16.3
Dec	20.8	5.8	13.3	Dec	20.8	5.4	13.1
Mean	**26.31**	**13.34**	**19.83**	**Mean**	**26.17**	**13.19**	**19.68**

2018	Tribhuvan international Airport			2019	Tribhuvan international Airport		
Month	**T(max)C**	**T(min)C**	**Mean T°C**	**Month**	**T(max)C**	**T(min)C**	**Mean T°C**
Jan	18.5	3.2	10.85	Jan	18.1	3.6	10.85
Feb	22.8	7	14.9	Feb	20.8	6.1	13.45
Mar	26.8	10.1	18.45	Mar	25.1	8.4	16.75
Apr	26.2	13.2	19.7	Apr	27.3	13.8	20.55
May	27.6	16.3	21.95	May	30.6	15.8	23.2
Jun	29.4	19.3	24.35	Jun	30.7	19.3	25
Jul	29.5	20.7	25.1	Jul	28.8	20.3	24.55
Aug	28.8	20.2	24.5	Aug	30.5	20.6	25.55
Sep	29.4	19.2	24.3	Sep	27.4	19.1	23.25
Oct	26.3	12.4	19.35	Oct	26.5	14.9	20.7
Nov	22.7	7.8	15.25	Nov	23.7	11	17.35
Dec	18.7	4.3	11.5	Dec	18.1	4.5	11.3
Mean	**25.56**	**12.81**	**19.18**	**Mean**	**25.63**	**13.12**	**19.38**

Source: Department of Hydrology and Meteorology

Table: 2 Rainfall

Rainfall(mm)			Tribhuvan International Airport									
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2010	1.9	23.3	35.7	45.3	148	141.7	354.9	486.3	217.1	24.5	0	0
2011	6.2	54.9	16.4	56.8	167.4	306	437.8	265.4	318	13	12.9	0
2012	17.8	41.8	15.6	80.1	42.2	149.2	452.3	289.6	262.2	13.2	0.7	0
2013	11.5	45.4	27.3	44.3	278.6	299.1	428.5	451.4	217.3	95.7	0	0
2014	4.2	26.7	58.7	6	15.5	165.8	461.9	294.5	279.4	91.2	0	36.7
2015	3.4	35.2	98.7	51	40.4	125.6	470.6	452	189	67.6	0	0
2016	0.4	25.3	6.3	11	92.3	370.2	477.8	126.8	281.7	91	0	0
2017	13.3	0.5	70	75.7	127.4	120	282.2	360.6	98.5	63.9	1.5	0.1
2018	6.1	1.5	27.7	148.8	154.7	240	408.9	402.8	126.6	11.9	0	0
2019	19.1	85.2	37.4	102.8	55.1	126.2	485.4	226.5	358	0	0	33.4

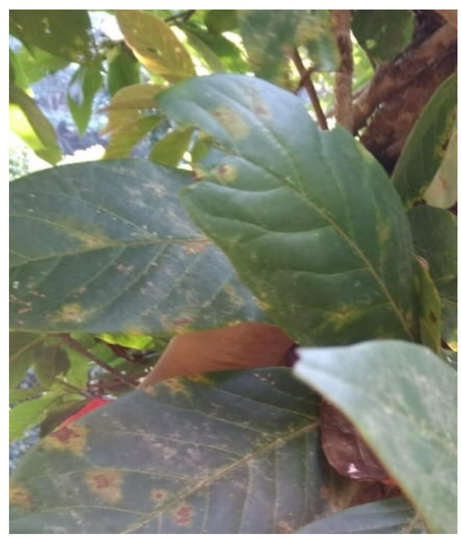
Source: Department of Hydrology and Meteorology

Annex 2

Important Value Index(IVI) of Tree Species		
Plant Species	**IVI of tree species at Southern aspect**	**IVI of tree species at Northern aspect**
*Schima walichii (*DC.) Korth.	36.7	29.45
Rhododendron arboreum Sm.	20.93	24.81
Quercus lanata Sm.	11.17	12.78
Quercus glauca	17.25	20.4
Myrica esculenta Buch-Ham ex D.Don	4.6	15.46
Myrica capitellata	9.52	12.55
Castanopsis indica	25.34	19.44
Lyonia ovalifolia	19.83	15.22
Eurya accuminata DC.	4.6	0
Alnus nepalensis	23.45	0
Quercus leucotrichophora A. Camus	54.36	40.55
Semecarpus anacardium	15.65	11.64
Myrsine semiserrata Wall.	5.17	7.63

Photo Plates


leaf and soil sampling

Leaf damage by insect.

Taking measurement of leaf

Sample collection

Laboratory Work