

**Population Structure and Microhabitat Preferences of the
Himalayan Yew (*Taxus wallichiana* Zucc.) in Panchase
Protected Forest in Central Nepal**



**THESIS SUBMITTED TO THE
DEPARTMENT OF BOTANY
AMRIT CAMPUS
INSTITUTE OF SCIENCE AND TECHNOLOGY
TRIBHUVAN UNIVERSITY
NEPAL**

**Submitted for the partial fulfillment of requirements for the award of
Master's Degree in Botany**

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DECLARATION

I hereby declare that the project work entitled “**Population Structure and Microhabitat Preferences of the Himalayan Yew (*Taxus wallichiana* Zucc.) in Panchase Protected Forest in the Middle Mountain Region of Central Nepal**” is a genuine work done by me and has not been published elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s). All the information in the project work is copyright to me and could be used for educational purpose by taking my permission.

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RECOMMENDATION

This is to certify that Ms. Deepmala Shrestha has completed this project work entitled **“Population structure and microhabitat preferences by Himalayan Yew (*Taxus wallichiana* Zucc.) in Panchase Protected Forest in the Middle Mountain Region of Central Nepal”** as a partial fulfillment of the requirements of M.Sc. in Botany under my supervision and guidance. To my knowledge, this research has not been submitted for any other degree, anywhere else. I, therefore, recommend the dissertation for acceptance and approval.

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LETTER OF APPROVAL

This dissertation work entitled “**Population Structure and Microhabitat Preferences of the Himalayan Yew (*Taxus wallichiana* Zucc.) in Panchase Protected Forest in the Middle Mountain Region of Central Nepal**” submitted by Deepmala Shrestha has been accepted as a partial fulfillment of Master Degree in Botany (ECOLOGY).

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ACKNOWLEDGMENTS

Foremost, I would like to express my sincere gratitude to my supervisor, Prof. Dr. Mohan Prasad Devkota, Amrit Campus, for his guidance and encouragement in carrying out this research for my thesis work. I am equally thankful to Prof. Dr. Kanta Poudyal, Head of Botany Department, Amrit Campus for providing necessary equipment to fulfill this study. I would also like to take this opportunity to thank Prof. Dr. Mukesh K. Chhetri, Co-ordinator, Amrit Campus for his perspective suggestions and help during my work.

I am indebted to Dr. Jyoti Prasad Gajurel (Director, NRAC) for the continuous support from the selection of topic to the design of the project and its finishing. I am thankful for his patience, motivation, enthusiasm, and immense knowledge that he shared during the work. His guidance helped me in all the time of research and writing of this work.

My sincere thanks to KATH (National Herbarium and Plant Laboratories) for helping me to identify the species. I am also thankful to Anil Choudhary sir for helping me design my study area in GIS. I am also grateful to all the teachers and staff members of Amrit campus for their direct and indirect help in different prospective.

Special thanks to my friends Dipak Bohara and Dipesh Pathak for helping me during field work. Last but not the least; I would also like to thank my family members, friends and local people of Panchase for their support while completing this assignment.

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ABSTRACT

Three species of *Taxus* occur in Nepal viz, *Taxus wallichiana* Zucc., *Taxus contorta* Griff. and *Taxus mairei* (Lemée and Lév). *Taxus wallichiana* is an evergreen dioecious plant that thrives under canopy having average life span of 500 years. Non availability of suitable micro-habitat and frugivory declines the number of the species besides its sale for timber. Based on the information collected from the study area, species distribution modeling was implemented in Maxent. Similarly, analysis for the relationships between different variables like temperature, precipitation, soil pH, litter thickness, canopy closure and occurrence of *T. wallichiana* was performed by using R program. Population of *T. wallichiana* was found scattered in the study area where it was found between the elevational ranges of 2200m to 2500m. Temperature and precipitation along with other variables had combined role for affecting the micro habitat preferences of *T. wallichiana*. Our result also showed effects of climate change on distribution of the species. We found that the new possible areas for its distribution will be towards Eastern Nepal. However, there will be no severe effect of climate change in the study area affecting the distribution of *T. wallichiana*. This study will help in developing new strategies for the conservation and management of *T. wallichiana*.

Key words: *Bioclimatic variables, distribution model, maxent, micro-habitat*

LIST OF ABBREVIATIONS

AIC	Akaike's Information Criterion
AUC	Area Under the Receiver Operating Characteristics Curve
CBH	Circumference at Breast Height
CDB	Central Department of Botany
CITES	Convention on International Trade in Endangered Species
DBH	Diameter at breast height
DD	Data Deficient
DPR	Department of Plant resource
FDA	Food and Drug Administration
GLM	General Linear Model
GPS	Global Positioning System
ha	Hectare
HKH	Hindu Kush Himalaya
IUCN	International Union for Conservation of Nature
KATH	National Herbarium and Plant Laboratories
°C	Degree centigrade
mm	Millimeter

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CHAPTER - 1: INTRODUCTION

1.1 BACKGROUND

Population structure is the result of a complex combination of its life history, ecological preferences, position in the ecosystem and historical factors (Meirmans et al., 2011). Plant population can be described in terms of age, size and shape of its individuals and genetic structure (Harper & White 1974). The factors like age, genetic variability, resources heterogeneity, competition, effect of herbivore, parasites or pathogens and disturbance can cause the differences in size (Weiner & Solbring 1984, Coomes et al., 2003, Muller-Landau et al., 2006). If size structure is related with the age of individuals, it gives information on the current regenerating capacity, past disturbances (Knowels & Grant, 1983, Agren & Zackrisson 1990) and the future expected occurrence (Odhum 2001). This plant's population adapts to certain types of habitat and become the ultimate choice maker through the process of evolution (Bazzaz 1991). The selection of habitat in plants may be driven by density (Gersani et al., 1998) or driven by evolutionary factors over a period of time (Bazzaz 1991) or shown through the phenotypic plasticity of plant (Bradshaw 1965). Plants that are clumped in their distribution are more specific in their habitat selection. Habitat selection studies in tropical regions on angiosperms have been under taken (Svenning 1999) whereas relatively much less is known about the gymnosperms.

A unique family among the gymnosperm is Taxaceae whose position in the classification system has been a source of controversy. Previously it was under Coniferales and then shifted to its own order Taxales for not bearing cones. At present, Taxaceae have six genera, viz., *Amentotaxus*, *Austrotaxus*, *Pseudotaxus*, *Cephalotaxus*, *Torreya* and *Taxus* (The Plant List, accessed on 28 July, 2018). The Plant List includes 161 scientific plant names of genus *Taxus*. Of which 31 are accepted species names, 126 synonyms, 0 unplaced and 4 unassessed. The classification of *Taxus* is given below

Kingdom	<i>Plantae</i>
Sub kingdom	<i>Tracheobionta</i>
Superdivision	<i>Spermatophyta</i>

Division	<i>Corniferophyta</i>
Class	<i>Pinopsida</i>
Order	<i>Taxales</i>
Family	<i>Taxaceae</i>
Genus	<i>Taxus</i> L.

Spjut (2007), proposed recognition of 24 species and 55 varieties based on chemical and morphological differences. However, Farjon 2010, confirmed 10 species of the genus *Taxus* which occurs scattered understorey forest trees mainly in the temperate zone of the northern hemisphere and mountains of tropical SE Asia . Spjut (2000, 20007b) classified *Taxus* in three groups on the basis of differences in leaf epidermal and stomatal features. They are:

- the Wallichiana Group consisting of 11 species which occur from central Himalayas to Indonesia (Sumatera, Sulawesi) and The Philippines, in North America in the Pacific Northwest and from Mexico to Central America with an isolated occurrence in Florida
- the Baccata Group having nine species in temperate Eurasia. Northern Africa and eastern North America.
- the Sumatrana Group comprising four species that overlap in distribution with the Wallichiana Subgroup in Asia but are absent from North America (Spjut 1998b, 2000c, 2007b).

1.2 DISTRIBUTION

1.2.1 Global distribution

The genus *Taxus* is distributed in the temperate zone of Northern Hemisphere with some intrusion to tropical hi-lands (Norway and Indonessia). The range of genus in Europe includes Britain to northern Italy; in Asia: Korea, Japan, China, Taiwan, India, Burma, Vietnam, Philippines; in North America: southeast Alaska to California,

southeast Canada to northeast USA, Florida, Mexico, Guatemala, El Salvador (Earle 2008).

1.2.2 In Hindu Kush Himalayan Region

The Hindu- Kush range and Himalaya region is generally known as Hindu Kush – Himalaya (HKH) which extends 3500km from eastern Afghanistan in the West to North Myanmar (Burma) and Southwest China in the East. In HKH region Yews are reported from eastern Afghanistan to Yunnan in the Southwest China. Their occurrence is found along the foothills of the Himalayas in a narrow band in Central Nepal and the small area of Southwest Xizang (Jilong) in China (Poudel et al., 2012). It has been reported that the Hangduwang Mountain and Sichuan valley provide habitat to different species of *Taxus* in China (Bhatt et al., 2017, DPR).

1.2.3 In Nepal

In the context of Nepal, there are 31 species of gymnosperm distributed from West to East Nepal and from tropical to alpine regions (Rajbhandari & Baral, 2010). Mostly tropical and temperate regions are dominated by gymnosperms. However, there are some gymnosperms like *Abies*, *Tsuga*, *Ephedra* which are found dominant in alpine and sub alpine regions (Chaudhary, 1998; NBSAP, 2014). Among the species of gymnosperm found in Nepal, genus *Taxus* consists of two naturally occurring species: *Taxus contorta* Griffith and *Taxus wallichiana* Zucc. (Rajbhandari & Baral 2010). In addition to it, Poudel et al., (2012) added one more species *T. mairei* (Lemee & H. Leveille) S.Y. Hu ex T.S. Liu to Nepal.

Taxus contorta is reported from Western Nepal, Darchula to Gorkha of Central Nepal. It is mostly found in the Northern slopes of Annapurna – Manaslu range (Poudel et al., 2012). *Taxus wallichiana* is distributed in the mid hills of Nepal Himalaya between 2300m to 3400m (Press et al., 2000; Thomas & Farjon 2011). It mostly occurs in the eastern part of Baglung district along the south of the Dhaulagiri and Annapurna range to East Nepal. The third species *T. mairei* is found in Sindhuli, Kavrepalanchok and in Mahabharat range of Makwanpur district. This species is found in an altitudinal range of 1500m and 2000m which is less as compared to the distributional range of the other two species (Poudel et al., 2012).

1.3 GEOGRAPHICAL INTER RELATIONSHIP BETWEEN THE TAXUS SPECIES

The geographical distribution of genus *Taxus* do not overlap with each other. *Taxus contorta* is distributed in the Western Himalayas from eastern Afghanistan to Central Nepal. It receives low summer rainfall as compared to high winter rainfall from the Mediterranean West. However, *T. wallichiana* with similar altitudinal range but occurs in the Eastern Himalayas from Central Nepal to Yunnan Province in China. Here, the species experiences high summer rainfall due to Indian monsoon, scarce winter rainfall and less annual extremes. Whereas, *T. mairei* which is found in lower elevations as compared to other two species, extends further South into the tropics, experiencing warmer temperatures and less seasonality, and varied precipitation (Poudel et al., 2012).

In Nepal, Dhaulagiri-Annapurna-Manaslu Himalaya range separates the occurrence of *T. contorta* and *T. wallichiana*. Similarly, *T. mairei* is separated from *T. wallichiana* as it is located in the Mahabharat range whereas *T. wallichiana* occurs in the Northern Himalayas. The other interesting fact that shows their non overlapping nature is seen in Kavrepalanchok and Gorkha Districts, Central Nepal. In Kavrepalanchok, *T. wallichiana* occurs in the higher altitude and *T. mairei* at the lower. Likewise, *T. contorta* is found over *T. wallichiana* in Gorkha District (Bhatt et al., 2017, DPR)

1.4 MORPHOLOGY AND ECOLOGY

Taxus wallichiana (falls under family Taxaceae of gymnosperm) is dioecious in nature, dispersed by birds and animals, pollinated by wind, highly clumped in distribution and not much is known about its habitat preferences the species exhibits. The species is commonly named as Himalayan yew and has various local names. For instance, it is called as Lauthsalla in all valleys of Nepal. Its name also varies according to the ethnicity of the local people, like it is often called as Dhyangre salla by Rai people, Sanga Sing by Sherpa and Shingensing by Lama.

Taxus wallichiana is a shade tolerant evergreen tree having relatively slow growing process that reaches its sexual maturity after approximately 70 years. Its average life

span is roughly 500 years (Milner 1992, Brzeziecki & Kienast 1994). It is sensitive to both frost and drought (Brzeziecki & Kienast 1994) which limits its occurrence to low altitudes in the north and high altitudes in the south (Tutin et al., 1964-80). Himalayan yew has thin, reddish and scaly bark, shed their needles in the month of May and June; flowers from March to May and the fruit ripens from September to November (Troup, 1921; Poudel et al., 2012). The fruit that ripens in late summer or autumn consists of a scarlet fleshy cup-like aril bearing a single; hard seed which although strongly dormant does not form a persistent seed bank (Schopmeyer 1974). Morphologically, both the young male and female trees are alike which cannot be distinguished until they bear their respective reproductive features. Male flowers have a globose head on common stalk whereas female flowers consists of single erect ovule surrounded by a disk on a peduncle, covered with imbricate scales. The female is devoid of cone but consists of fruit which is a solitary seed, half enclosed in a red aril. Females produce fruit in most years and these are consumed by the birds (mainly *Turdus spp.*) which disperse the seed intact in their excreta (Snow & Snow 1988). Dispersal of fruit is also carried out by animals like Langurs (Minhas et al., 2010), birds (Troup 1921) and Thrushes (Martínez et al., 2008). Seeds of *Taxus* are predated on by rodents (García et al., 2005) and rabbits (Watt 1926) too. Frugivory of seeds and sales of timber are the reason behind the declining number of *T. wallichiana* (Paul et al., 2013, Gajurel et al., 2014) besides grazing (Alverson et al. 1988, Perrin et al., 2006) and non-availability of micro habitats (Humble, 1996) that leads to poor regeneration. However, it is possible to propagate the species by cutting its stem (Maden 2003).

It is found associated with conifers like *Abies pindrow*, *Acer caesium*, *Betula utilis*, *Pinus wallichiana* and other broad leaved species like *Quercus semicarpifolia*, *Rhododendron arboreum*, *Acer sp*, *Castanopsis sp.*, *Cinamomum sp.*, *R. arizelum*, *R. grande*, *R. kendrickii* (Purohit et al., 2001, Paul et al., 2013)

1.5 USES OF TAXUS

The species is made more unique by the fact that it is an important medicinal plant. The discovery of the anticancer compound paclitaxel and the development of the chemotherapeutic drug 'Taxol' (Wani et al., 1971) have increased the importance of

yews by many folds. (Poudel et al., 2012), it was mostly used for the gastrointestinal ailments, cough and cold, skeleton–muscular system problems and other medicinal purposes by the different indigenous communities of Nepal. Being a novel anticancer agent (Mitchell 1997), it is said that one gram of taxol cost US\$600 in USA and 2gm is needed to cure breast cancer (Pant & Joshi 1999). It has been approved by FDA clinical treatment of ovarian and breast cancer in 1983 and also has significant activity in the treatment of patient with melanoma and other solid tumors (Wickremshine & Arteca 1993).

In the context of Nepal, annually, in the Eastern part middleman buy huge quantity of fleshy leaves and small twigs at the rate of Rs.10/ kg from the community and national forest, and semi dried leaves and twigs normally at higher price as Rs.30/kg (Maden 2002a). A medium sized tree normally gives a harvest of two quintals of fleshy leaves worth providing Rs. 2,000 net without tree felling. The leaves are pruned from September to April. Earlier villagers used to cut down the trees for leaves but these days they cut only the small branches. It is estimated, from a single district Sankhuwasabha, traders exported semi dried leaves around hundred tones in the year 2002 (Maden 2002b). Excessive collection of *Taxus* leaves through tree felling is an undesirable practice, which if continued would impact on the loss of *Taxus* from its habitat. It is even used for the household tools, agricultural implements and timbers. Several archaeological records show the uses of yews from Neolithic to the Roman period for bows, axe shafts and spears (Hartzell, 1991). Its tough and long lasting timber was used for buildings and the high aesthetic appeal made yew a popular decorative material (Dovciak 2002)

1.6 CONSERVATION OF *TAXUS*

Because of its many medicinal and other uses, Yews has been exploited to the state of extinction. The species has already been listed in the Appendix II of CITES List of Nepal and is also listed in the protected list by the Government of Nepal (DPR, 2012). It was assessed as data deficient (DD) by IUCN in 2006 (Paul et al., 2013). Deforestation and human land uses are the other factors responsible for the degradation of the species besides its exploitation for the medical purpose (Samant et al., 2001).

The thin bark of *Taxus* is very much susceptible to fire and its poor natural regeneration character (from seeds) are also the other reasons for its declining number (Sukla et al., 1994, Nandi et al., 1994, Rikhari et al., 1998).

For the conservation, awareness and concern have been raised for years on the local, national and international level to conserve population of yews in the HKH region.

Table 1. Global conservation status of *Taxus wallichiana* Zucc.

Region/Country	Status	Source
World	Lower risk	World list of threatened trees (od field et al., 1998)
World	Not threatened	Farjon (1998)
World	Endangered (A2acd)	IUCN 2017
China	Endangered	Fu and Jin (1992)
China	Vulnerable	Xiang (2004)
China	Critically low, greatly restricted & threatened	Khan (2005)
Northern India	Critically endangered	Molur and Walker (1998)
Arunachal Pradesh, Sikkim, Jammu & Kashmir, Himachal Pradesh and Uttaranchal	Endangered	Ved et al., (2003a, 2003b)
Meghalaya (India)	Critically Endangered	Ved et al., (2003a, 2003b)
Nepal	Data Deficient	IUCN 2006, (Paul et al., 2013)
Nepal	Threatened	Sharma, 2006
Northern Vietnam	Vulnerable	Thomas and Due (2004)
Southern Vietnam	Endangered	Thomas and Due (2004)
Bhutan	Rare	Pradhan 1993

Source: Swer (2013)

The Nepal government has placed *Taxus* under Forest Regulation Act (1995) that sets strict criteria for commercial collection and prohibits the felling of trees. Similarly, other countries along the HKH region i.e. Bhutan, China and India have completely banned wild harvesting of *Taxus* (Mulliken & Crofton 2008).

1.7 RATIONALE

1.7.1 Distribution and population structure

Plants are rapidly declining mainly due to habitat destruction by humans, fragmentation, widespread deforestation, over exploitation for fuel, fodder, timber etc in Nepal. Besides, medicinal benefit is another reason behind the degrading number of the plant like *T. wallichiana*. The species was listed in CITES Appendix II (Thomas and Farjon 2011) in 1955. According to Bhattarai and Karki (2004) it was assessed as Nationally Endangered in Nepal while as Data Deficient (DD) by IUCN in 2006 (Paul et al., 2013). Likewise, Forest Act 1993 prohibits illegal cutting of *T. wallichiana* in Nepal.

Panchase Protected Forest has great biological, cultural and religious diversities and natural beauty with heavy precipitation that harbors species like *T. wallichiana*. According to the elderly people of Panchase Protected forest area, peak of Panchase had a dominant forest of *Taxus* 50-60 yrs ago. But it was later harvested by group of people for different unknown reasons. It represents as an important ecological zone and serves as a only corridor linkage of Lowland (Chitwan- Nawalparasi) and of Annapurna Himalaya range. Therefore conserving the species would be highly beneficial for the conservation of biodiversity. Panchase holds a fine patch of *T. wallichiana* at the peak but the study on this plant has not been attempted before. Moreover, not much is known about its ecological preferences. As it falls under the data deficient category, this study will be a step towards fulfilling the informational gap regarding the distribution and ecological preferences of *T. wallichiana*. This study will also help in finding the possible sites of *T. wallichiana* in future which will help in its sustainable conservation and protection.

The key questions are:

- a. What are the environmental variables that are concerned with the distribution pattern of *Taxus wallichiana*?
- b. Is habitat preferences one of the factors for influencing the population structures?

1.7.2 Micro habitat

Taxus thrives in various habitats but there must be some specific factors governing its regeneration and growth and there must be some role of the associated species since *Taxus* is known to grow under canopy.

So the questions arising are:

- a. What are the various factors responsible for the occurrence of *Taxus* in any particular site?
- b. What are the associated species?

1.8 OBJECTIVES

The main objectives of the study are:

1. Mapping distribution and predicting potential sites for *Taxus wallichiana* in the study area.
2. To compare the population structure of *Taxus wallichiana* across different habitat types
3. To study micro site preferences and associates of the species

1.8 LIMITATION OF THE STUDY

The altitudinal range of the study area was less where the species was encountered which limited our work. No other location was found near Panchase of same altitudinal range so, comparison could not be done. Moreover, due to the steep slope of the study area, perhaps the population of *T. wallichiana* could have been missed for safety purpose.

CHAPTER - 2: LITERATURE REVIEW

2.1 HISTORICAL BACKGROUND

Linnaeus (1753) recognized *Taxus baccata* in Europe which is also called as European Yew. It was then considered to be just one species of *Taxus*. Then Thunberg (1775-1776), a student of Linnaeus discovered Yew in Japan which was considered to be the same as the European Yew except for the cuspidate bud scales. In 1785 yew was again recorded in Canada by Marshall but this time it was different from the one recorded by Linnaeus as European Yew. The yew found in Canada was shrub like of low growth than *Taxus* and it was called as *T. canadensis* or Canadian Yew.

In Nepal, Wallich (1822) mentioned the occurrence of yew in Shivapuri, Kathmandu in his book “Tentamore Florae Nepalensis” and named it as “*Taxus nucifera*”. But in 1843 after the detail study, Joseph Zuccarani changed the name of *Taxus nucifera* to *Taxus wallichiana*.

In 1955 H. Kihara edited a book ‘Fauna and Flora of Nepal Himalaya’ vol. 1 in which *T.wallichiana* is reported in 1952 from Titman and Thonge pasture land, Rasuwa district. It was reported above 2800m and 2645m in respective places. Similarly, Yoshisake Satake (1963) in his book ‘The Flora of Eastern Himalaya’ mentioned the presence of *T. baccata* L. subsp. *wallichiana* (Zucc.) Pilger from Mai pokhari. Olangchungola, Biblatte bhanjyang, Eastern Nepal. CDB (1976) published a catalog of Nepalese Vascular Plants, Flora of Langtang and Cross Section Vegetation Survey (1976) and Flora of Kathmandu Valley (1986), concluded that the *Taxus* found in Nepal was *T.wallichiana* rather than *T. baccata*. They also mentioned that *T. baccata* is not present in Nepal. Before Pilger (1903) had considered that there is only one species of *T. baccata* and others are the sub species and varieties.

(Source: www.kath.gov.np)

2.2 DISTRIBUTION

Shah et al., (2008), on the basis of molecular and morphological data showed that the European *Taxus baccata* only reaches eastward into Iran and that it is then replaced by *Taxus contorta* Griff. spreading from Pakistan to Western Nepal, where it is then replaced by *Taxus wallichiana* Zucc.

Poudel et al., (2012), during his study in the Hindu Kush Himalayan region by using an integrative and molecular morphological taxonomic approach demonstrated the occurrence of three species of *Taxus* in Nepal. *Taxus mairei*, (a species that was previously considered to be endemic to the South of China) at an altitudinal difference of 1500-2000m, *T. wallichiana* at 1900 – 2700m (-3300m) and *T. contorta* at 1900-3300m (-3450m). *Taxus contorta* is distributed in the Western Himalayas from eastern Afghanistan to Central Nepal. Similarly, *T. wallichiana* is recorded in Eastern Himalayas from Central Nepal to Yunnan Province in China and *T. mairei* extends further South into the tropics

Gajurel et al., (2014) studied six valleys of Nepal Himalayas belonging to three regions with different precipitation gradients in the southern slopes. *T. wallichiana* was searched along altitudinal gradient from the valley bottom and along the vertical gradient. Altogether 812 individuals were recorded in the six valleys with in an altitudinal range of 2200m to 3450m. However, most of them were distributed from 2600m to 2800m. According to their study, there was a sharp increment in the no. of individual between the altitudinal range of 2800m and 3100m. But after this, the number of individual decreased to patch or sometime confined to one or two individuals only.

Table 2 Herbarium records of *T. wallichiana* deposited in KATH, Nepal

S.N	Districts	Location	Remarks
1	Baglung	Hila	Poudel et al., 2014
2.	Myagdi	Chimkhola, Ghodepani	KATH Herbarium
3.	Parbat	Nisaldhor, Nayathati, Ulleri	KATH Herbarium, Parajuli et al., 1999

4.	Kaski	Ghandruk, Banthanti, Upallo lalka, Panchase	KATH Herbarium
5.	Lamjung	Bhujung	Poudel et al., 2014
6.	Gorkha	Kaskigau, Shivarang, Umiya	KATH Herbarium, Poudel et al., 2014
7.	Nuwakot	Nuwakot	Parajuli et al., 1999
8.	Rasuwa	Banthalo, Dadagau, Tatopani	KATH Herbarium
9.	Kathmandu	Shivapuri, Bagdhuwar, Deurali, Bhorlang Bhanjyang	KATH Herbarium
10.	Shindhupalchowk	Helambhu, Lihi, Chorangbudada, Pati bhanjyang	KATH Herbarium, Poudel et al., 2014
11.	Kavrepalanchowk	Nangechowr, Gairibhanjyang, Kamikhoriya, Beti khotiya	KATH Herbarium
12.	Ramechap	Kerakakhola, Banti V.D.C	KATH Herbarium
13.	Dholkha	Suspa chewawati, Badare ban	KATH Herbarium, Poudel et al., 2014
14.	Solambhu	Lukla, Lamujo-chumowa, Kharte- paying	KATH Herbarium, Poudel et al., 1999
15.	Shankhuwasabha	Thapang, Gufapokhari, Rametey, Tashigau-ghauma, Bhaise kharka- dada kharka, Hatiya, Syakim-khiraunly, Minchin dhap-Mulpokhari	KATH Herbarium, Poudel et al., 2014
16.	Bhojpur	Suntale	TUCH Herbarium
17.	Dhankuta	Tute- Tinjure, Phedi	KATH Herbarium
18.	Tehrathum	Basantapur	TUCH Herbarium
19.	Ilam	Chintap, Chitrakhola	KATH Herbarium
20.	Panchthar	Bhuspate dada, Sidin	KATH Herbarium. Poudel et al., 1999

21.	Taplejung	Kalikhola, Jhankharka, Tallo phedi, Selap, Jongi, Olangchungola	KATH Herbarium
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Source: Bhatt et al., 2017 (DPR)

2.3 POPULATION STRUCTURES

Rikari et al., (1998) studied population structure of *T. wallichiana* from Jageshwar, Almora in Central Himalaya. The study was done in disturbed and undisturbed sites. The disturbed plots had a population structure with a lower number of individuals both towards the lower and higher size classes. Similar population structure shown by the undisturbed plots had seedlings which were more abundant than individuals of their size classes. However, regeneration of the species was found to be better in the moist and shady microsites at undisturbed location than in the disturbed sites.

Rikari et al., (2000) studied the effect of disturbance levels, forest types and association on the regeneration of *T. baccata*. He found that despite the wide elevational distribution (1770- 3400m), it never formed extensive stretch and commonly occurred as an under canopy species. Along the disturbance gradient, stable population of *T. wallichiana* was found in the least disturbed mixed broad leaf forest association. Whereas, in moderately disturbed sites, saplings and some of the subsequent size classes were not found. At highest disturbed sites, only the oldest tree category was present that indicated the poor regeneration. A similar pattern was seen in cedar forest.

Pant and Samant (2008) conducted a study on *T. wallichiana* of Khokan Wildlife Sanctuary in Kullu, Himachal Pradesh which showed that aged population with lack of recruitment. The size class distribution showed that over 42% individuals were >90cm in CBH, nearly 18% were between 70 and 90cm, almost 11% were between 50 and 70cm and almost 30% were between 30 and 50 cm. The number of saplings and seedlings were very less in number.

Piovesan et al., (2009), studied population ecology of *T. baccata* in the central Apennines, Italy and found that its population structure followed irregular bell shaped patterns in relation to the gradients of elevation, aspect and slope of all study areas.

Behera et al., (2000); Saqib et al., (2006) and Ganguly (2011) generated information on spatial distribution and mapping of *T. wallichiana* in Talle Valley in Arunachal Pradesh, Pallas valley in Pakistan and Uttarkashi in Central Himalaya respectively. Predictive modeling of *T. wallichiana* with the help of GIS technique showed the patchy distribution of the species. Studies also revealed that *T. wallichiana* grows under canopy and is highly clumped in distribution within most forests.

Ganguly (2011) studied the population structure and micro habitat preferences of *T. wallichiana* in Uttarkashi as a partial fulfillment of Master's Degree in Wildlife Science. She concluded that combination of the slope, litter depth and the interaction between the aspect and temperature are the micro habitat variables that influences the presence of *Taxus*. Likewise, Swer (2013) during his study for the degree of doctor of philosophy found that the yews are located in the East Khasi Hills, West Khasi Hills and Jaintia Hills of Meghalaya.

2.3 ECOLOGY AND ASSOCIATES

Singh and Singh (1992) pointed that *T. wallichiana* is a late successional species and is closely associated with *Betula utilis*, *Abies pindrow*, *Acer caesium*, and *Pinus wallichiana* and also found in small patches under the *Quercus semecarpifolia* and *Rhododendron arboreum* association.

Behera et al., (2000) during their study in Talle Valley found that *T. baccata* L. bearing forest consisted of swampy and marshy covered with various peats and non-vascular cryptogams. Their study site had the presence of gregarious bamboos that formed unique community. Bamboo species found were *Arundinaria spp.* and *Pleioblastus simonii*. Other than bamboo scrubs, *Taxus* was found associated with *Abies densa*, *Tsuga dumosa*, *Cephalotaxus spp.* *Beteula alonoides* and some other broad leaved trees like *Jatropha gossypifolia*, *Phyllanthus spp.*, *macrotanax denticulata* etc.

Rikari et al., (2000) during his study at Jageshwar in Kumaon Hiamalayan found that *T. wallichiana* occurs in small groups of 5-10 individuals in two association between 1810m and 2050m altitude. First in cedar forest which was characterized by the dominance of *Cedrus deodara*. *T. wallichiana* was also found in the under canopy of *Neolitsea pollens*. Second, it was found associated in broad leaf forest characterized by

co-dominance of tree species in the canopy of *Juglens regia*, *Aesculus india*, *Q. leucotrichophora* and *Q. floribunda*

Purohit et al., (2001) found that in Nanda Devi Biosphere Reserve (NDBR) of Garhwal region of Central Himalaya, *T. wallichiana* is widely but sparsely distributed along the cool temperature belt between 2600 and 3300m.

Garcia et al., (2005b) research indicated that yew recruitment was driven by factors at the micro-habitat scale but sapling establishment differed considerably between sites, suggesting that landscapes factors such as topography (altitude, aspect and slope), vegetation (canopy cover) and disturbance caused differences in germination and survival.

Pant and Samant (2008), during their study in Khokan Wildlife Sanctuary in North Western Himalaya (Himachal Pradesh) found that Himalayan Yew occurred only in six out of sixty- five sites sampled within an altitude of 1600- 3000m. The associates of *T. wallichiana* varied with the altitude as shown in Table 3.

Table 3 Associates of *T. wallichiana* in six communities in Khokan Wildlife Sanctuary in North-Western Himalaya

Site	Altitude (m)	Habitat	Slope	Community type	Associates
1	2380	SM	10	<i>Abies pindrow</i>	<i>Persea odoratissima</i> , <i>Picea smithiana</i> , <i>Quercus floribunda</i>
2	2220	SM	35	<i>Abies pindrow</i> - <i>Cedrus deodara</i> mixed	<i>Quercus floribunda</i> , <i>Picea smithiana</i> , <i>Aesculus indica</i>
3	2320	R	60	<i>Cedrus deodara</i>	<i>A. pindrow</i> , <i>Cornus macrophylla</i> , <i>Pinus wallichiana</i>
4	1800	SM	35	<i>Picea smithiana</i>	<i>A. pindrow</i> , <i>Prunus cornuta</i> , <i>Q. leucotrichophora</i> , <i>Q. floribunda</i>
5	1790	SM	35	<i>Q. floribunda</i>	<i>P. wallichiana</i> , <i>Q. leucotrichophora</i>
6	2340	SM	15	<i>Q. semecarpifolia</i>	<i>Q. floribunda</i> , <i>P. odoratissima</i> , <i>Aesculus indica</i> , <i>Juglens regia</i>

Source: Pant and Samant (2008)

Abbreviation used: SM= Shady Moist; R= Reverine

Piovesan et al., (2009) analyzed three population of *T. baccata* in Apennines, Italy. Here, yew grew in European Beech (*Fagus sylvatica* L.) stands. In all stands, yew occupied the forest understory, growing beneath Beech trees.

Ganguly (2011) during her study found that *T. wallichiana* is associated with *Abies pindrow*, *Quercus semecarpifolia*, *Picea smithiana* and *Quercus dilatata*.

Poudel et al., (2012) in their study in HKH region provided niche modeling of three species of *Taxus* in which they summarized that *T. wallichiana* receives high summer rainfall due to Indian monsoon and scarce winter rainfall. It experiences less annual temperature extremes.

Paul et al., (2013) states that the species is found associated with other broad leaved tress like *Acer sp*, *Castonopsis sp.*, *Cinanomum sp.*, *Rhododendron arizelum*, *R. grande*, *R. kendrickii*, *Rhododendron sp.*, and also with other conifer species like *Abies spp.*, *Pinus wallichiana* etc.

CHAPTER - 3: MATERIALS AND METHODOLOGY

3.1 STUDY AREA

Panchase literally refers to ‘five sacred seats’ (Paanch meaning five and ‘aasan’ means seats in sanskrit) represented by the confluence of five peaks. Panchase Protected Forest is spread in three VDCs of mountainous districts of Kaski, Parbat and Syangja of state number 4 in the Middle Mountain Region of Central Nepal Himalayas. The forest covers area within Annapurna Gaupalika and Pokhara-Lekhnath Municipality of Kaski District, Kusma Nagarpalika of Syangja District and Modi Gaupalika of Parbat District (MoFAGA, 2074). It has great biological, cultural, and religious diversities and natural beauty and represents an important Middle Mountain’s ecological zone.

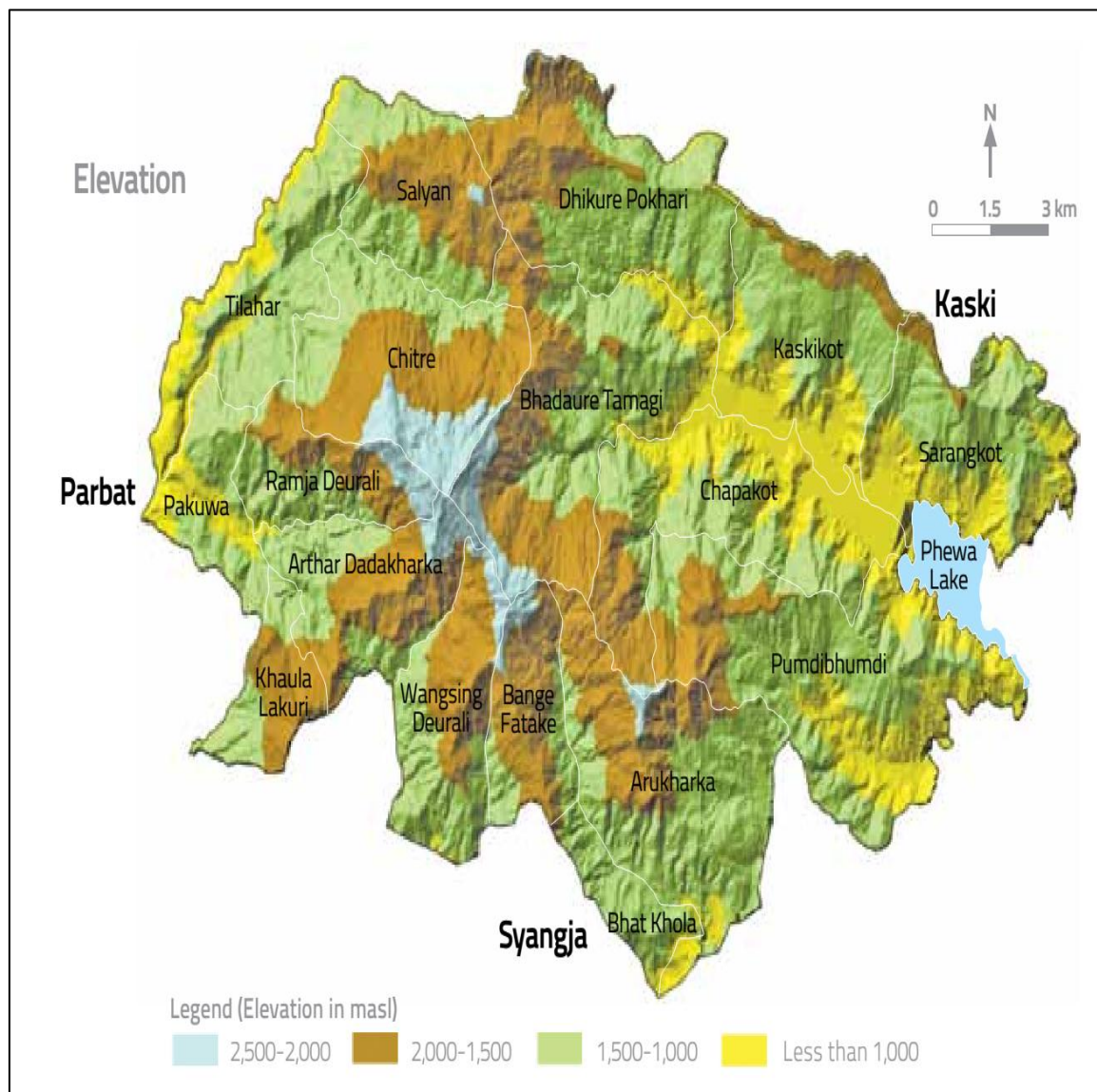


Figure 1 Map of study area

Source: MoFAGA, 2074

Panchase Protected Forest has been recently declared as a protected forest recognizing its rich biodiversity, forest resources as well as cultural and spiritual values. It was gazetted in 2012 and has an area of 57.76 sq kilometers and lies between 28° 10' 55"- 28° 15' 56" N and 83° 48' 03"- 83° 49' 53" E. It represents an important ecological zone which is less addressed amongst the country's protected area system and is only one corridor linkage of Lowland (Chitwan–Nawalparasi) and of Annapurna Himalaya range. Forest here starts from 1450 to 2517m altitude which is characterized by sub tropical to temperate mixed evergreen forest.

3.1.2 Drainage

The aquatic ecosystem which is located in the lower reaches constitutes a deep water zone and a shallow peripheral zone. The wetland ecosystem is represented swampy and marshland located along the flood plains of various streams that drain down. It is a major water catchment for a number of watersheds. The Phewa catchment, which also includes the Harpan Khola watershed and parts of Parbat and Syangja district, is an important watershed followed by Andhi Khola watershed and Phedi Khola watershed. The significance of Panchase lies in its capacity to feed water to these watersheds.

3.3.3 Climate and precipitation

Panchase area lies in warm temperate and cool temperate climatic zone with sufficient altitudinal variation and heavy precipitation during monsoon. Summers are generally warmer in low elevation but colder at higher elevation. According to IUCN 2012, the Arthur VDC has not witnessed a snowfall since 2007. The meteorological station data of Panchase is shown in graph (figure 2).

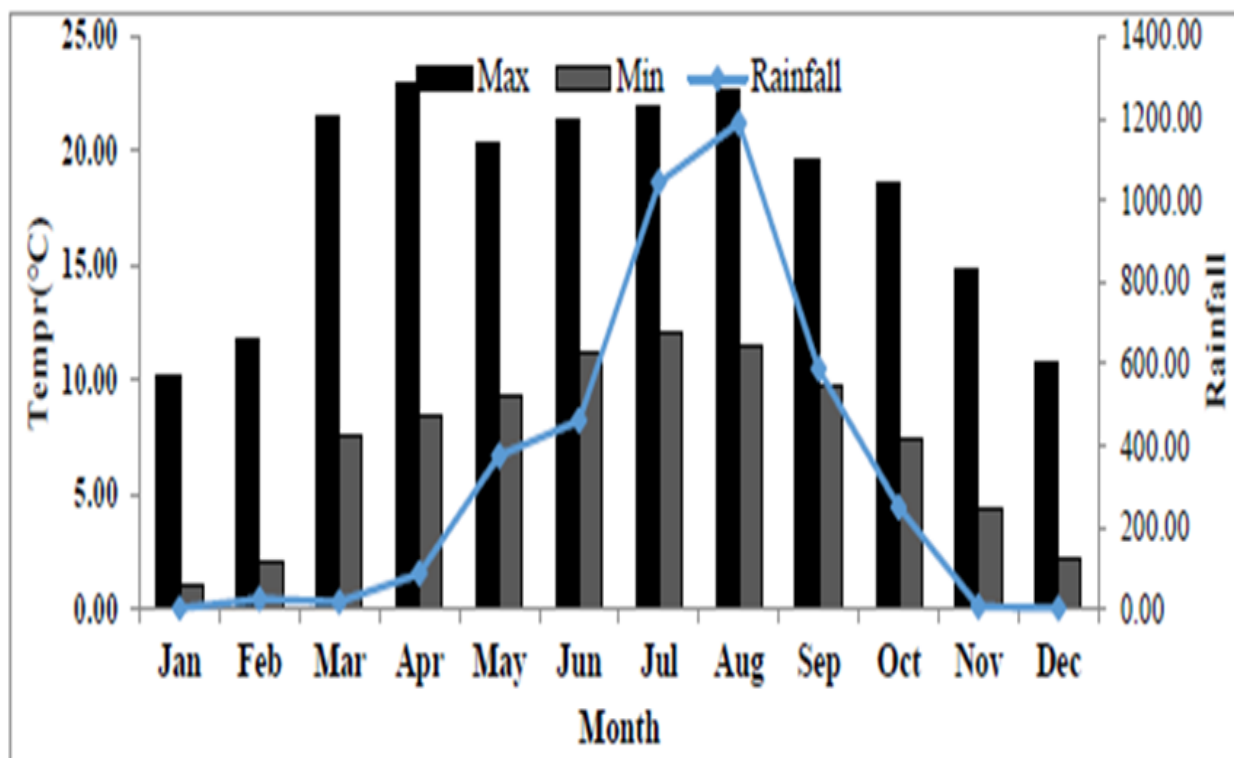


Figure 2 Average temperate and rainfall of the study area (2012-2015)
 Source: CBS, 2017

The total average annual rainfall is 4054.87 mm. The above graph shows that the maximum rainfall is reached in April and the minimum is reached in January. According to the rainfall data from 2002 -2012 the maximum rainfall data was recorded on August (1549.50 mm). The maximum temperature reaches up to 23.9 °c in August and the minimum temperature falls to 1.2 °c in December

3.3.4 Topography

The altitudinal variation of Panchase is from 500m to 2517m. The lowest elevation lies in the valley of Seti Nadi and Modi Khola. The altitude rises from all directions upto the peak of the Panchase at 2517m. Panchase area is composed of hills and valleys of different elevation ranging from extreme steep slopes and moderately sloping to flat areas.

3.3.6 Forest and vegetation

Forest in Panchase area starts from 1450 m to 2517m with sub-tropical to temperate mixed evergreen forest. There are five major forest types; Alder Forest, Chir Pine Broad Leaved Forest, East Himalayan Oak-Laurel Forest, Lower Temperate Oak

Forest, and *Schima-Castanopsis* Forest have been reported from the area. *Quercus semecarpifolia* (Kharsu), *Quercus lamellosa* (Banjha) and *Rhododendron arboreum* (Laligurans) are major species found in the upper cooler part of the study area whereas *Schima wallichii* (Chilaune), *Castanopsis indica* (Katus), *Daphniphyllum himalayense* (Rakchan) are found at the lower warmer elevation. There are more than 589 flowering plant species recorded from the Panchase forest, among them 386 species of medicinal plants, 8 species of fiber yielding plants, 23 species of natural dye yielding plants; 18 wild species potential for floriculture (except Orchids), 56 species of wild mushroom, and 98 species of ferns are found in the area (Suwal et al., 2013) shelters as many as 589 flowering plant species (Suwal et al., 2013) and cultivated fodder and grasses. Among 412 species of orchid reported from Nepal, this region contains 113 species including 2 endemic species, *Panisea panchasenensis* and *Eria pokharensia* (Suwal et al., 2013). Hence this place is also known as the ‘Kingdom of wild Orchids’.

3.3.7 Culture

Panchase area is famous among the Hindus and Buddhists since it holds various cultural and religious significance. The panchase hill is considered as a holy place connected to Lord shiva. The Siddha Baba Temple, Home Kunda, Balaji Panchayan Temple are the notable sites in the region. The Panchase lake is considered as a famous site for religious pilgrimage during Balachaturdasi in November

3.2 FIELD METHOD

3.2.1 Reconnaissance

Reconnaissance survey of the study site was under taken at the end of July 2017 to collect basic information to design and plan a detail study. Afterwards, two detail field studies were carried out with the help of supervisor in November for 10 days and the second field visit was carried out in April 2018 for a week.

3.2.2 Primary data collection

With the requisite size of quadrat as 100 sq² meter, systematic vegetative sampling was done. As the study area was small starting from the Sidhababa Temple to the lake along the ridge, quadrats were laid wherever *T. wallichiana* was encountered on both the northern and southern aspect of the ridge. Sampling area is shown in the figure 3.

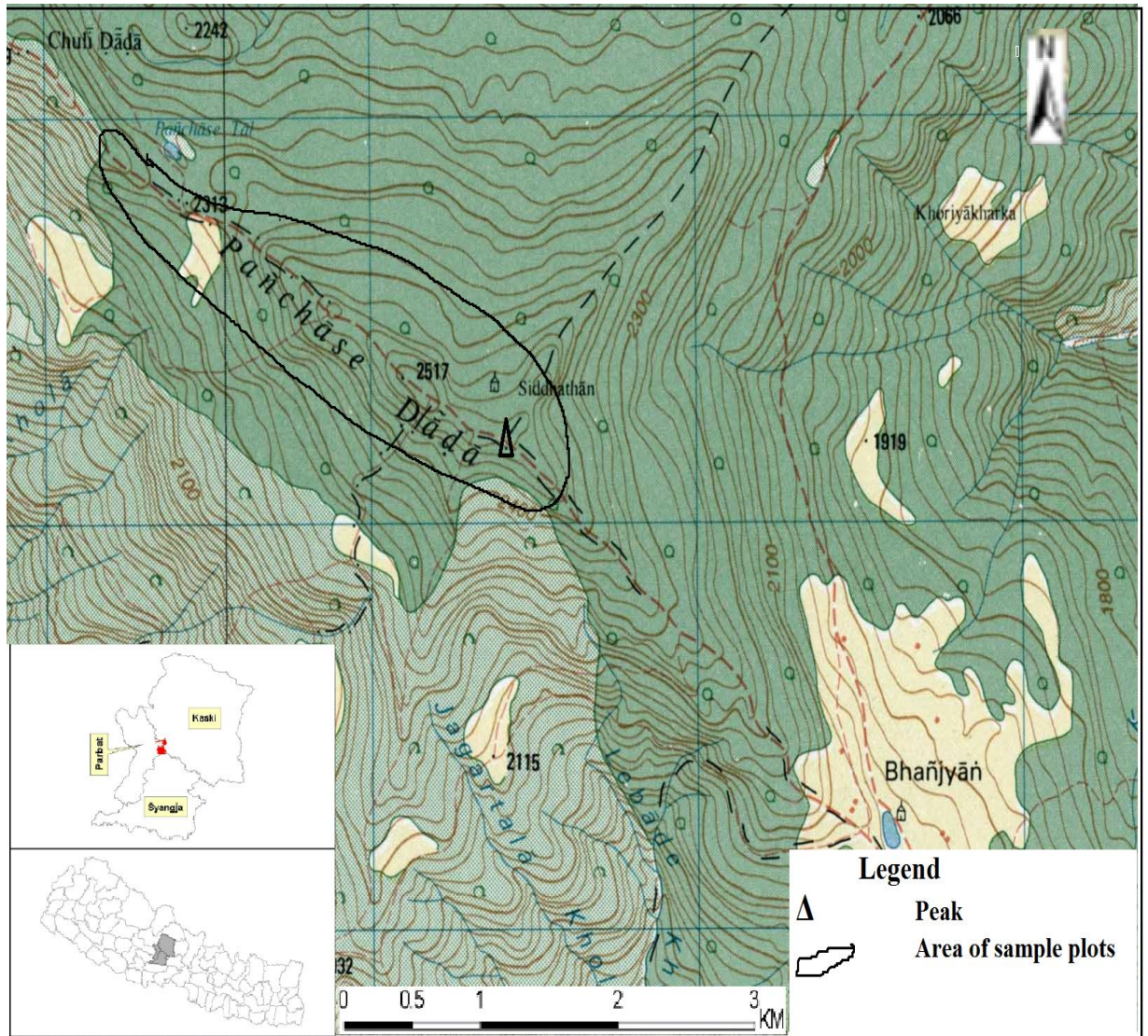


Figure 3 Map showing area of sample plots (Source: Department of Survey)

The objective specific methods are described below:

Objective 1. Mapping distribution and predicting potential sites for *Taxus wallichiana* in the study area.

GPS locations were recorded from all individuals encountered. Species distribution modeling was done with default parameters in Maxent v3.3.3.k (Phillips et al., 2006).

Objective 2. To compare the population structure of the species across different habitat types in the study area.

Sampling was carried out and the following parameters were recorded.

Percent canopy closure was estimated using a spherical densiometer at five places and average was taken, for each quadrat. Similarly, height of each *Taxus wallichiana* tree within the quadrat was calculated using Clinometre. DBH of each encountered individual of *Taxus wallichiana*, within the quadrat, was measured using DBH tape. Soil samples were collected from the surface, removing the litter, from five places from each plot and were mixed in one bag, transported to Botany Department lab of Amrit Campus to determine the pH. Severity of disturbance factors, for each quadrat, such as grazing, lopping, firewood collection, fire, timber collection were observed and were assigned a value as following:

1- no obvious disturbance, 2- weak disturbance, 3- medium disturbance and 4- heavy disturbance. Likewise, aspect for each quadrat was recorded using GPS.

Objective 3. To study micro site preferences and associates of the species

To meet these objective same sampling plots were used.

Aspect was recorded using a compass, slope with the help of clinometer, percent canopy cover was measured using densitometer, altitude was recorded using GPS and soil pH was estimated in the laboratory with the soil samples collected from the plots by using Auto Delux pH meter, model LT-10. Correspondingly, the litter thickness was also recorded by using a ruler. The associated species were recorded in every sample quadrat and the coverage of dominant ground vegetation was also recorded.

3.3 COLLECTION AND PREPARATION OF HERBARIUM SPECIMENS

Samples of *T. wallichiana* were collected from the locality of the study area. Those samples were carefully pressed in the newspaper and their important description and tagging was done in the field and herbariums were prepared. Some samples were in flowering state so flowers were first wrapped in tissue paper before pressing in the newspaper. Specimens were later shifted to herbarium sheets. All the required information were noted on the sheet and stored properly.

3.4 SECONDARY SOURCE OF DATA

Secondary data of precipitation and temperature was obtained from Department of Hydrology and Meteorology.

Information was also collected from the National Herbarium and Botany Laboratory (KATH) Godawari, Lalitpur.

3.5 MORPHOLOGICAL STUDY

The morphological study of the herbarium specimen was done with the help of stereomicroscope and dissecting-microscope. Relevant literature (Spjut, 2007) was used for morphological study. The altitudinal distribution of the species was calculated from R 3.0.1 (R Development Core Team, 2013).

3.6 PHOTOGRAPHS

Photographs of habits, plant parts and other field activities were taken and are included in the thesis wherever necessary.

3.7 DATA ANALYSIS

Density

Density is the number of individuals of a species per unit area. It represents the numerical strength of the species in the community.

$$\text{Density} = \frac{\text{Total number of individual of a species}}{\text{Total number of plot studied} \times \text{Area of plot}} \times 10,000$$

Microsoft Excel for data entry, R program, SPSS 16.0 for windows and Maxent software were used for data analysis.

Species distribution modeling was done with default parameters in Maxent v3.3.3.k (Phillips et al., 2006). The presence records from the research were used as data for

input file. Similarly, 19 Bioclim data (current and future HadGEM2-ES) including Bioclim altitude at a spatial resolution of 30 arc were taken from WorldClim (Hijmans et al., 2005).

Two models (First and second models) were based on current climate conditions and on future (HadGEM2-ES) climate condition following Gajurel et al., 2014. All bioclim variables were tested for Pearson's correlation (R 3.0.1). Variable which were highly correlated were excluded from the study.

Six eco-physiologically important future bioclim (HadGEM2-ES) variables (bio 4 = temperature seasonality, bio 5 = max temperature of warmest month, bio 6 = min temperature of coldest month, bio 12 = annual precipitation, bio 15 = precipitation seasonality, bio 17 = precipitation of driest quarter) were used.

For training data, 50% of points from the site were taken randomly. Similarly, remaining 50% of points were used as best at predicting. The value of AUC (the area under the receiver operating characteristics curve) was compared with recent publication.

For the relationship between occurrence of the population of *Taxus wallichiana*, canopy, altitude, soil pH, exposition, bioclim variables in the study areas were tested with general linear models (GLM) in R. The best models were selected on the basis of Akaike's Information Criterion, AIC (Akaike 1974).

Similarly, cluster analysis was performed based on environmental variables obtained from site and bioclim variables. Hierarchical cluster analysis was done using statistical software SPSS 16.0 for windows with nearest neighbor option. Besides, the data with the occurrence was also used in the spreadsheet.

CHAPTER - 4: RESULTS

4.1 MORPHOLOGICAL STUDY

The maximum height of tree *Taxus wallichiana* Zucc. measured was 11.5m in the study area whereas the least height observed was 4.1m. The key characters were the persistent bud scales, leaves 1.3 to 3.4 cm long and 0.3 to 2.6mm wide, narrowly lanceolate leaf, apex acuminate and leaf underneath not shiny.



Figure 4 The species collected from site

The species collected from the study site was confirmed as *Taxus wallichiana* through the morphological study of the herbarium specimens. Dense persistent bud scales were observed and a single green seed was present which was covered by red fleshy aril in the female plant (figure: 4). The herbarium specimens were compared with the specimens collected in KATH and available literatures. Some of the studied herbarium specimens in KATH are mentioned in table 4.

Table 4 List of herbarium specimens studied from KATH

Species	Herbarium no.	Date of collection	Location (District)	Altitude (m)	Name of collector
<i>T. wallichiana</i>	75/2902	1975	Myagdi	2400	D.P. Joshi & T. K. Battacharya
	RC1432	2010	Kaski	2400	R. C. Poudel
	7477	1983	Kaski	2300	K. R. Rajbhandari
	7603	1983	Kaski	2700	K. R. Rajbhandari
	RC 1209	2010	Rasuwa	2415	R. C. Poudel
	RC 1241	2010	Sindhupalchok	2370	R. C Poudel
	RC 1092	2010	Kathmandu	2467	R.C Poudel & L.M. Gao
	RC 1081	2010	Kathmandu	2392	R.C Poudel & L.M. Gao
	RC 1071	2010	Kathmandu	2300	R.C Poudel & L.M. Gao
	RC 1072	2010	Kathmandu	2300	R.C Poudel & L.M. Gao
	75/794	1975	Kathmandu	2780	Joshi & K.R. Rajbhandari
	B109	2007	Panchthar	2870	R.M Kuwar, R.C. Poudel & N. B. Khatri
	2024	2011	Taplejung	2840	G. Parmar, L.R. Tharu, D. dawadi & K. T
<i>T. contorta</i>	RC 1614	2010	Baglung	2644	R. C. Poudel
	RC 1588	2010	Baglung	2545	R. C. Poudel
	7906	1983	Mustang	2530	K.R. Rajbhandari
	8871	1983	Manang	3000	K.R. Rajbhandari
	8899	1983	Manang	2700	K.R. Rajbhandari
	RC1312	2010	Manang	2690	R.C. Poudel
	RC1335	2010	Manang	2645	R.C. Poudel

Source: Bhatt et al., 2017, (DPR)

In case of *Taxus contorta*, the leaves were straight and narrow and the leaves were also observed all over the branches.

4.2 ECOLOGICAL CONDITION

The population of *T. wallichiana* was found more in the Northern aspect as compared to Southern aspect. Only 12 individuals were recorded in Southern aspect while Northern aspect had 110 individuals (fig.5). Ground vegetation cover was high in the site which was wire fenced for the protection of *T. wallichiana* whereas sites without wire fenced contained less ground vegetation cover. Species observed on the ground were *Arundinaria spp.*, *Eragrostis spp.*, *Cyperus spp.*, shrubs of *Lindera pulcherrima*, *Eurya accuminata* and some ferns like *Pteris spp.* But as observed in the study, *Arundinaria spp.* was found in most of the ground vegetation of the sites.

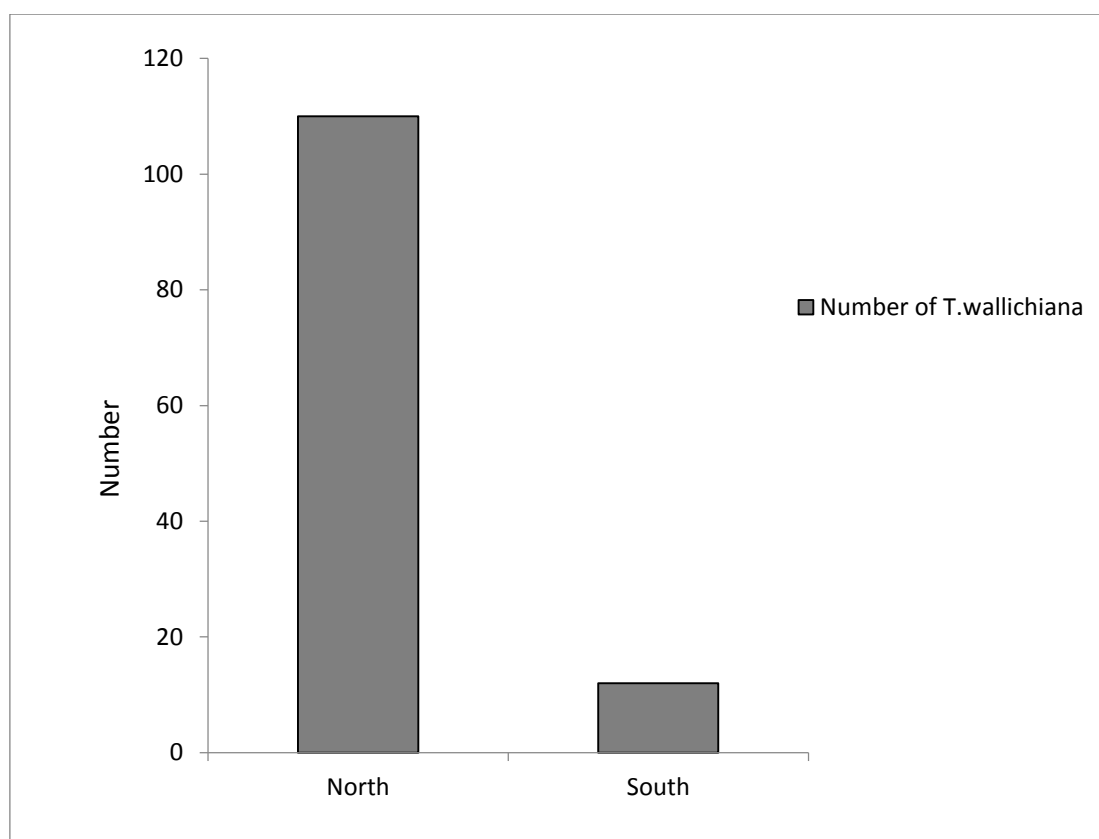


Figure 5 Occurrence of *T. wallichiana* in Northern and Southern aspects

The associates of *Taxus wallichiana* in the study area were *Lyonia ovalifolia*, *Daphniphyllum himalensis*, *Rhododendron arboreum*, *Simplocos ramosissima*,

found in the elevational range from 2300m to 2400m (fig. 7). The population increases to some altitude and then it declines (fig. 7).

Table 5 Number of saplings observed in the study area.

Plot no.	No. of saplings
1	1
8	2
28	2
Total	5

Saplings were observed in only three plots out of thirty one. Those three plots had only five saplings altogether which indicated very low regeneration rate of the study area (Table 5).

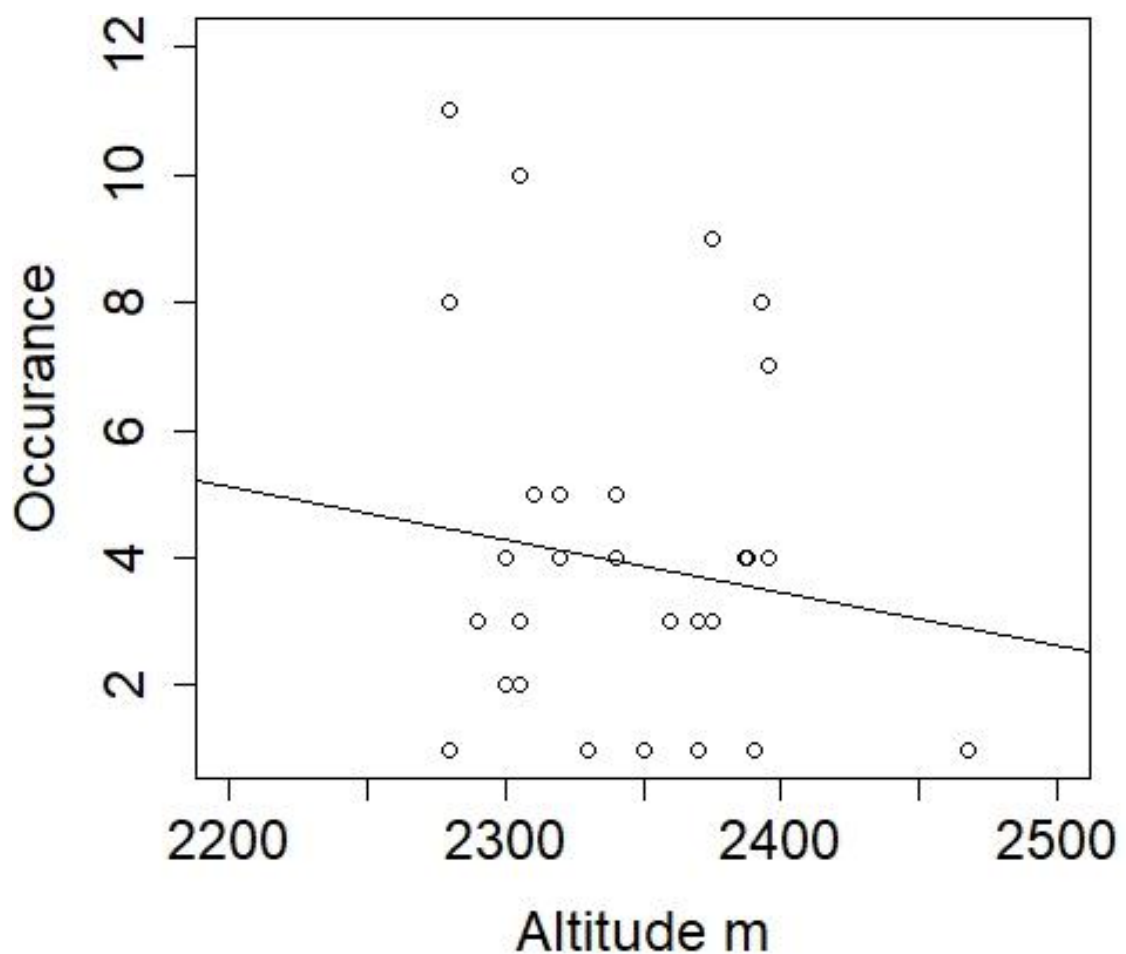


Figure: 7 Occurrence of the populations of *T. wallichiana* along the altitudinal gradient

The study also revealed the sex bias nature of *T. wallichiana*. Out of 122 individuals, female population was found to be only 12 and the rest were males, so the female to male ratio was 12:110 (fig.8). Female population was found in only three plots out of 31 plots (table 6).

Table 6 Male and female population of *T. wallichiana* in the study area.

Sex	Count of population (sample plots)
Female	3
Male	28
Total plots	31

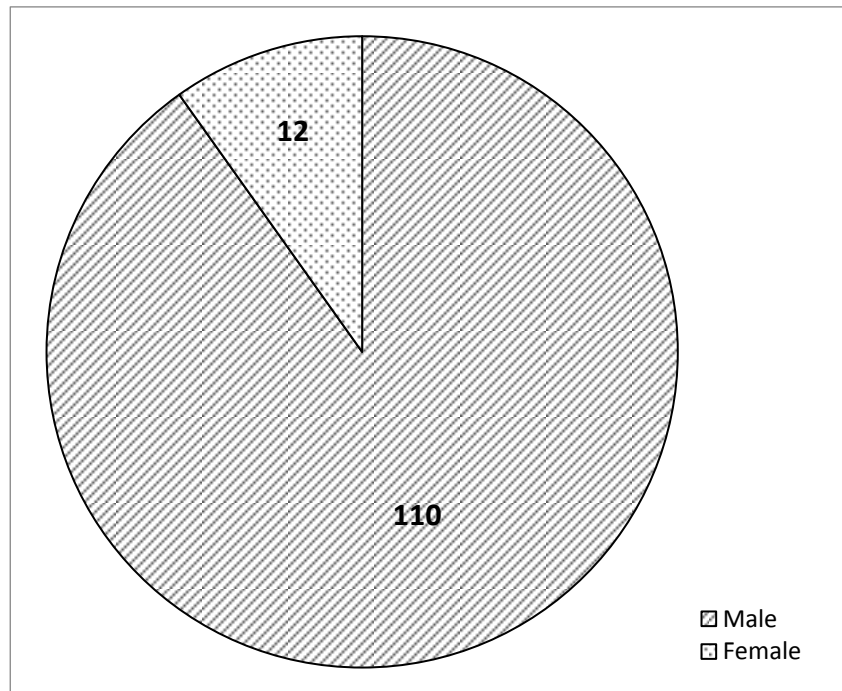


Figure 8 Female to male sex ratio.

The study recorded that the DBH range of most of the *T. wallichiana* trees were between 10cm to 20cm (fig.9) whereas the least number of *T. wallichiana* were in between the DBH class of 50cm to 60cm.

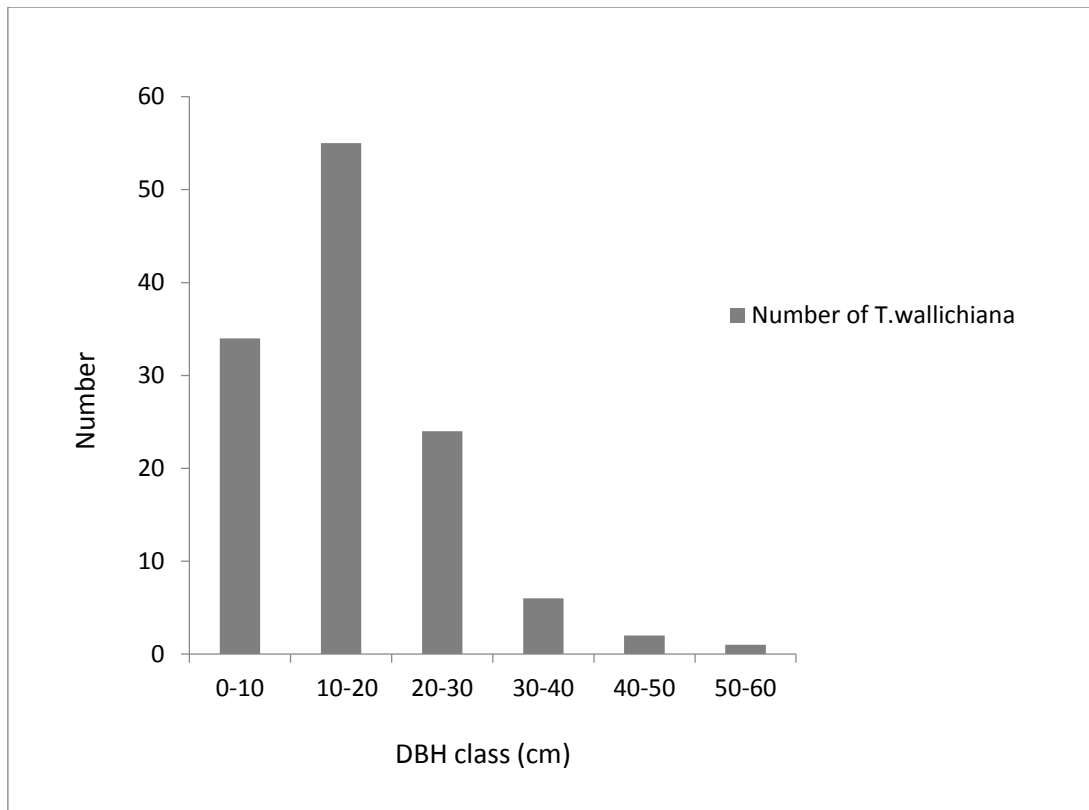


Figure 9 DBH class of *T. wallichiana* in the study area.

4.4 MICROHABITAT PREFERENCE AND RELATIONS WITH ENVIRONMENTAL VARIABLE

The result from the General Linear Model showed that there was significant combined effect of different environmental variables to the occurrence of *T. wallichiana* (Table 6). Model 7 and 8 showed the significant effect of altitude, canopy, litter thickness, bioclim temperature and precipitation on the occurrence of *T. wallichiana*. Similarly, model (11, 12, 13, 14, 17, 20) with soil pH, canopy cover, litter disposition, bioclim temperature and precipitation and altitude showed that presence of *T. wallichiana* is also affected by their combined effect. Models 18 and 19 (separate bioclim variables) also showed the distribution of this species is affected by the bioclim temperature and precipitation). The result also showed the habitat preference of this species in suitable temperature, precipitation, soil litter composition, soil pH, canopy cover and other dominant species as determined in this study (Table 7).

Table 7 Selection of General Linear Model for species occurrence

Model names	Null deviance	Residual deviance	AIC	Sig. code
Model with less correlated variables				
model 1: occur ~1	239.87	239.87	155.4	** *
model 2: occur ~ Alt	239.87	235.45	156.83	
model 3: occur ~ Alt+canop	239.87	225.07	157.43	
model 4: occur ~ Alt+canop+Litter	239.87	225.06	159.43	
model 5: occur ~ Alt+canop+Litter+BIO4	239.87	202.90	158.21	
model 6: occur ~ Alt+canop+Litter+BIO4+BIO5	239.87	202.88	160.21	
model 7: occur ~ Alt+canop+Litter+BIO4+BIO5+BIO6	239.87	174.71	157.58	.
model 8: occur ~ Alt+canop+Litter+BIO4+BIO5+BIO6+BIO15	239.87	170.98	158.91	.
model 9: occur ~ Alt+canop+Litter+BIO4+BIO5+BIO6+BIO15+BIO17	239.87	167.05	160.19	
Model with Bioclim Alt and veg.				
model 10: occur~Litter	239.87	238.11	157.18	
model 11: occur~Litter+ph	239.87	202.17	154.1	*
model 12: occur~Litter+ph+GRVEGCOV	239.87	202.06	156.09	*
model 13: occur~Litter+ph+GRVEGCOV+DOMSPCOV	239.87	184.31	155.23	*
model 14: occur~Litter+ph+GRVEGCOV+DOMSPCOV+Alt	239.87	183.27	157.06	.
model 15: occur~Alt+canop+Litter+BIO4+BIO5+BIO6+BIO15+BIO17+GRVEGCOV+DOMSPCOV+DBH+Heig	239.87	153.28	165.52	
model 16: occur~Alt+canop+Litter+BIO4+BIO5+BIO6+BIO15+BIO17+GRVEGCOV+DOMSPCOV+DBH+Heig+ph	239.87	132.48	163	.
model 17:	239.87	165.8	159.	.

occur~Alt+canop+Litter+GRVEGCOV+DOMSPCOV+DBH+Heigh+ph	7	8	97	
model 18: occur~BIO4+BIO5+BIO6+BIO15+BIO17+BIOAlt	239.8 7	167.5 8	154. 29	*
model 19: occur~BIO4+BIO5+BIO6+BIO15+BIO17	239.8 7	167.5 8	154. 29	*
model 20: occur~canop+Litter+GRVEGCOV+DOMSPCOV+DBBH+Heig+ph	239.8 7	166.5 1	158. 09	**
model 21: occur~BIO4+Litter+ph+BIO17+ph	239.8 7	189.8 0	156. 15	

Note: Akaike's information criterion (AIC) and Significance codes: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1, Alt-Altitude, Canop-Canopy, DOMSPCOV- Dominant species cover, GRVEGCOV- ground vegetation cover, Litter- Litter thickness, Veg- Vegetation, ph- soil pH, DBH- Diameter at breast height, Heig- Height, BIO 4- temperature seasonality, BIO 5- maximum temperature of warmest month, BIO 6- minimum temperature of coldest month, BIO 15- precipitation of seasonality and BIO17- precipitation of driest quarter.

4.5 CLUSTER ANALYSIS OF POPULATION OF SITES

This figure 10 shows slight difference in the populations. Population in 24th plot was distinct compared to rest while populations at sites 2, 3, 4, 5 and 6 plots were similar compared to rest. This distinction into three groups based on different environmental variables shows that environmental requirement for the populations are different for the different patches.

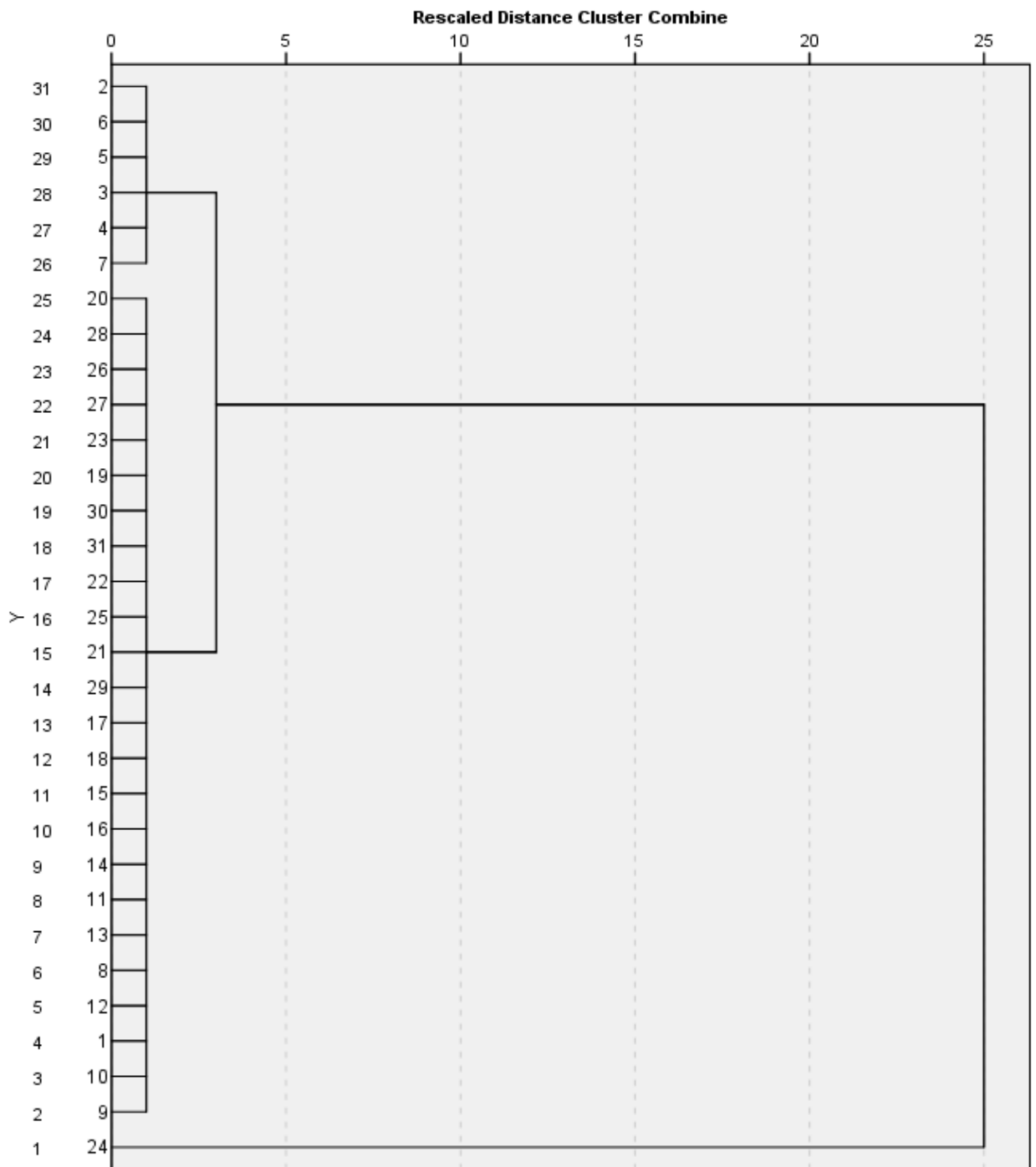


Figure 10 Dendrogram of population of *Taxus wallichiana* on environmental variables.

4.6 SPECIES DISTRIBUTION MODELS

Two types of species distribution model were prepared, present distribution model and future distribution model. Both scenes show that the current and future distribution will be affected by environmental variables related to temperature and precipitation.

4.6.1 Present Species Distribution Model

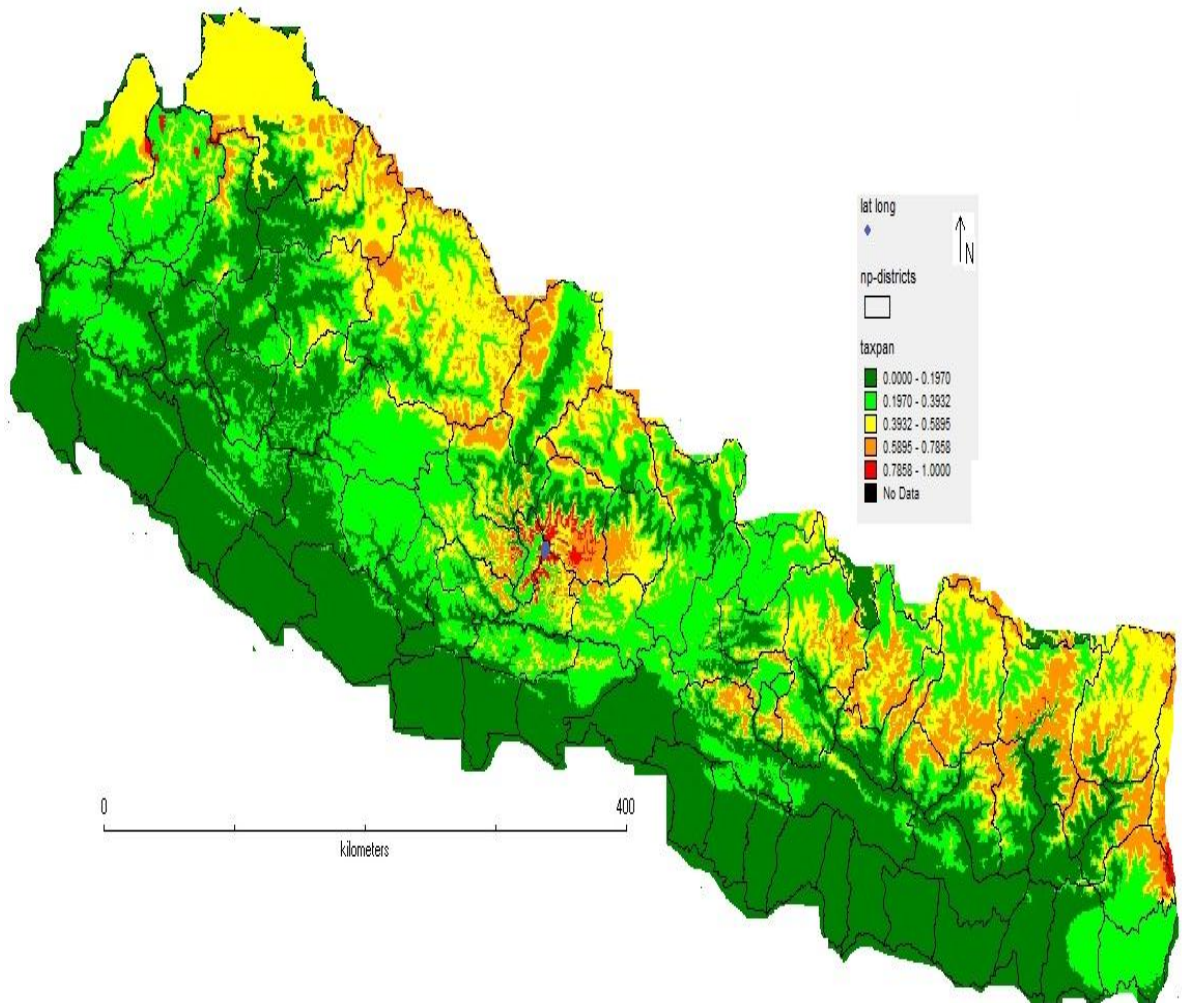


Figure 11 Species distribution model of *Taxus wallichiana* in Panchase for present climate condition.

In the figure 11, the red areas are possible occurrence of the species which was found to be true. When rests of the sites of the collection were fitted in the map, it fell on the red zone which is current possible areas. This justifies the usefulness of this distribution model. This model also shows habitat preference of the species towards higher altitude with high precipitation and lower temperature.

4.6.2 Future Species Distribution Model

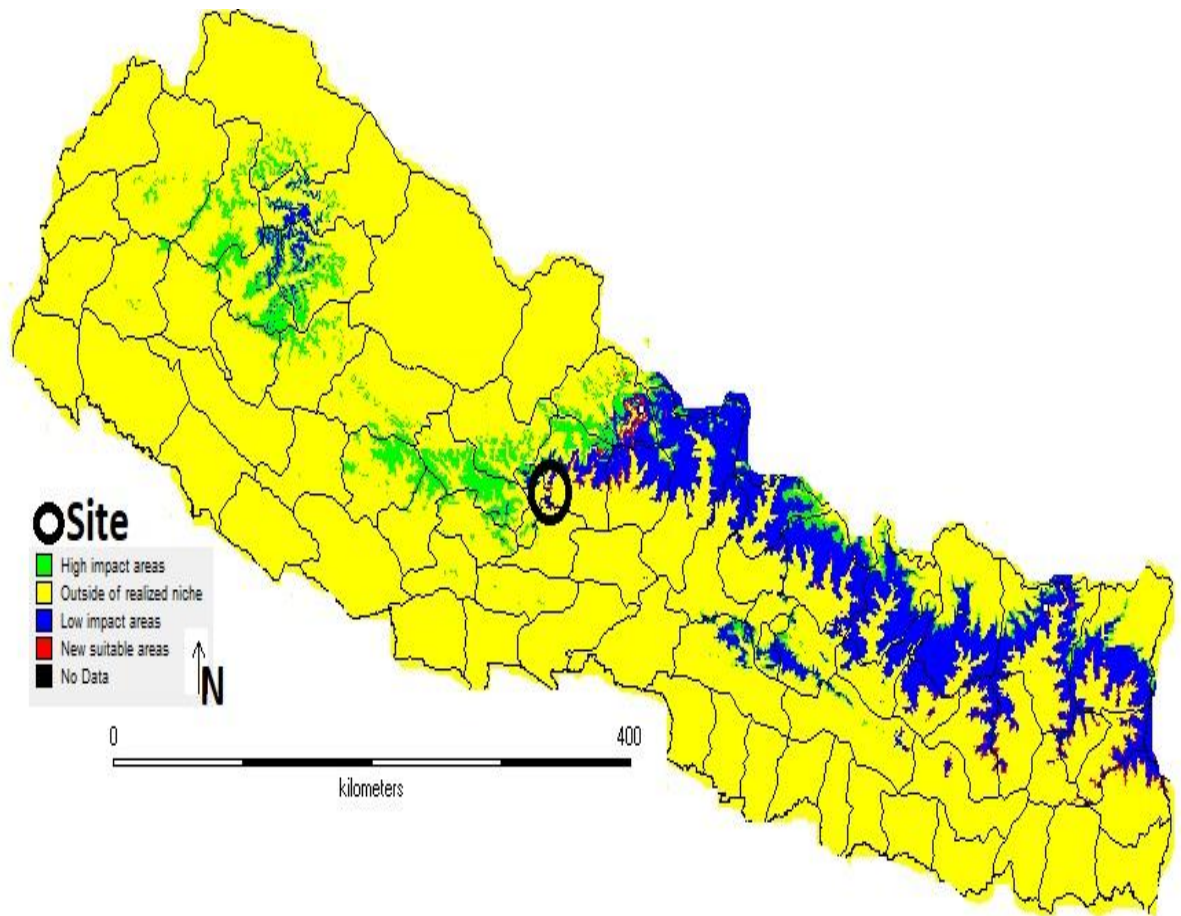


Figure 12 Species distribution model of *Taxus wallichiana* in Panchase for future climate condition

Figure 12 shows the high impact areas in future distribution as indicated by green ones, so the area of the Panchase does not seem to be much affected by climate change. The new possible areas for the distribution of the species are towards upper part of Eastern Nepal. However, the western part has less suitable areas for this species.

CHAPTER - 5: DISCUSSION

5.1 MORPHOLOGICAL STUDY

The morphological features observed in this study are similar to that of Spujt 2007, Poudel et al., 2012 and Gajurel et al., 2014. The leaves of *Taxus wallichiana* are pectinate and tapering towards the end. Bud scales are present at the base of branchlets whereas the leaves of *T. contorta* are arranged irregularly pectinate. Likewise, *T. mairei* consists of pectinate leaves which are flat and lanceolate. Unlike the two other species, *T. mairei* has shiny underneath (Poudel et al., 2012).

5.2 POPULATION STRUCTURE

Population of *Taxus wallichiana* does not show any specific distribution pattern rather it has a very scattered arrangement. The species was found only between the altitudinal ranges of 2200m to 2500m within a narrow altitudinal belt. The finding of this study is similar to that of Poudel et al., 2012 where they described that the elevational range of *T. wallichiana* is from 1900m to 2700m(-3000m) in Hindu Kush Himalaya region. Present study suggests that the distribution pattern of *T. wallichiana* goes on increasing with altitude to some extent and then the population declines similar to the observation of Gajurel et al., 2014 in Nepal Himalaya. The occurrence of *T. wallichiana* was observed less along the ridge at 2500m. This finding is similar to Gajurel et al., 2014 where the species distribution increases sharply in the altitudinal range between 2800m and 3100m showing the same narrow altitudinal range. After this, the population sharply decreases to a patch or sometimes becomes confined to one or two individual. Ganguly 2011 also stated that the population of *T. wallichiana* was found mostly at an altitudinal range of 2500m to 3500m and then the number of species dropped. According to Gajurel et al., 2014 the most preferable altitude of the species is 2600m to 3000m. The elevational range of the study area being less than 2600m, it limits the encounter of the plant in the most preferable altitude. Present study also showed the sex biased nature of *T. wallichiana* as number of female plant is very low as compared to males. This finding resembles other studies done by Allison 1990; Svenning and Mgard 1999; Garcia et al., 2000; Hilfilker et al., 2004.

5.3 ECOLOGICAL CONDITION AND MICRO HABITAT PREFERENCES

The study showed that any one variable did not exercise complete control over the number of *T. wallichiana* present in the study area. The study shows that environmental variables required for species are different as stated by Poudel et al., 2012 and Gajurel et al., 2014.

Three different types of ecological niches are described by Poudel et al., 2012 for three different species of *Taxus* which points that, this species *T. wallichiana* requires different environmental variables like other two species. Similar case was found by Ganguly 2011, where micro habitat like steeper slope, greater litter thickness and cooler aspect favored the presence of *T. wallichiana*. The interaction of temperature, slope, aspect, litter depth played the significance role that affects the occurrence of the species in her study area. The micro habitat preference of this species related variables like bioclim temperature, bioclim precipitation, soil pH, litter thickness, aspect, etc as determined in different models are similar to the findings of Ganguly 2011, Poudel et al., 2012 and Gajurel et al., 2014. The results shown by the cluster analysis is similar to the study carried out by Ganguly 2011 in Uttarkashi. The requirement of different environmental variables by the different patches of population shows their different preferences for occurrence. The high occurrence of *T. wallichiana* in the Northern aspect also indicates its preferences towards cooler aspect.

Population of *Taxus wallichiana* was associated with different tree species and ground vegetation. The dominant associates of *T. wallichiana* were *Rhododendron arboreum* and *Quercus semecarpifolia*. This result is similar to that of Paul et al., 2013; Singh and Singh 1992 and Ganguly 2011. The study site which was wire fenced had huge crowd of *Arundinaria spp.* As Panchase is a protected area, certain part of the area is wire fenced mainly for the conservation of *T. wallichiana*. This site has huge bushes of *Arundinaria spp.* as ground vegetation. This result is similar to the finding of Behera et al., 2000 and Poudel et al., 2012 where they recorded *T. wallichiana* associated with *Abies*, *Acer*, *Pinus*, *Quercus*, *Rhododendron*, *Tsuga*, bamboos and Laurels. The site being fenced with wire, it is inaccessible which may be the reason for the presence of bushy bamboos. Other than bamboo scrubs, shrubs of *Eurya serasifolia*, *Lindera*

pulcherrima, ferns, *Eragostis spp.* and *Cyperus spp.* were also observed. These observations were seen more in the sites which were not fenced by wire.

The germination of seed of *T. wallichiana* occurs in natural condition in forest. The seeds that fall in suitable micro habitats germinate successfully and those in unfavorable micro habitat fail to germinate. The suitable micro habitats for germination are determined by soil texture, moisture, litter thickness and light interception. The germination rate was very low in the study area as only five saplings were found in 31 plots. The reason may be due to the thickness of litter which was 32 cm (Highest recorded) and the high canopy closure too. Natural regeneration is more common under open or sparse canopy (Haridasan et al., 2001; Purohit et al., 2001; Nimachow et al., 2010). Moreover, the study area had high degree of slope where the seeds can roll over easily decreasing the chances of germination. The other factors inhibiting the germination of *T. wallichiana* may be the emission of allelopathic substance by the tree itself. Thomas and Polwart, 2003 reported that *T. baccata* emits allelopathic substance which diminished the seed germination and eliminated the seedling in their first growth stages. The other reason could be the plant being sex biased. But it must be mentioned here that it was difficult to differentiate the sex of the plant. Plants were differentiated based on the presence of fruit.

Disturbance has significance effect in the distribution of *T. wallichiana* (Gajurel et al., 2014). However, the study area in this study is a Protected Forest area which points towards the low disturbance level. Very less disturbance was observed where *T. wallichiana* occurring on the walking trail were cut down. This was probably done for building the walking trails. Grazing and fire were not observed since most of the *T. wallichiana* were present in the deep forest and most sites were wire fenced too.

5.4 SPECIES MODELING

Species distribution model can be used to identify the species potential distribution at which reintroduction programs can be focused. Finding potential sites for species distribution allows prediction of community composition for any site and such prediction helps in identification of conservation priorities (Peterson et al., 2000).

On the bases of current and future climate condition, the study of Poudel et al., 2012 and Gajurel et al., 2014 also predicted that the most suitable sites for *T. wallichiana* ranged from Eastern Nepal through Central Nepal. The most preferable sites for *T. wallichiana* will be towards upper Eastern part of Nepal since it receives high precipitation and temperature is also low. Since the suitable habitat will shift towards North, it justifies our finding that there will be no severe effect of climate change in the study area. Despite the fact that *T. wallichiana* is not found in far West Nepal; however, the suitability of habitat in the west shows that those areas could be potential for cultivation. The limitation in this study is that no other locations data were used to get the best distribution.

CHAPTER - 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSION

T. wallichiana has very narrow range of distribution and is mostly limited to the top of the Panchase forest, especially along the ridge at 2500m.

Different variables as single or their combined role affected the distribution of *T. wallichiana*. Canopy closure, soil pH, litter thickness, precipitation, temperature, ground vegetation cover and dominant species were the most important variables affecting the micro-habitat of *T. wallichiana*. *Rhododendron arboretum*, *Quercus semecarpifolia* and *Lyonia ovalifolia* were the dominant tree species while *Arundinaria spp.* was the dominant ground vegetation. The study area also showed extremely poor regeneration rate of the species.

The new possible areas for the distribution of the species will be towards the upper part of Eastern Nepal, whereas Western Nepal has less suitable distribution. However, there will be no severe effect of climate change on the distribution of *T. wallichiana* in the study area.

6.2 RECOMMENDATION

The present study conducted in Panchase Protected Forest Area intends to provide an understanding of future climatic condition affecting the distribution of the species. The study is also about the population status of the species, *Taxus wallichiana* which is an endangered species. Therefore I would point out the following recommendations for its conservation:

- More studies are needed in habitats similar to Panchase.
- Anatomical and molecular studies are needed to distinct population as found here in cluster analysis.

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- To cultivate the species in suitable areas as mentioned in thesis with mixed population of *T. wallichiana* from different parts of Nepal.
 - As natural regenerating capacity of *Taxus* is low, vegetative propagation can be taken as alternative in the suitable sites.
 - Awareness programs should be conducted aiming sustainable management and utilization of the species targeting the local people or major stake holders to protect the species in its natural habitat.
 - The potential sites as predicted by the model in this study will help in conservation planning and help in sustainable management of the useful species facing severe threat.

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Appendixes

Annex 1 Individual species with total occurrence, DBH and height

plot no.	serial no.	species name	DBH (cm)	height (m)
1	1	Species 1	12.5	6.2
2	1	Species 2	8.8	6.2
	2	Species 3	15.9	6
	3	Species 4	8.5	4.5
	4	Species 5	17.9	9.2
3	1	Species 6	21.9	6.5
	2	Species 7	10	6.2
	3	Species 8	12	7.2
	4	Species 9	9.2	5.1
	5	Species 10	7.9	4.3
	6	Species 11	11.4	3.5
	7	Species 12	13.3	8.6
	8	Species 13	15.3	4.8
4	1	Species 14	19.2	8.6
	2	Species 15	10.4	7.9
	3	Species 16	46.7	11.3
	4	Species 17	29	9.4
5	1	Species 18	16.6	7.2
	2	Species 19	12.5	8.6
	3	Species 20	8.9	4.1
	4	Species 21	9.6	4.1
	5	Species 22	20.4	7.5
	6	Species 23	18.8	8.3
	7	Species 24	12.6	8.6
6	1	Species 25	7.8	4.1
	2	Species 26	37.5	6.3
	3	Species 27	26.5	6.8
	4	Species 28	21.2	8.2

7	1	Species 29	20.9	8.9
8	1	Species 30	25	6
	2	Species 31	13.5	8.2
	3	Species 32	29	6.1
	4	Species 33	13.4	7.1
	5	Species 34	14.7	9.7
	6	Species 35	14.6	4.3
	7	Species 36	13	6.4
	8	Species 37	22.3	6.8
	9	Species 38	10.9	4.5
9	1	Species 39	22.3	11.5
10	1	Species 40	66.2	5.7
	2	Species 41	33.6	5.3
	3	Species 42	13.2	6.2
11	1	Species 43	15.4	8.7
12	1	Species 44	15.9	4.5
	2	Species 45	12.8	9.2
	3	Species 46	6.3	5.2
13	1	Species 47	9.9	8.2
	2	Species 48	13.1	7.3
	3	Species 49	11.7	8.2
14	1	Species 50	26.8	9.3
15	1	Species 51	8.3	8.7
16	1	Species 52	12.9	9.6
	2	Species 53	36.4	8.3
	3	Species 54	23.9	7.8
	4	Species 55	37.3	10.6
17	1	Species 56	16.6	9.7
18	1	Species 57	46.5	9.7
19	1	Species 58	24.7	7.9
	2	Species 59	19.5	6.1
	3	Species 60	9.3	6.3
	4	Species 61	10.2	7.2

	5	Species 62	13.4	6.2
	6	Species 63	8.9	5.8
	7	Species 64	19.3	4.7
	8	Species 65	11.8	4.8
20	1	Species 66	22.4	8.2
	2	Species 67	34.1	7.1
	3	Species 68	7.1	5.8
	4	Species 69	10.5	4.6
21	1	Species 70	5.5	5.2
	2	Species 71	9.5	6.8
	3	Species 72	23.6	6.1
	4	Species 73	3.7	4.7
	5	Species 74	3.7	5.4
22	1	Species 75	19.7	5.5
	2	Species 76	18.3	8.3
23	1	Species 77	19	4.9
	2	Species 78	13.9	5.2
	3	Species 79	11.9	4.2
	4	Species 80	16	4.6
24	1	Species 81	20	7.1
	2	Species 82	20.9	7.2
25	1	Species 83	31.2	9.2
	2	Species 84	26.5	10.8
	3	Species 85	8.5	5.1
26	1	Species 86	17.8	7.2
	2	Species 87	20.1	7.2
	3	Species 88	13.7	5.9
27	1	Species 89	10.8	6.4
	2	Species 90	9.2	4.8
	3	Species 91	7.7	5
	4	Species 92	8.8	9.8
	5	Species 93	14.4	6.2
	6	Species 94	9.9	7.1

	7	Species 95	14	7.9
	8	Species 96	10	6.9
	9	Species 97	15.6	8.2
	10	Species 98	13.4	6.2
28	1	Species 99	22.9	9.1
	2	Species 100	6.4	7.5
	3	Species 101	7	6.5
	4	Species 102	17.7	9
	5	Species 103	8.5	7.8
29	1	Species 104	14.2	7.4
	2	Species 105	21.2	5.1
	3	Species 106	6.4	5.8
	4	Species 107	16.2	8.1
	5	Species 108	16.4	8.5
30	1	Species 109	13.5	8.1
	2	Species 110	8.2	5.3
	3	Species 111	26.8	10.8
31	1	Species 112	23.7	8.6
	2	Species 113	16.5	7.9
	3	Species 114	21.7	7.2
	4	Species 115	22.6	9.2
	5	Species 116	8.9	4.3
	6	Species 117	8.6	6.4
	7	Species 118	5.7	4.1
	8	Species 119	19.3	5.2
	9	Species 120	23.3	6.2
	10	Species 121	7.2	7.9
	11	Species 122	13	7.2

Annex 2 Plot with Bioclim

POP	BioALt	BIO4	BIO5	BIO6	BIO12	BIO15	BIO17
plot1	2106	4431	235	6	2455	112	34
plot2	2376	4512	223	-6	1704	105	38
plot3	2376	4512	223	-6	1704	105	38
plot4	2376	4512	223	-6	1704	105	38
plot5	2376	4512	223	-6	1704	105	38
plot6	2376	4512	223	-6	1704	105	38
plot7	2376	4512	223	-6	1704	105	38
plot8	2106	4431	235	6	2455	112	34
plot9	2149	4420	232	4	2325	111	35
plot10	2111	4425	234	5	2442	111	34
plot11	2111	4425	234	5	2442	111	34
plot12	2111	4425	234	5	2442	111	34
plot13	2111	4425	234	5	2442	111	34
plot14	2111	4425	234	5	2442	111	34
plot15	2111	4425	234	5	2442	111	34
plot16	2111	4425	234	5	2442	111	34
plot17	2111	4425	234	5	2442	111	34
plot18	2111	4425	234	5	2442	111	34
plot19	2220	4474	230	0	2108	109	36
plot20	2220	4474	230	0	2108	109	36
plot21	2220	4474	230	0	2108	109	36
plot22	2220	4474	230	0	2108	109	36
plot23	2220	4474	230	0	2108	109	36
plot24	1728	4216	249	27	3916	119	30
plot25	2220	4474	230	0	2108	109	36
plot26	2220	4474	230	0	2108	109	36
plot27	2220	4474	230	0	2108	109	36
plot28	2220	4474	230	0	2108	109	36
plot29	2220	4474	230	0	2108	109	36
plot30	2220	4474	230	0	2108	109	36
plot31	2220	4474	230	0	2108	109	36

Annex 3: Occurrence of the species with different environmental variables.

Population	Alt (m)	Canopy cover (%)	Aspect	litter thickness (cm)	Slope (%)	Soil pH	Occur
plot1	2390	95	north	32	55	5.28	1
plot2	2395	85	north	29	55	5.68	4
plot3	2393	90	north	16	60	5.3	8
plot4	2388	85	north	12.5	70	5.59	4
plot5	2395	85	north	0	60	4.84	7
plot6	2387	85	north	12	55	5.59	4
plot7	2370	85	north	6	45	5.35	1
plot8	2375	75	north	7.5	45	5.56	9
plot9	2468	90	north	5.8	60	6.48	1
plot10	2375	70	south	22	75	6.36	3
plot11	2370	85	south	5.5	70	5.46	1
plot12	2370	80	south	15	30	5.59	3
plot13	2360	90	south	16.6	75	6.2	3
plot14	2350	45	north	22.7	55	5.58	1
plot15	2330	70	south	6	60	5.74	1
plot16	2320	65	north	6	70	5.42	4
plot17	2280	80	south	7.3	45	5.27	1
plot18	2280	60	south	4	45	5.16	1
plot19	2280	80	north	31	55	5.06	8
plot20	2340	80	north	14	55	5.64	4
plot21	2320	70	north	14.9	60	5.45	5
plot22	2300	70	north	18.2	60	5.33	2
plot23	2300	70	north	10	20	5.41	4
plot24	2305	40	north	3.6	20	5.04	2
plot25	2305	80	north	4	45	4.94	3
plot26	2305	60	north	15	35	5.33	3
plot27	2305	60	north	9.3	35	5.06	10
plot28	2340	85	north	10	70	5.33	5
plot29	2310	80	north	6.2	75	5.23	5
plot30	2290	85	north	6	65	5.26	3

plot31	2280	85	north	3.2	75	5.11	11
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Annex 4: Photographs during field work



Measuring DBH of *T. wallichiana*.



Measuring litter thickness.



Working at KATH for plant identification.



Collecting soil sample from the study site.

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