Forest Structure, Regeneration and Plant Invasion in Sal and Riverine Forest of Chitwan, Central Nepal

A Dissertation submitted for the Partial Fulfillment of the Requirement for the Master's Degree in Botany

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DECLARATION

I, Niraj Khanal, hereby declare that the content in this work is entirely my own, unless stated otherwise with proper references. It has not been published or submitted elsewhere, in whole or in part, for the requirement for any other degree or professional qualification. Any information or contributions from others that are cited in this thesis have been appropriately acknowledged and listed in the references.

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This is to recommend that the Master's thesis entitled **"Forest Structure, Regeneration and Plant Invasion in Sal and Riverine Forest of Chitwan, Central Nepal"** is carried out by "**Niraj Khanal**" under my supervision. The entire work is based on original scientific investigations and has not been submitted for any other degree in any institutions. I therefore, recommend this thesis work to be accepted for the partial fulfilment of M.Sc. Degree in Botany.

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LETTER OF APPROVAL

The thesis work entitled **"Forest structure, Regeneration and Plant Invasion in Sal and Riverine Forest of Chitwan, Central Nepal"** submitted to Department of Botany, Amrit Campus, Tribhuvan University by Niraj Khanal, Exam Roll No.: BOT 828/076, T.U. Registration No.:5-2-0019-0495-2015 under the supervision of Assistant prof. Mr. Krishna Prasad Sharma has been accepted for the partial fulfilment of the requirement for Master's Degree in Botany.

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ABSTRACT

The study assessed tree species diversity, regeneration, and the impact of invasive alien plant species in Sal and Riverine forest of Bhimwali Community Forest within south central Nepal. A total of 40 (20m×20m) plots, 20 plots in each forest type was laid by quadrate sampling method. Forest sampling was done in November 2022 and supplementary data were collected in November 2023. For data collection transects were drawn perpendicular to the river at 200m distance for each transect. In each transect 4 - 6 quadrats were laid. Minimum distance between each quadrat was 50m. Inside main plot sub-plot 5m × 5m was constructed for shrubs/saplings and 1m × 1m plot was conducted for herbs/seedlings respectively. From each quadrat all vegetation and plot characteristics were recorded. Altogether, 118 vascular plant species were recorded; 30 trees, 33 shrubs, 42 herbs, 7 ferns, and 6 climbers. Riverine forest has higher species richness than the Sal forest. In Sal forest 13 species of trees from 11 families were found, with *Shorea robusta* being the most dominant tree species with highest importance value index (IVI 212.33). In the riverine forest, 22 species of trees from 16 families were observed, with *Trewia nudiflora* as the most dominant tree species (IVI 100.76). The overall forest regeneration was relatively better in Sal forest in compared to Riverine forest with reverse J-shaped d-d curve. We observed that riverine forest has significant invasive plant impact than Sal forest. In the Sal forest, 9 invasive alien plant species were recorded, with *Chromolena odorata* having the highest frequency (80%), followed by *Mikania micrantha* at 75%. While in the Riverine forest, 11 invasive alien plant species were reported, with *Mikania micrantha* having the highest frequency (75%), followed by *Chromolaena odorata* at 55%. We have observed that the Riverine forest, being close to human settlements, experienced higher anthropogenic activities, leading to increased plant invasion and a direct adverse impact on forest regeneration. In contrast, the Sal forest exhibited better regeneration and lower instances of plant invasion in compared to the Riverine forest. The observed variations highlight the need of targeted conservation efforts in Riverine forest, especially in areas susceptible to human-induced disturbances. Addressing these challenges is crucial for sustaining the ecological balance and biodiversity of Bhimwali Community Forest in the coming years.

Keywords: Community forest, Tree diversity, IAPS, *Shorea robusta*, *Trewia nudiflora.*

सोधसार

यस अध्यनमा दक्षिण मध्य नेपालको चितवन जिल्ला कालिका नगरपालिकामा अबस्थित भीमवली सामुदायिक बनमा पर्ने साल र नदी किनार बनमा रहेका रुख प्रजातिको विविधता पुनर्उत्थानमा र यसमा बाह्य मिचाहा बनस्पतिका प्रभाबको तुलना गरिएको छ। यस सामुदायिक बनमा कुल ४० ओटा प्लट (प्रति प्लट २० मि × २० मि), जस मध्य २० ओटा प्लट साल जङ्गल र २० ओटा प्लट नदी किनारको जङ्गलमा अध्ययन गरिएको थियो। ती प्लटहरूको अध्ययन गर्दा कुल ३० ओटा रुख, ३३ बुट्यान, ४२ झारपात, ७ उन्यू र ६ लहरे प्रजाति गरि ११८ बनस्पति record गरियो। अध्ययनको क्रममा साल क्षेत्रको जङ्गलको तुलनामा नदी किनारको जङ्गलमा धेरै बनस्पतिको प्रजाति भेटिएको थियो। साल क्षेत्रको जङ्गलमा ११ परिवारका १३ रुख प्रजातिहरु फेला परेका थिए, जसमा सबैभन्दा प्रमुख प्रजाति सालको रुख (*Shorea Robusta*) रहेको थियो, जसको महत्व सुचकांक (IVI) २१२.३३ थियो। यसै गरि नदी किनारको बनमा १६ परिवारका २२ प्रजातिका रुखहरु देखिएका थियो। जसमा सबैभन्दा प्रमुख प्रजाति भेल्लरको रुख (*Trewia nudiflora*) रहेको थियो, जसको महत्व सुचकांक (IVI) १००.७६ थियो। साल जङ्गलमा भन्दा नदी किनारको वनमा बाह्य मिचाहा प्रजातिका विरुवाहरूको प्रभाव धैरे देखियो। यसका साथै मानवीय हस्तक्षेप पनि बढि देखिएकाले नदी किनारको वनमा regeneration थौरे मात्रामा देखियो। अवलोकन गर्दा देखिएका तथ्यहरुको आधारमा नदी किनार जङ्गलमा विशेष गरी मानवीय हस्तक्षेपलाई नियन्त्रण गरी वन जङ्गल संरक्षण तथा पुनर्उत्थानमा विशेष ध्यान दिनुपर्ने र केही मिचाहा प्रजातिका वनस्पतिहरुको रोकथाम गर्नुपर्ने देखिन्छ । आगामी वर्षहरुमा भीमवली सामुदायिक वनको पारिस्थितिक सन्तुलन र जैविक विविधतालाई दीगो राख्न यी चुनौतिहरुको समाधान गर्नुपर्ने देखिन्छ । यद्यपि वन संरक्षणमा भीमवली सामुदायिक वन उपभोक्ता समूहको भूमिका भने अत्यन्त सह्रानीय देखिन्छ ।

मुख्यशब्दहरु: सामुदायिक बन, बाह्य मिचाहा बनस्पतिका प्रजाति (IAPS), साल (*Shorea Robusta*), भेल्लर (*Trewia nudiflora*)

ACRONYMS AND ABBREVIATIONS

°C	Degree Celsius
%	Percentage
<	Less than
>	Greater than
Spp	Species
CFs	Community Forests
cm	Centimeter
m	Meter
ha	Hectare
sq.km	Kilometer square
DBH	Diameter at Brest Height
DFRS	Department of Forest Research and Survey
IAPS	Invasive alien plant species
IVI	Importance Value Index
CF	Community Forest
VDCs	Village Development Committee
DHM	Department of Hydrology and Metrology
GPS	Global positioning system
d-d	density-diameter
Km	Kilometer
BA	Basal Area
RBA	Relative Basal Area
RF	Relative Frequency
RD	Relative Density

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CHAPTER 1: INTRODUCTION

1.1 Background

1.1.1 Forest composition and diversity

Forests are ever-changing ecosystems, evolving over time and space, and their nature can be understood by looking at their composition, function, and structure (Franklin *et al.,* 1981). It is recognized as the largest terrestrial ecosystem, stands out for its remarkable biodiversity, surpassing other ecosystems (Myers *et al.,* 2000). The composition, community structure, and diversity patterns within a forest play crucial roles in ecological systems (Gairola *et al.,* 2008; Ahmad *et al.,* 2010). The community composition refers to the collection of both living and non-living elements within the forest, often expressed through the presence and dominance of various species and occasionally through relative descriptors like diversity indices. Forest structure, on the other hand, encompasses the physical arrangement and characteristics of the forest, providing a visible and easily described aspect (Stone and Porter, 1998). Trees are thought to have originated more than 300 million years ago, marking a period when the development of woodiness became prevalent in various plant families throughout the taxonomic spectrum (Kenrick and Crane, 1997; Fitzjohn *et al.,* 2014). Evaluating tree communities becomes imperative for gauging the status of tree diversity and the overall health of forest communities, considering factors such as composition, dominance, abundance, and distribution (Longman and Jenik, 1987; Puhlick *et al.,* 2012; Sarkar and Devi, 2014). It is noteworthy that the structure and composition of a forest ecosystem are predominantly shaped by its plant components rather than other living entities within that ecosystem (Sarkar and Devi, 2014).

The arrangement of a forest community is directly influenced by the diversity of species, serving as the biological foundation for sustaining ecosystem functions (Tilman and Downing, 1994). Measuring diversity helps evaluate how the environment is doing and allows for comparisons between different places (Paudyal, 2022). The variety of plants in a forest is affected by things like the area's land, soil, weather, and location (Ram *et al.,* 2004). In tropical forest studies, most of the focus has been on tree types rather than other life forms (Richards, 1996). Individual trees are crucial in their ecosystems because they create a base for many other species, forming the start of the food chain (Beech *et al.,* 2017). Tree diversity refers to the mix and amount of tree types in a specific area. Ecologists use different measures to understand species diversity, and two popular ones are Simpson's index (Simpsons, 1949) and Shannon-Wiener Index (Shannon and Weaver, 1949). A straightforward and easily understandable measure of biological diversity is the richness of species, providing a simple indicator (Peet, 1974).

1.1.2 Forest Regeneration

The process of regeneration in trees and forests is the mechanism by which they ensure their continued existence and flourishing over an extended period, as elucidated by Ballabha *et al.,* (2013). This entails the renewal and rejuvenation of plant life, allowing for the sustained vitality and growth of these ecosystems. Regeneration plays a crucial role in maintaining the stability of plant species in a community, influenced by various climatic and soil factors (Singh and Singh, 1992). The health of a forest is reflected in its regeneration status, with a robust regeneration indicating a promising future. Forests facing anthropogenic pressures, like tree felling and grazing, require special attention to ensure adequate regeneration (West *et al.*, 1981). A healthy population should exhibit a satisfactory number of seedlings and saplings, while a shortage of seedlings and saplings indicates poor regeneration (Tripathi and Khan, 2007). Tree diameter distribution reflects a forest's population structure. A reverse J-shaped curve, with a peak in seedlings that decreases in higher stages, indicates strong regeneration potential. Conversely, an old growth forest may exhibit a J-shaped curve, suggesting regeneration challenges (Chauhan *et al.*, 2010).

The future species composition and stability of a forest depend on its regeneration pattern, making it crucial for sustainability. The health of a forest and its potential for successful regrowth in the future are indicated by the extent of regeneration. The presence of diverse age groups of seedlings, saplings, and trees influences the forest's capacity for regeneration and productivity (Chauhan *et al.*, 2010). Successful plant regeneration relies on factors like seed output, seed viability, dormancy, dispersal, seedling and vegetative growth, and reproductive success. A higher number of well-established seedlings is particularly favorable for effective regeneration (Napit, 2015). Natural regeneration involves the growth of new plants in a community, playing a vital role in maintaining stable age structures affected by climatic and soil factors (Singh and Singh, 1992). Forests undergo natural regeneration influenced by factors such as seed yield, dormancy, viability, seed distribution, seedling recruitment, and competition among seedlings, both within and between species (Basyal *et al.,* 2011; Napit, 2015).

1.1.3 Forest and Plant invasion

Invasive alien plant species (IAPS) are non-native plants introduced outside their natural range, posing threats to biodiversity, ecosystems, and human well-being (CBD, 2002). They exhibit common traits like rapid seed production, high germination rates, long-lived seeds, early maturation, strong vegetative growth, and phenotypic plasticity (Tiwari *et al.,* 2005). Additionally, IAPS can alter soil properties, including pH, moisture, organic matter, nutrient concentrations (Ehrenfeld, 2003; Timilsina *et al.,* 2007) and impact microbial communities (Mangla and Callaway, 2008; Chacon *et al.,* 2009).

IAPS have significant and irreversible effects on ecosystems, leading to substantial damage to biodiversity and the economy. Their invasion can cause profound and irreversible changes in ecosystem functioning (Ratnayake, 2014). Biological invasions, recognized as part of global environmental change, pose significant threats to native biodiversity. Invasive alien species (IAS) raise significant concerns for conservationists and natural resource managers due to their rapid spread, competitiveness, and ability to colonize new areas quickly (Rejmanek and Richardson, 1996). IUCN Nepal conducted the initial assessment of invasive alien plant species (IAPS) from 2002 to 2003, revealing that 21 flowering plant species with self-sustaining populations were identified as invasive in Nepal (Tiwari *et al*., 2005). In Nepal, the issue of plant invasions is escalating, with 26 out of 179 naturalized plant species identified as invasive (Shrestha, 2019). Notably, species like *Ageratina adenophora, Chromolaena odorata, Mikania micrantha, Lantana camara, and Hyptis suaveolens* pose serious threats, disrupting forests and shrublands in Nepal (Tiwari *et al.,* 2005). The wide range of climatic conditions in Nepal, from tropical to alpine, facilitates the easy adaptation of introduced plant species from various bioclimatic regions (Shrestha *et al.,* 2019).

1.1.4 Community Forestry

Community forestry is a sector of forestry where the local community actively participates in the governance and decision-making processes related to forest resources (FAO 2005). In 1976, Nepal introduced the Community Forestry (CF) policy through the National Forest Plan. This policy acknowledged the collective rights of villagers to manage the forests crucial for their livelihoods (Chettri, Larsen and Smith-hall, 2012). The most recent data reveals that Nepal has more than 17,937 community forest user groups (CFUGs), comprising 1.6 million hectares of forests, which accounts for a one fourth of the country's total forest area (DOF, 2012). Community Forests (CFs) have shown effectiveness in preserving woodlands, increasing local community awareness, and promoting decentralized forest governance methods (Pagdee *et al.*, 2006).

1.2 Justification

The current world faces a significant global challenge in the form of biological invasion. The primary concern lies in invasive alien species, posing a major threat to biological diversity. These species not only reduce the diversity of native flora and fauna but also exert negative impacts on ecosystem functions. Additionally, they alter the composition of native populations and communities, as highlighted by Elton, (1958). The threat posed by invasive alien species to native biodiversity surpasses that of environmental pollution and is identified as a leading cause of global biodiversity loss (Reddy *et al.*, 2008). Recognizing the distribution of invasive alien species becomes crucial for the preservation and conservation of biodiversity.

Nepal is currently grappling with a significant problem of biological invasion (Tiwari *et al*., 2005). The country's national biodiversity is particularly vulnerable to invasive alien plant species (IAPS) because these species have invaded a broad spectrum of habitats and environmental conditions (Tiwari *et al*., 2005). Few works related to invasive plants species have been conducted in Chitwan district and most of the works related to plant diversity, forest regeneration are focused on National park area only. Kalika municipality is recently settled area and it is rapidly undergoing urbanization with new road construction and forest destruction. This change directly or indirectly show impact on plant diversity and regeneration of forest. Moreover disturbed land use types are highly vulnerable to biological invasion, which makes Kalika municipality prone to IAPS. Therefore the assessment of tree diversity, forest regeneration and plant invasion on Sal and Riverine Forest of Bhimwali Community Forest, Kalika municipality of central Chitwan will be considered in the present study. This project aims to explore the diversity of tree species, observe the natural growth of new trees, and assess the presence and effects of plant invasion in significant forests. This study will help to know the current ecological health of the forest which is vital for biodiversity conservation. The outcomes of this research are anticipated to inform sustainable forest management practices and contribute to the broader understanding of forest ecosystems, prioritizing management option to control biological invasions as well as to aware the people about the negative impact of invasion, which directly help in the conservation of biodiversity.

1.3 Research questions

i) What is the vascular plant diversity in the study forest?
ii) What is the population structure and regeneration status of the forest?
iii) What is the status of invasive alien plant species in different Forest type?
iv) What are the impact of IAPS on tree diversity and regeneration?

1.4 Objectives

General Objective

The general objective of this study is to generate data and information on plant diversity in various forest types, along with information on the distribution and diversity of invasive alien plant species (IAPS) and their impact on the regeneration of forest in the Bhimwali Community Forest within Kalika Municipality, Chitwan Nepal.

Specific Objectives

i) To document the vascular plant diversity of different forest type of Bhimwali Community Forest.
ii) To compare the impact of Invasive alien plant species on plant diversity and regeneration on different forest types.
iii) To analyze the soil characteristics and compare its role on different forest types.

1.5 Limitations of the study

The limitations of the study are

i) Irrespective of forest area we only sampled 20 plots in each forest type.
ii) Sampling was done in only one season just after the monsoon.
iii) Only vascular plants were studied.

CHAPTER 2: LITERATURE REVIEW

2.1 Forest Composition and Diversity

Nepal's landscape comprises approximately 44.74% forest cover, as reported by the Department of Forest Research and Survey (DFRS, 2018). The country encompasses six distinct biomes and is characterized by 35 different forest types, classified by climatic variations and vegetation types (Stainton, 1972). Furthermore, there are 118 ecosystems identified based on these parameters.

Within Nepal, the Terai plain holds around 487,300 hectares of forestlands, constituting approximately 11% of the total forest area, as documented by the Ministry of Forest and Soil Conservation (MPFS, 1989). This region is predominantly characterized by the prevalence of high-value Sal (*Shorea robusta*) forests. Several studies have investigated the biodiversity and community dynamics of forests in different regions of Nepal, shedding light on the importance of community management practices in fostering diverse ecosystems.

Joshi *et al.*, (2021) investigated the community-managed natural mixed Sal forest in the far western Terai region, identifying 22 tree species, with *Shorea robusta* exhibiting the highest Importance Value Index (IVI) recorded at 178.49 in the Ramnagar community forest. Similarly, Timilsina *et al.*, (2007) conducted a study in the western Terai, discovering 131 plant species, including 28 trees, 10 shrubs, 6 climbers, and 87 herbs, among which *Shorea robusta* stood out as the dominant tree species, emphasizing the positive impact of community management efforts on fostering plant diversity. In the Charpala Community Forest of the Rupandahi district, Paneru and Chalise (2022) documented 161 vascular plant species, with Sal emerging as the predominant vegetation type, indicating favorable density across different growth stages. Napit (2015) focused on Banke National Park, highlighting its richness in flora, with *Shorea robusta* identified as the dominant species based on IVI values, followed by *Terminalia alata*. Furthermore, Sharma and colleagues (2020) examined the species diversity and regeneration status of the community-managed hill Sal forest in PalloPakha CF of Baglung district, identifying *Shorea robusta* as the predominant tree species, underscoring its significance in the surveyed forest ecosystem. These studies collectively underscore the importance of community-based forest management in maintaining biodiversity and fostering the growth of dominant tree species like *Shorea robusta* across different regions of Nepal.

2.2 Forest Regeneration

Regeneration potential is crucial for a species to complete its life cycle and thrive in diverse environmental conditions (Khumbongmayum *et al.,* 2005). Natural regeneration refers to the critical process of spontaneously growing or generating new individual plants within a community. This process holds paramount importance in sustaining the stable age structure of plant species within a community, influenced by a range of climatic and soil-related factors, as emphasized by Singh and Singh in 1992. The significance of regeneration becomes particularly pronounced in forests facing anthropogenic pressures such as tree felling, grazing, trampling, and other human activities, as underscored by West *et al.,* (1981).

In recent years, there has been notable research focused on forest regeneration in the Terai region of central Nepal. A recent investigation led by Joshi *et al.,* (2021) explored the regeneration status and carbon sequestration potential in Sal forests managed by local communities in the Kanchanpur district of the Terai region. The results suggest that community-based forest management has proven effective in fostering both forest regeneration and carbon storage in the area.

In the community-managed forest at Tanahun District, Poudel *et al.,* (2021) explored the recovery of Sal trees and revealed encouraging findings about Sal regeneration, showing a notable increase in Sal tree density after the forest was handed over to the local community. The results indicate that community management played a crucial role in positively influencing forest regeneration and overall productivity.

Similarly, in Parroha community forest of Rupandahi district Acharya *et al.,* (2011) discovered robust regeneration of tree species, particularly *Shorea robusta* and *Terminalia alata*, with a distinct size distribution characterized by a typical reverse J-shape. This result also suggest that since the community took control of the forest, there has been noticeable improvement in the Parroha Community Forest (PCF). The forest now boasts a robust supply of diverse plant species, a high number of different species, a strong potential for natural regrowth, and trees that are in moderate to good shape.

2.3 Biological invasion in Nepal

Nepal boasts rich biodiversity, attributed to its diverse topography and climate. The varying environmental conditions, spanning from tropical to alpine, make it conducive for introduced plant species from different bioclimatic regions to thrive (Shrestha *et al*., 2018). Notably, Nepal has recorded at least 219 alien species of flowering plants (Tiwari *et al.* 2005; Siwakoti, 2016) and 64 species of animals (Budha, 2015) that have naturalized in the country.

The first assessment of invasive alien plant species (IAPS) in Nepal was conducted by IUCN in 2002-2003, identifying 21 naturalized flowering plant species as invasive (Tiwari *et al.,* 2005). Subsequently, additional species were reported, bringing the total to 27 problematic invasive alien plant species in Nepal (Shrestha *et al.,* 2022). These species, constituting 0.5% of Nepal's flora, belong to 14 families and 24 genera, with Asteraceae being the most species-rich family.

Of the 27 invasive species, four *Lantana camara*, *Eichhornia crassipes*, *Mikania micrantha*, and *Chromolaena odorata*are considered among the world's 100 worst invasive species (Shrestha *et al.,* 2022). These IAPS pose significant threats due to their rapid spread, competitiveness, and ability to colonize new areas swiftly.

In Nepal, the issue of plant invasions is escalating, with 26 out of 179 naturalized plant species classified as invasive (Shrestha *et al.*, 2017). Certain IAPS, including *Ageratina adenophora*, *Chromolaena odorata*, *Mikania micrantha*, *Lantana camara*, and *Hyptis suaveolens*, are particularly disruptive in forests and shrublands (Tiwari *et al.,* 2005).

Protected areas, presumed to have low susceptibility to biological invasion, are increasingly experiencing the influx of alien species (Pauchard *et al*., 2009; Shackleton *et al*., 2020). Tourism-related activities contribute to the introduction of alien species into protected areas (Anderson *et al.*, 2015). Proximity to roads, human settlements, and natural corridors like rivers also influences the occurrence of IAPS.

The presence of IAPS poses a severe threat to protected areas in Nepal, especially in the lowlands. In national parks and wildlife reserves, species such as *Chromolaena odorata*, *Mikania micrantha*, *Lantana camara*, *Ipomoea carnea*, and *Parthenium hysterophorus* are identified as common and problematic. These invasive species are causing disruptions in various ecosystems, including the Sal forest habitat in the Terai region (Bhuju *et al.*, 2013). The Terai region's Sal forest habitat is under threat from the harmful invader, *Chromolena odorata* (Tiwari *et al.*, 2005).

Based on above literature review it was found that several study related to regeneration and plant invasion has been conducted in Chitwan, but most of them are focused on Sal forest and National Park area. No any research has been conducted in riverine forest about this issue. Furthermore Comparative study of Forest structure, Regeneration and Plant Invasion between two forest types has not been studied yet. This research will focus on Comparative study on this issue between Sal and Riverine forest of Bhimwali Community Forest. This will help to know the current ecological health of the forest which is vital for biodiversity conservation.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

3.1.1 Location and geomorphology

The study was conducted in Bhimwali Community Forest, located in Kalika Municipality within the Chitwan District, Central Nepal (Figure 1). Encompassing a total area of 169.49 square kilometers, it is situated at a latitude of 27° 41' 15" N and a longitude of 83° 30' 42" E at an elevation ranging from approximately 141 meters (463 feet) to 1,194 meters (3,917 feet) above sea level. As per the 2011 National Census, the municipality hosts a population of 42,493, residing in 9,116 households, with 22,275 females and 20,218 males.

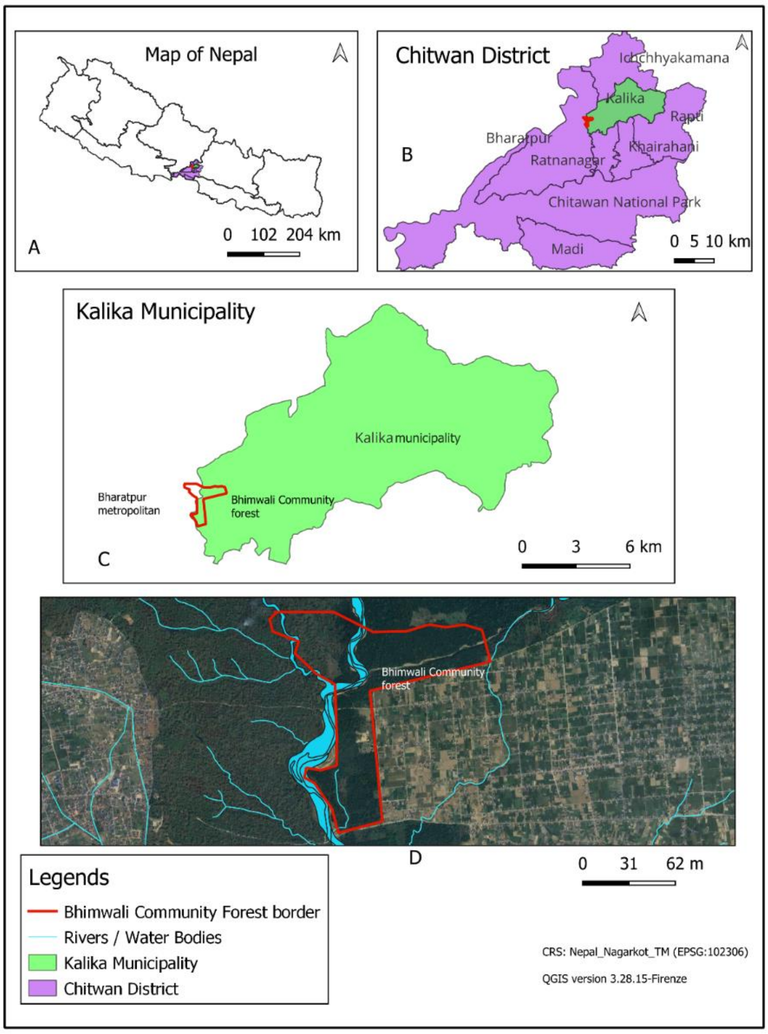


Figure 1. Map of study area showing, (A. Map of Nepal, B. Chitwan District, C. Kalika Municipality D. Bhimwali Community Forest)

Bhimwali Community Forest is situated in ward number 5 of Kalika Municipality, spanning a total area of 199.53 hectares, at an elevation of approximately 210 meters (688 feet) above sea level. Its establishment dates back to the year 2059 BS. This community forest encompasses two distinct forest types, namely a riverine forest predominantly characterized by *Trewia nudiflora* and a Sal forest dominated by *Shorea robusta*.

3.1.2 Climate

The study area lies in the central part of the terai region, within the tropical climatic zone containing hot and humid summer and cold and dry winter. Temperature and precipitation data of 14 years (2009-2022) from the nearest station of the study area, Bharatpur were collected from Department of Hydrology and Metrology Kathmandu Nepal. Based on the collected data, the monthly average maximum temperature, minimum temperature, and precipitation were calculated. The findings revealed that the mean maximum temperature reached 35.6°C during the months of April and May, while the mean minimum temperature was recorded at 9.7°C in January. In terms of precipitation, the highest average monthly rainfall occurred in July, amounting to 572.24mm. On the other hand, the lowest average monthly rainfall was observed in November, measuring only 5.61mm (Figure 2).

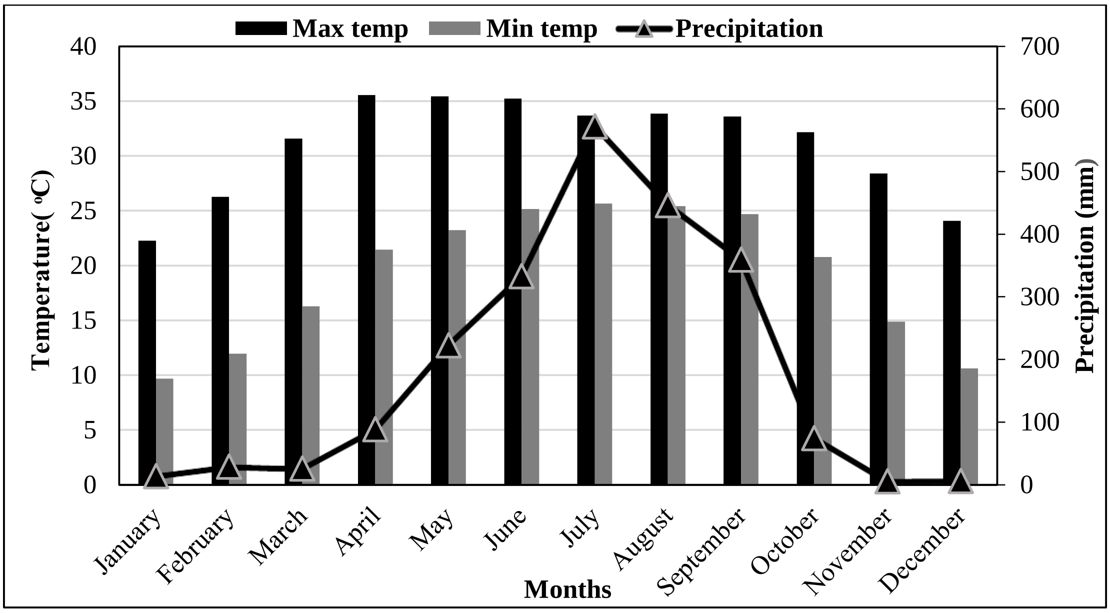


Figure 2. Fourteen year (2009-2022) average monthly maximum (Tmax) and minimum (Tmin) temperature and precipitation recorded at Bharatpur weather station.

(Source: Department of Hydrology and Meteorology, Government of Nepal)

3.2 Vegetation sampling

Field sampling was conducted in November 2022 and supplementary data were collected in November 2023. Vegetation data collection was done by quadrate sampling method applying systematic sampling. The sampling process involved setting up 5 transects at a minimum distance of 200 meters perpendicular to the river flow direction, at least four plots were established in each transect for both the Riverine forest and Sal forest. A total 40 nested sample plots of size 20m×20m were established, (20 plots in each forest type). To ensure accurate mapping of the study area, GPS points were recorded during the fieldwork.

To analyze the vegetation in detail, quadrats of size 20m×20m were used as main plots for trees, while smaller quadrats measuring 5m×5m inside the main plot was utilized for shrubs. Additionally, within each main plot, two subplots measuring 1m×1m were established specifically for studying herbaceous plants. Individuals of tree species was divided into three growth stages: trees (DBH ≥ 5 cm and height > 1.37m), saplings (DBH >1 cm to DBH < 5cm and height below 1.37m) and seedling (height < 50 cm) as per Sharma *et al*., (2020). In order to investigate the process of regeneration in a particular tree species, a comprehensive assessment was conducted by counting the total number of seedlings and saplings within each designated plot. Diameter at breast height (DBH at 137 cm above the ground) of each tree species was also measured for further calculation using DBH tape.

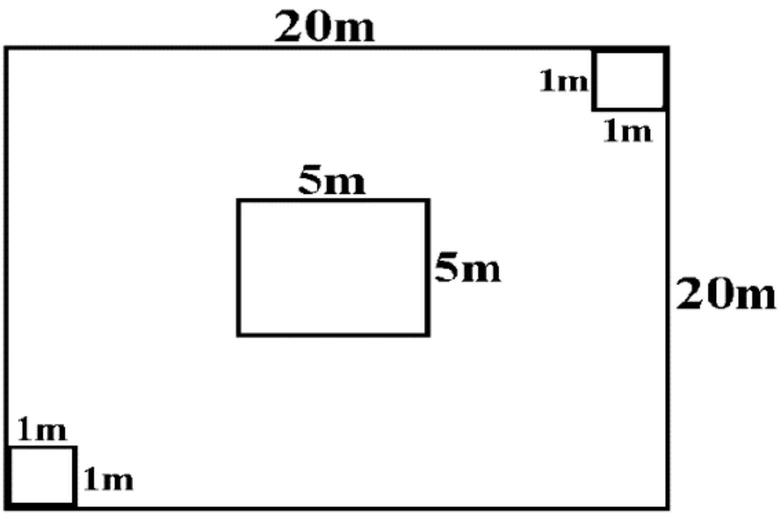


Figure 3. Outline of vegetation sample plot.

During the analysis, quadrats with an invasive alien plant species (IAPS) coverage exceeding 10% were classified as invaded quadrats, indicating a higher presence of non-native plant species. On the other hand, quadrats with an IAPS coverage of less than 10% were categorized as non-invaded quadrats, indicating a lower prevalence of non-native plants. Total number as well as number and coverage of each of the IAPS in each quadrats was also noted.

3.3 Numerical Analysis

The information gathered from the field was utilized to compute Frequency (F), Relative Frequency (RF), Density (D), Relative Density (RD), Coverage (C), Relative Coverage (RC), and Important Value Index (IVI) using the method outlined by Zobel *et al.*, (1987)

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

Relatives Frequency (RF %) = $\frac{\text{Frequency of individual species} \times 100}{\text{Total frequencies of all species}}$

Density (D) = $\frac{\text{Total number of individuals of a species in all plots} \times 10000}{\text{Total number of plot studied} \times \text{Size of the plot (m2)}}$

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

Coverage (C) = Visual Estimation

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

Basal area (BA) = $\pi \times \frac{d2}{4}$

Where,

d = DBH (diameter at breast height)

π = 3.1416

Basal area of a species (m^2/ha) = $\frac{\text{Total basal area of a species} \times 10000}{\text{Size of the plot (m2)}}$

Relative basal area (RBA %) = $\frac{\text{Basal area of individual species} \times 100}{\text{Total basal area of all species}}$

Important value index (IVI) = RD + RF + RBA

Species Diversity Index (H')

The Shannon index, introduced by Shannon and Weiner (1949), is widely used to measure species diversity. In simpler terms, this index helps us understand the variety of species in a particular environment to calculate it, we use a specific formula.

$$H' = -\Sigma\ Pi \ln Pi$$

Where,

H' = Species Diversity Index

Pi = Proportion of the species

Pi = ni / N

N = Total number of species

ni = Number of individual of each species

Index of Dominance

The Dominance index is determined by using Simpson's index of dominance, a measure that assesses diversity variations (Simpson, 1949). In simpler terms, it helps gauge how different or dominant certain species are in a given environment.

$$\text{Simpson's Index of dominance (D)} = 1- [\Sigma n\ (n-1)/N(N-1)]$$

Where,

n =No. of individual of a species

N= Total no. of individual of all species

3.4 Soil Sampling and Analysis

In both forest soil was collected from each quadrat (at 15cm depth) from each four corners and center, and they were mixed thoroughly and took about 600 g, which was then packed in zip-lock polythene bags. The soil was air dried and taken to the lab for further analysis. Soil moisture and soil pH were determined in the lab. Soil pH was measured using a pH meter following Soil Survey staff (2014). For this 10g air dried soil was mixed with 10 ml of distilled water (1:1) and pH readings were recorded with three replicates for each sample to obtain concordant readings. For soil moisture determination, the soil was oven dried for 48 hours in the first phase and then for 24 hours in the second and third phases to get constant weight. Soil temperature was recorded in the field using a digital thermometer.

Calculation,

Initial wt. of the soil (Wi) = Moist soil weight

Final wt. of soil (Wf) = Dry soil weight

$$\text{Soil water content (Ws)} = \frac{\text{Initiai wt of soil (Wi)} - \text{Final wt of Soil (Wf)}}{\text{Final wt of soil (Wf)}} \times 100\%$$

$$\text{Soil moisture (\%)} = \frac{\text{Sum of soil moisture of each plot}}{\text{Total number of plot studied}}$$

3.5 Regeneration analysis

The assessment of tree species regeneration status was established by evaluating the population sizes of seedlings, saplings, and adults, as outlined in Gebrehiwot and Hundera (2014). The regeneration is considered to be:

- "Good" when the density of seedlings is higher than that of saplings, which in turn is greater than the density of adult trees.
- "Fair" when the density of seedlings is higher than that of saplings, but the density of saplings is either equal to or less than that of adult trees.
- "Poor" when the species survives only in the sapling stage but not in the seedling stage.
- "None" for species without sapling or seedling stages but present as adult trees.
- "New" when adult trees of a species are absent, but sapling and/or seedling stages are present.

3.6 Plant identification

The identification process of plants was based primarily upon the local names given by the people in the area, as well as photographs taken in the field. To verify the species of each plant, the book "Plants of Nepal" by Shrestha *et al.,* (2022) was used as a reference. In cases where plants couldn't be identified, herbarium samples were prepared and consulted with teachers. Furthermore Comparison was also made with the herbarium collection at Amrit Campus to determine the correct identification.

3.7 Statistical Analysis

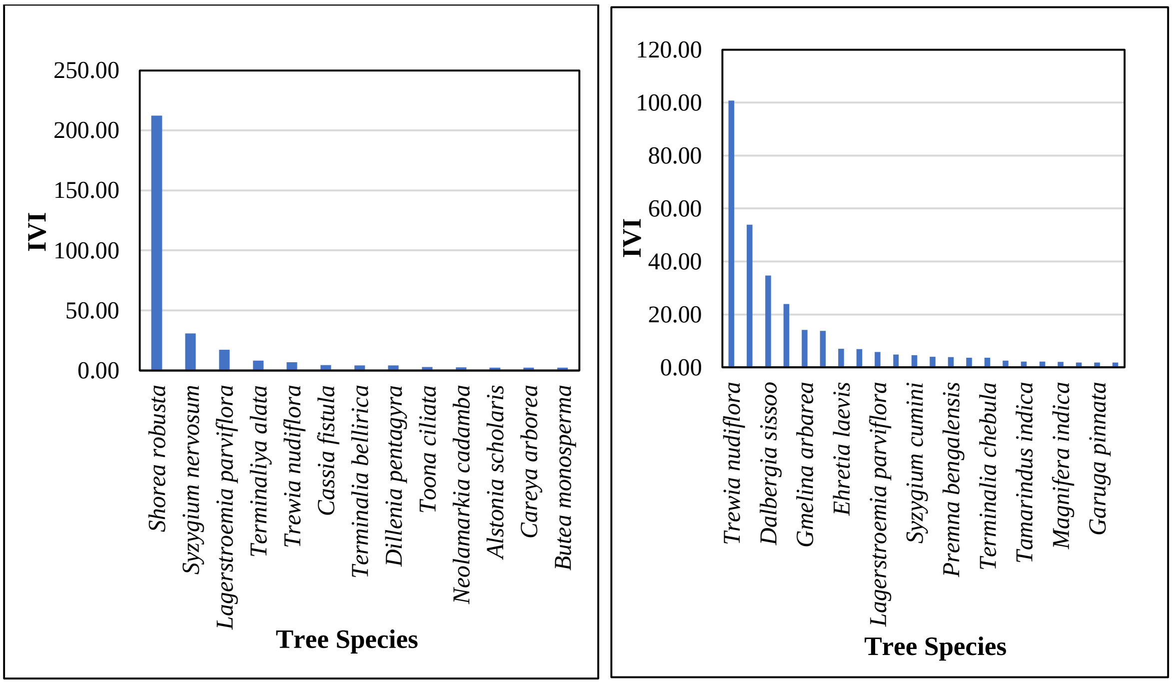
In both of the forest IVI and diversity indices were computed using the respective formulas. Species richness, population proportion of different life forms (Seedling, Sapling, and Tree) and different soil characteristics (Moisture, Temperature and PH) were compare between two forest type by independent sample t-test (student t-test). Before analysis normality of the data were checked. Linear regression analysis was carried out to know whether seedling and sapling density was related with tree basal area. Similarly linear regression was applied to know the relationship between invasive species density, coverage with seedling, sapling, ground vegetation, and soil pH. Furthermore, t-test was also conducted between seedling and sapling density with tree basal area as well as between invasive species density, coverage with seedling, sapling, ground vegetation, and soil pH to know the significance level using R. Pearson correlation coefficient was used to show relationship between different parameter in the forest. All the data obtained were managed in Microsoft-excel Version 2013 and were analyzed using R-Studio core team (2022).

CHAPTER 4: RESULTS

4.1 Forest Composition and Diversity

Altogether 118 plant species were found among which 30 were tree, 33 shrub, 42 herbs, 7 fern and 6 climbers. In Sal forest 13 species of tree belonging to 11 families were found, among which, based on IVI the most dominant species was *Shorea robusta* (212.33) followed by *Syzium nervosum* (30.80), *Lagerstroemia parviflora* (17.20) (Figure 4 (a), Appendix V). Likewise the least dominant species was recorded as *Butea monosperma* (2.27) followed by *Careya arborea* (2.30) (Figure 4 (a), Appendix V).

While in case of riverine forest 22 species of tree belonging to 16 families was found, among them the most dominant species was *Trewia nudiflora* (100.76) based on IVI followed by *Albizia lucididior* (53.91) and *Dalbergia sissoo* (34.74). Likewise, the least dominant species was recorded for *Garuga pinnata* (1.78) and *Melia azedarach* (1.78), followed by *Aegle marmelos* (1.86) (Figure 4 (b), Appendix V).



(a) (b)

Figure 4. Importance value Index (IVI) of tree species in (a) Sal forest (b) Riverine forest.

4.2 Diversity of Native, Naturalized and invasive plant species

In Sal forest a total of 64 species were found among which 50 were native, 14 were naturalized and 9 were invasive (Table 1). While in case of riverine forest a total of 88 plant species were recorded among which 68 were native, 20 were naturalized and 11 were invasive (Table 1). In comparison riverine forest were found to have high species richness both native and non-native.

Table 1. Number of native, naturalized and invasive plant species in Sal and riverine forest.

Richness			
Plant Category		**Sal Forest**	**Riverine Forest**
Total Plant species		64^{a}	88^{a}
Native Plant species		50^{a}	68^{a}
Non-Native Plant species	i) Naturalized	14^{a}	20^{b}
	ii) Invasive	9^{a}	11^{a}

Note: Value sharing different letters along the row of individual category are significance at P<0.05 in student t-test.

4.3 Diversity Indices

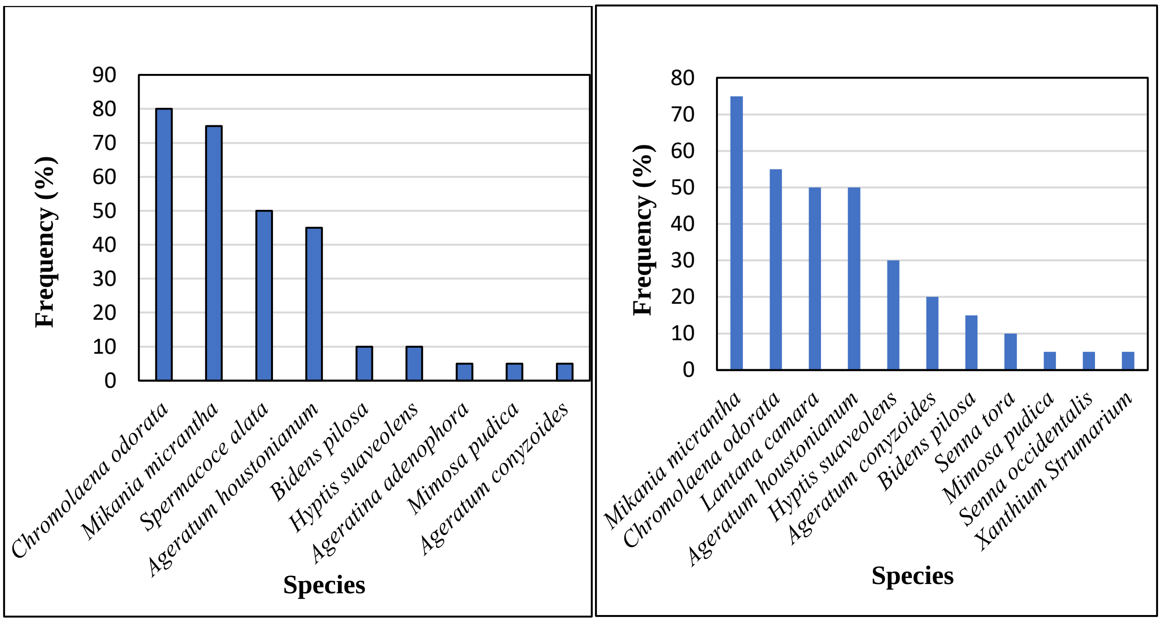
In Sal forest Shannon's index was found to be 0.83, with species richness of 13 and Simpson's index of dominance was reported to be 0.34 (Table 2). Similarly, in Riverine forest Shannon's index was found to be 1.86, with species richness of 22 and Simpson's index of dominance was reported be 0.73 (Table 2). Comparing both of the forest both Shannon's and Shannon's index was found to be high in Riverine forest.

Table 2. Shannon's and Simpson's Index of diversity of tree species in Sal and Riverine forest.

Diversity Indices	Sal Forest	Riverine Forest
Shannon's index	0.83	1.86
Simpson's index	0.34	0.73

4.4 Plant invasion

In Sal forest 9 species of invasive alien plant were recorded, among which *Chromolena odorata* was found to have highest frequency of 80% followed by *Mikania micrantha* with 75% and *Spermacace alata* with 45% frequency. Likewise *Ageratina adenophora*, *Mimosa pudica*, and *Ageratum conyzoides* was found to have 5% frequency (Figure 5 (a)).



(a) (b)

Figure 5. Frequency of Invasive Alien Plant species in (a) Sal forest (b) Riverine forest.

In Riverine forest altogether 11 species of invasive alien plant species were recorded, among which *Mikania micrantha* was found to have highest frequency of 75% followed by *Chromolaena odorata* with 55% frequency. Likewise *Mimosa pudica*, *Senna occidentalis* and *Xanthium strumarium* was found to have lowest frequency of 5% (Figure 5 (b)).

4.5 Forest structure and Regeneration

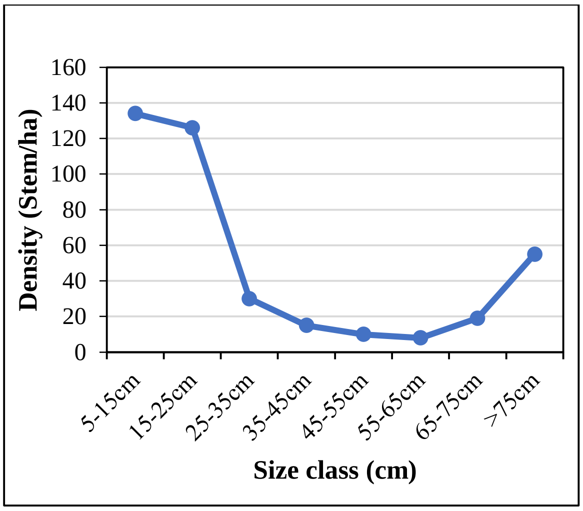
In Sal forest life form ratio shows that the forest comprise of 78% seedlings12% saplings, and 10% tree species. Similarly, in riverine forest the seedlings occupied 31%, saplings 27% and mature trees 42% (Table 3).

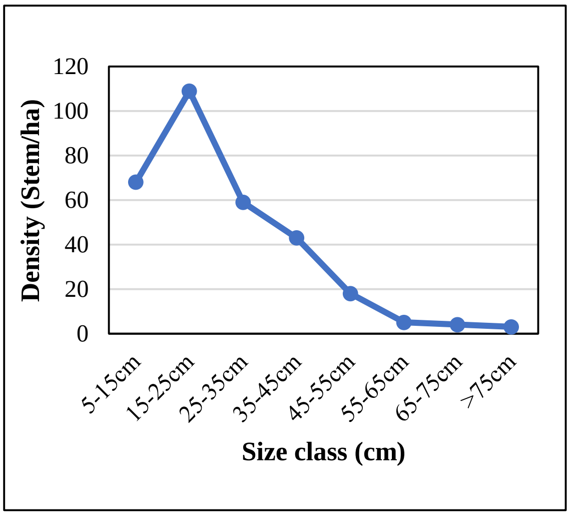
Table 3. Population proportion of different life forms in Sal and Riverine forest.

Life Stage	Population /ha	
	Sal forest	Riverine forest
Seedling	2944 (78%)±2787 [a]	229 (31%)±227[b]
Sapling	454 (12%) ±303[a]	204 (27%)±151[b]
Tree	398 (10%)±248[a]	309 (42%)±116[a]

Note: Value sharing different letters along the row of individual category are significance at $P<0.05$ in student t-test.

Density diameter curve of adults of both forest shows a reverse J-shaped curve, with more young, narrower trees than adult ones in case of Riverine forest while slight deviation was seen above dbh class 65cm in case of Sal forest (Figure 6) which indicates that large tree diversity is also significant in the Sal forest, receiving more attention for protection compared to riverine forest because of its valuable timber.





(a) (b)

Figure 6. Density diameter (d-d) curve of trees species in (a) Sal forest (b) Riverine forest.

The regeneration status of different species in both of the forest was also analyzed by creating d-d curve (Figure 7, 8). In case of sal forest, *Shorea robusta* shows the good regeneration status with reverse J-shaped curve, and show slight deviation above dbh class 65. The density-diameter curve of *Shorea robusta* reveals a pattern where the population of seedlings is greater than that of saplings, saplings are more abundant than young tree species, and young tree species are more prevalent than old tree species. This observation suggests a promising regeneration process for *Shorea robusta* in the Sal forest. *Lagerstroemia parviflora* and *Syzium nervosum* also shows reverse J-shape curve with slight deviation between dbh class 15-25 cm. In compare to other species it was found that *Shorea robusta* had high regeneration rate.

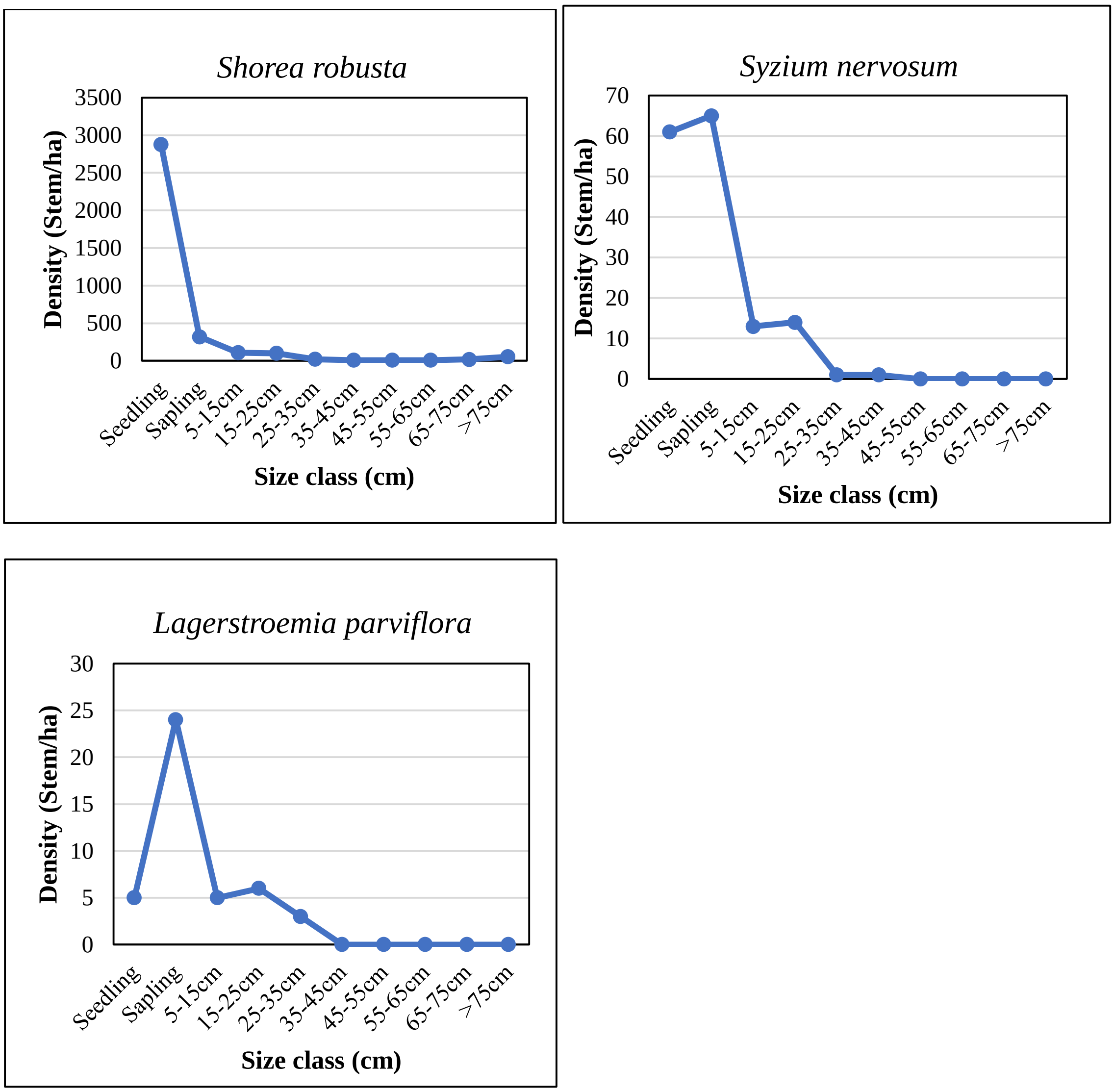


Figure 7. Density diameter (d-d) curve of dominant tree species in Sal forest.

In Riverine forest *Trewia nudiflora* showed reverse J-shape curve with slight deviation between dbh class 15-25cm. The numbers of tree was observed high between dbh class15-25 cm. It was also observed that the numbers of seedling and sapling was higher than young trees and young trees was higher than old trees. Similarly *Albizia lucidor* also showed deviation from reverse J-shaped curve where higher number of individuals were observed in 25-35 cm dbh interval. Likewise *Acacia catechu* and *Dalbergia sissoo* shows bell shape curve. In case of A*cacia catechu* neither seedling nor sapling was observed. The numbers of tree between dbh class 15-25 was observed high and after that it drastically decreases and no tree was observed above dbh class 55cm. In case of *Dalbergia sissoo* also no seedling and sapling was observed and number of adult tree was higher than old trees. This shows that there was poor regeneration in *Acacia catechu* and *Dalbergia sissoo* (Figure 8).

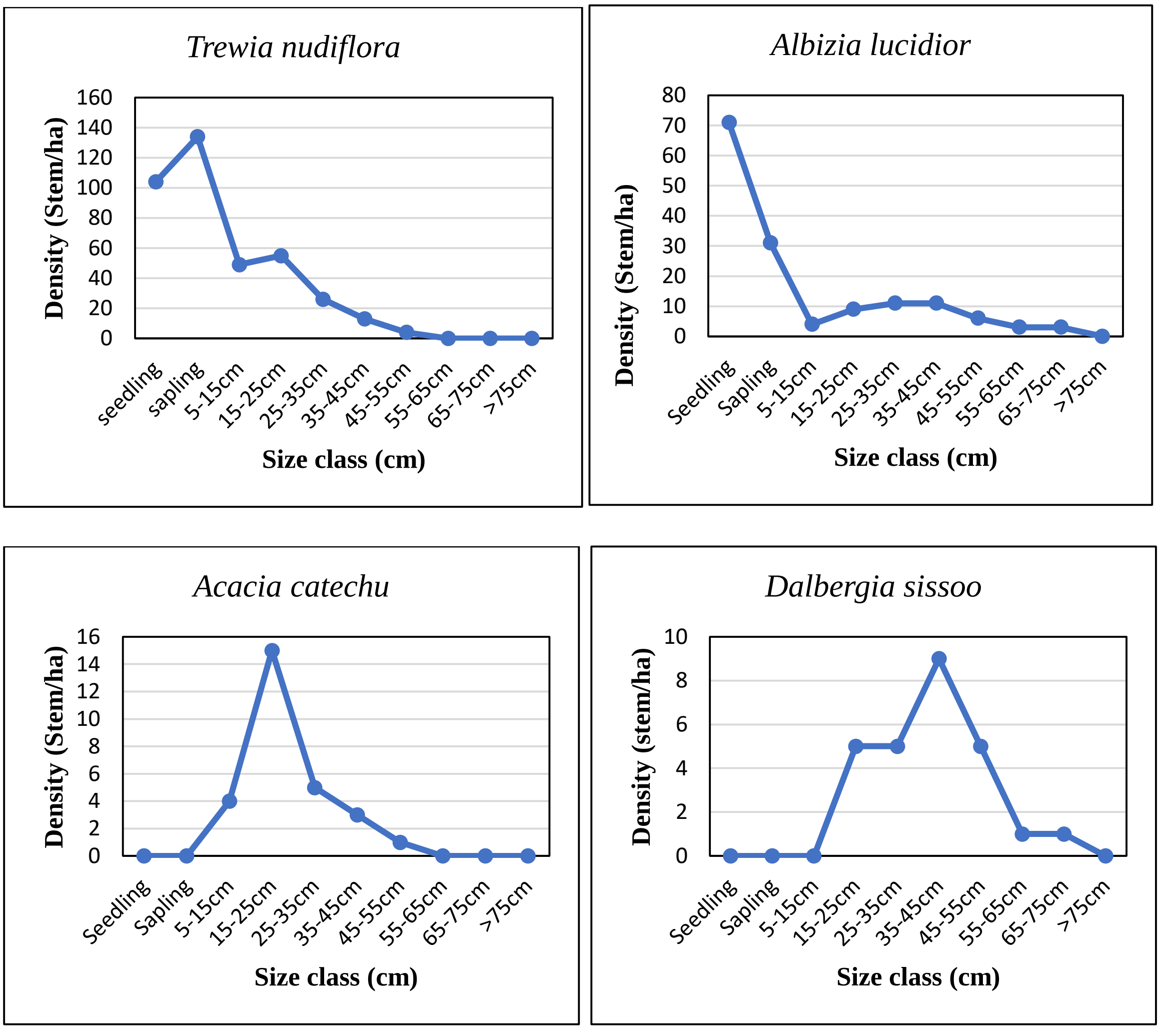
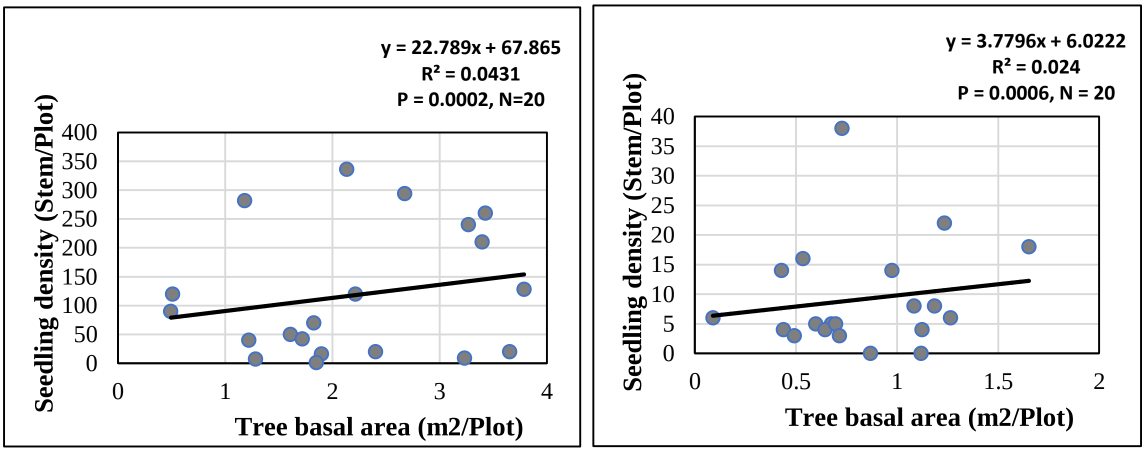


Figure 8. Density diameter (d-d) curve of dominant tree species in Riverine forest.

4.6 Relationship between Seedlings and Saplings with Tree basal area

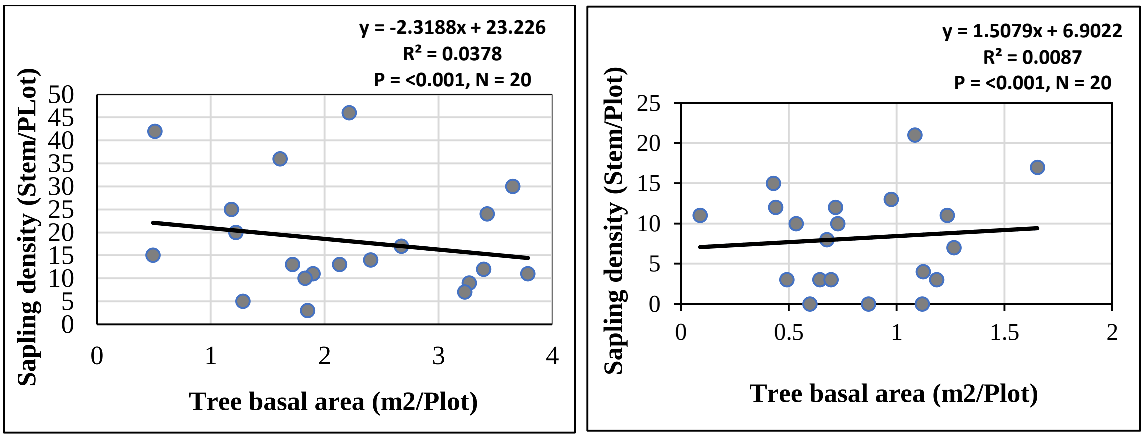
In both forest type the regression analysis shows that there was a significant positive relationship between seedling density and tree basal area ($p<0.05$). The trend line shows that on increasing basal area the density of seedling was also increases (Figure 9).



(a) (b)

Figure 9. Regression between tree basal area and seedling density in (a) Sal forest (b) Riverine Forest.

Regression analysis shows that there was an significant negative relationship in Sal forest type and Significant positive relationship in Riverine forest type between sapling density and tree basal area ($p<0.05$). The trend line shows that on increasing basal area the density of sapling was decreases in Sal forest and increases in Riverine forest (Figure 10).

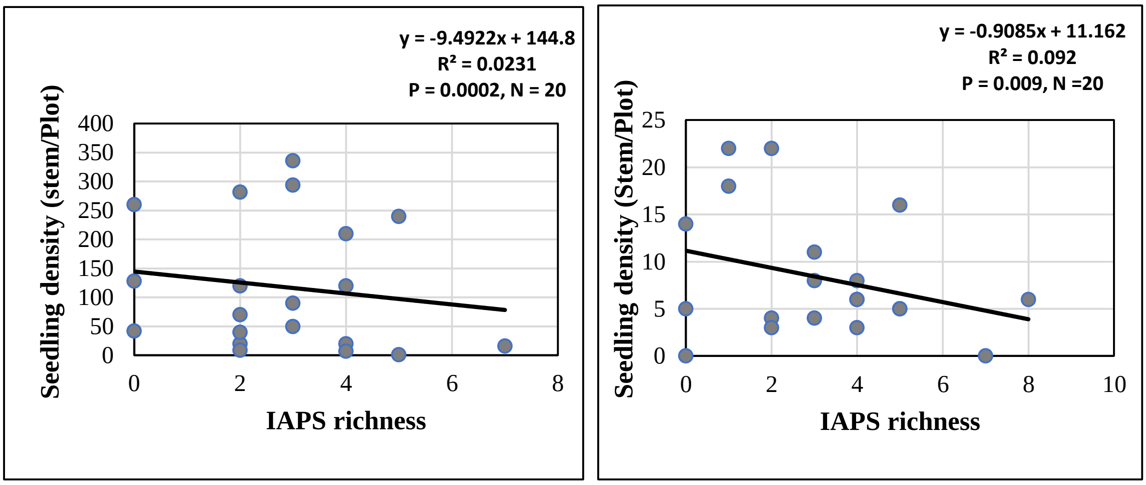


(a) (b)

Figure 10. Regression between tree basal area and sapling density in (a) Sal forest (b) Riverine forest.

4.7 Impact of invasive alien plants in forests

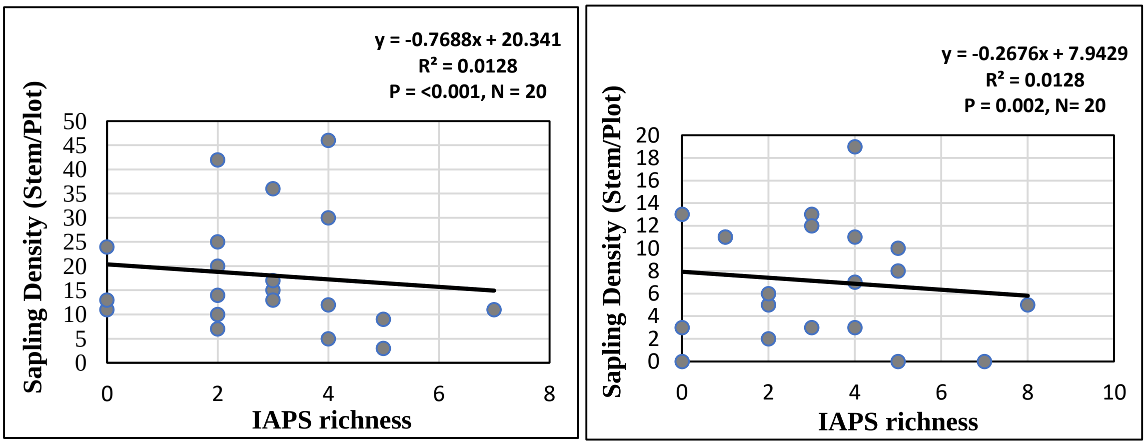
In both forest types having more than 10% IAPS cover, the regression analysis shows that there was a significant negative relationship between IAPS richness and seedling density ($p<0.05$). The trend line shows that with increasing in invasive species richness, seedling density of tree species decreases (Figure 11).



(a) (b)

Figure 11. Regression between IAPS richness and tree seedling density in (a) Sal forest (b) Riverine forest.

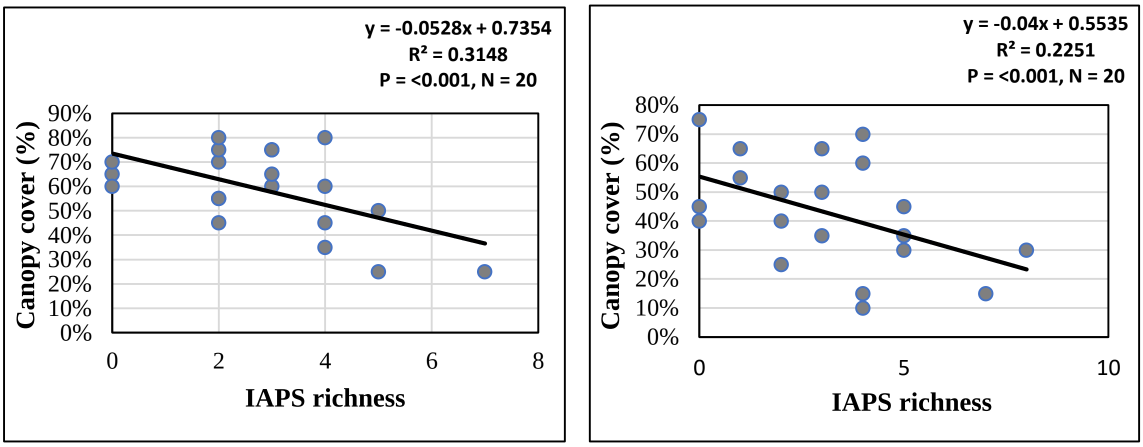
Significant negative relation was seen between IAPS and sapling density ($P< 0.05$) in both of the forest type. This indicate that with the increase of IAPS richness sapling density decreases and vice versa (Figure 12).



(a) (b)

Figure 12. Regression between IAPS richness and tree Sapling density in (a) Sal forest (b) Riverine forest.

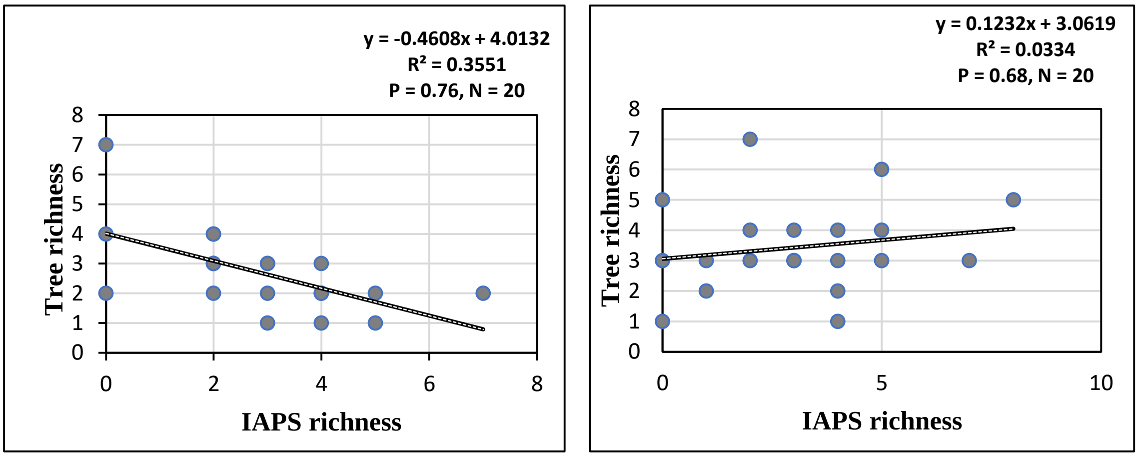
The relation between IAPS and Canopy cover showed negative trend in both of the forest type which indicate that with the increase in canopy cover the IAPS richness decreases. The regression analysis shows that there was a significance negative relationship between canopy cover and IAPS richness ($p<0.05$) in both forest type (Figure 13).



(a) (b)

Figure 13. Regression between IAPS richness and Canopy cover in (a) Sal forest (b) Riverine forest.

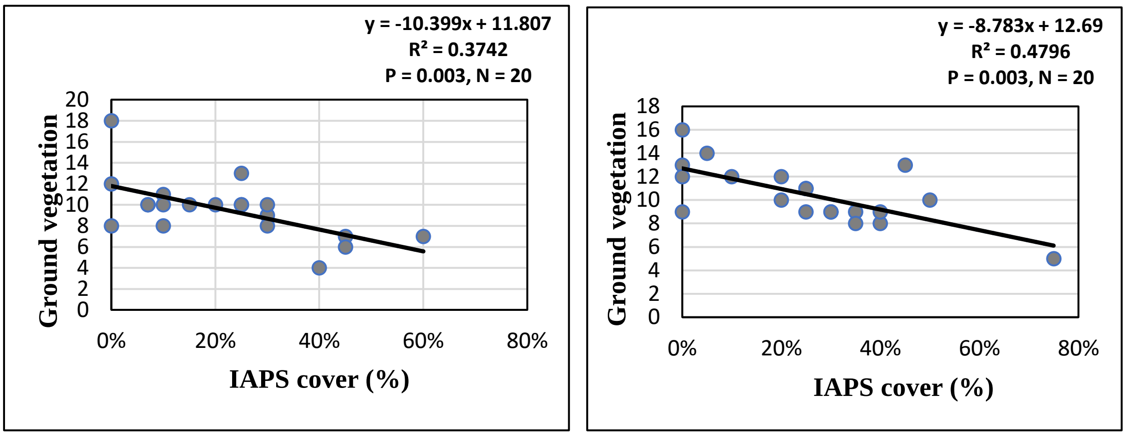
The regression analysis shows that there was insignificant negative relationship between IAPS richness and tree richness ($p>0.05$) for Sal forest. But insignificant positive relationship was observed ($p>0.05$) in Riverine forest (Figure14).



(a) (b)

Figure 14. Regression between IAPS richness and Tree richness in (a) Sal forest (b) Riverine forest.

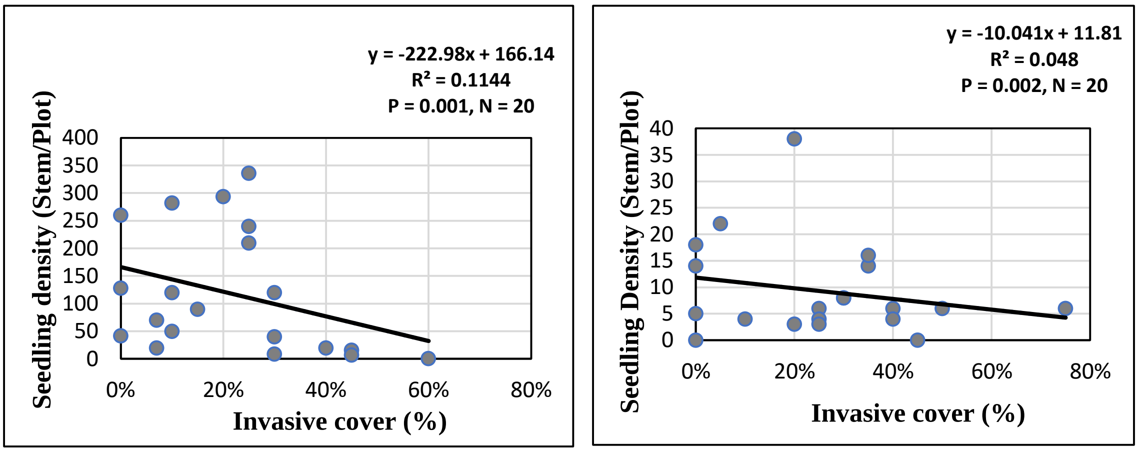
In both forest type the regression analysis shows that there was significant negative relationship between ground vegetation richness and IAPS cover ($p<0.05$). The trend line shows that with the increase of IAPS cover there was a decrease in ground vegetation (Figure 15).



(a) (b)

Figure 15. Regression between IAPS coverage and Ground vegetation in (a) Sal forest (b) Riverine forest.

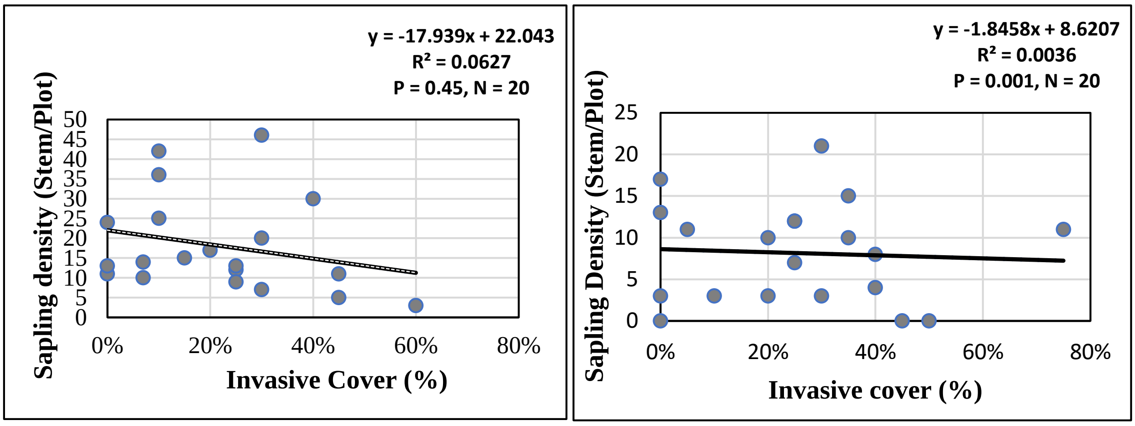
The relation between IAPS Coverage and seedling density showed negative trend in both of the forest type which indicate that with the increase in IAPS cover seedling density decreases. The regression analysis shows that there was a significance negative relationship between IAPS coverage and Seedling density richness ($p<0.05$) in both forest type (Figure 16).



(a) (b)

Figure 16. Regression between IAPS coverage and Seedling density in (a) Sal forest (b) Riverine forest.

Insignificance negative relationship was seen between IAPS coverage and sapling density (p>0.05) in Sal forest, while in Riverine forest significance negative relationship was observed (p<0.05). The trend line shows that with the increase of IAPS cover there was a decrease in sapling density (Figure 17).



(a) (b)

Figure 17. Regression between IAPS coverage and Sapling density in (a) Sal forest (b) Riverine forest.

4.8 Soil Characteristics

In Sal forest the average soil moisture of the forest was recorded 14.74 %. The value ranges from 9.37- 19.18 %. The temperature of soil ranges from 22°C- 24°C. The average temperature was 22.7°C.The average value of soil pH was recorded 5.58 which signify the presence of acidic soil in the studied area (Table 4).

While in Riverine forest the average soil moisture of the forest was recorded 19.32 %. The value ranges from 3.83- 36.59 %. The temperature of soil ranges from 23°C- 27°C. The average temperature was 24.3°C.The average value of soil pH was recorded 6.82 which signify the presence of neutral soil in the studied area (Table 4).

Table 4. Different Soil Characteristics in Sal and Riverine forest.

Soil Characteristics	Sal forest	Riverine forest
Moisture (%)	14.74[a]	19.32[b]
Temperature (°C)	22.7[a]	24.3[b]
PH	5.58[a]	6.82[b]

Note: Value sharing different letters along the row of individual category are significance at P<0.05 in student t-test.

4.9 Correlation between the parameters in riverine and Sal forest

The diagram illustrates correlation levels using various colors: white indicates weak correlation, blue signifies positive correlation, with darker shades indicating stronger positive correlation, and dark blue represents high positive correlation. Conversely, red denotes negative correlation, with darker shades indicating stronger negative correlation, and dark red signifies high negative correlation. The value of +1 shows perfect positive correlation and the value of -1 shows perfect negative correlation (Figure 18 and19).

In the Sal forest, the data indicates notable correlations between various ecological factors. For instance, there is a robust positive correlation (0.8) between the richness and cover of IAPS, while a strong negative correlation (-0.78) is observed between tree canopy cover and invasive species cover. Moreover, a substantial negative correlation (-0.62) exists between native species richness and invasive species richness, as well as between canopy cover and invasive species richness (-0.56). Additionally, there is a slight negative correlation between invasive species richness and the density of seedlings (-0.15) and saplings (-0.11), while a slight positive correlation is observed between canopy cover and the density of seedlings (0.22) and saplings (0.48) (Figure 18).

In the Riverine forest, the data also indicates notable correlations between various ecological factors. For instance, there is a robust positive correlation (0.76,) between the richness and cover of IAPS, while a strong negative correlation (-0.56) is observed between invasive species cover and tree canopy cover as well as between canopy cover and invasive species richness (-0.48). Moreover, slight negative correlation (-0.28) exists between invasive species cover and native species richness. Additionally, there is a slight negative correlation between invasive species richness and density of seedlings (-0.34) and saplings (-0.25). Furthermore moderate negative correlation (-0.47) is observed between invasive species richness and soil PH (Figure 19).

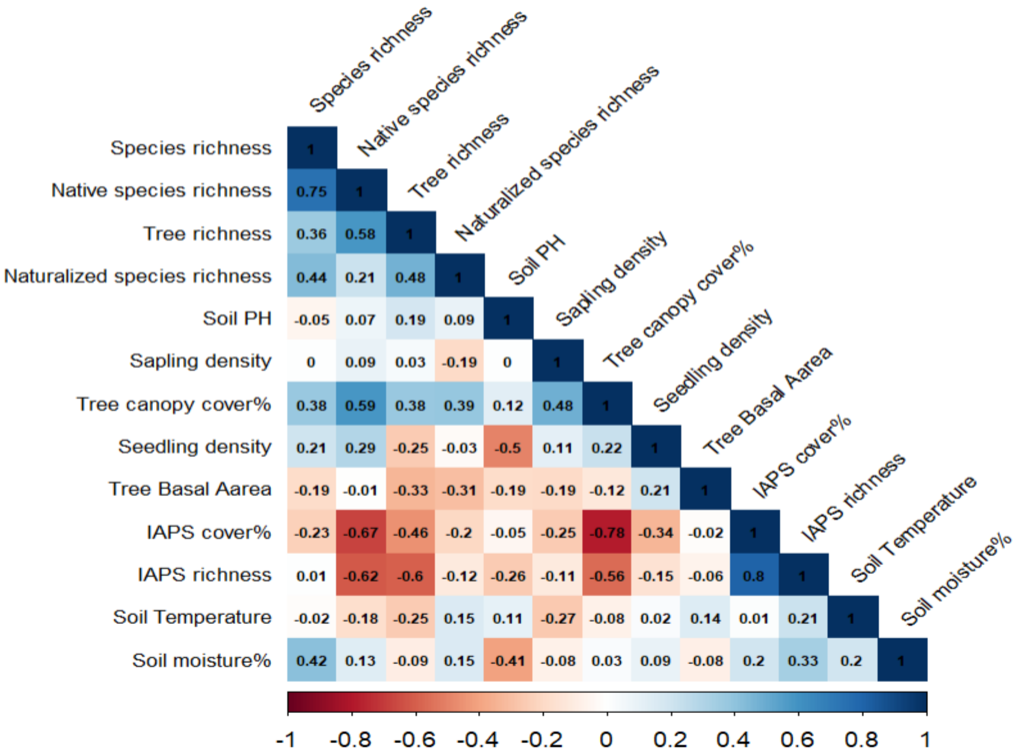


Figure 18. Correlation between the parameters in Sal forest.

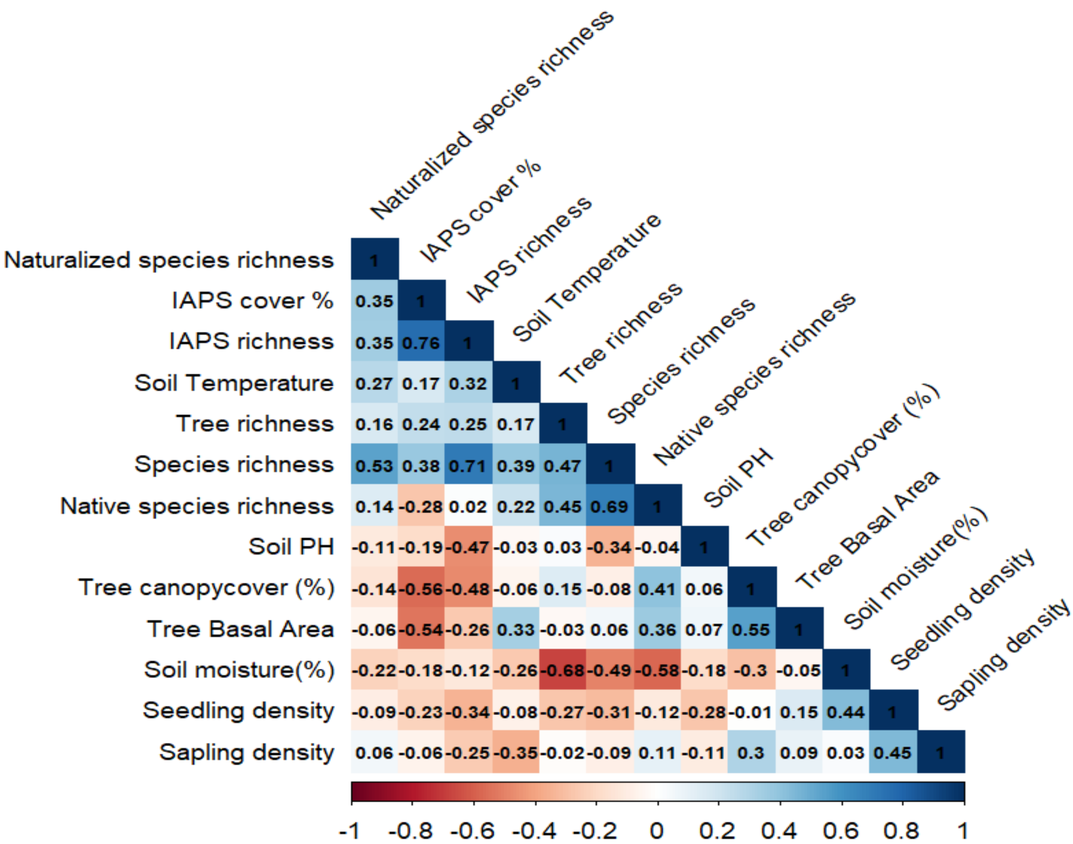


Figure 19. Correlation between the parameters in Riverine forest.

CHAPTER 5: DISCUSSION

5.1 Forest Composition and Diversity

The research area is a natural community forest with two distinct types: riverine and sal, both part of the same community forest. In the Sal forest, there were a total of 64 plant species, including 50 native, 14 naturalized, and 9 invasive species. On the other hand, the riverine forest had a total of 88 plant species, comprising 68 native, 20 naturalized, and 11 invasive species. The Sal forest contained 13 tree species from 11 families, while the riverine forest had 22 tree species from 16 families. This indicates a distinct species composition between the two forest types, likely influenced by environmental factors such as soil type, water availability, and microclimate. In Sal forest *Shorea robusta* (332 pl/ha) is most dominant species with the IVI of 212.33 followed by *Syzium nervosum* (29 pl/ha) with the IVI of 30.80 and *Lagerstroemia parviflora* (14 pl/ha) with the IVI of 17.20. This suggests that *Shorea robusta* is not only abundant but also has significant ecological importance within this forest type. The existence of *Shorea robusta* dominance is similar with the findings of Acharya *et al.*, (2011) in the Parroha Community forest of Rupandehi district. Awasti *et al.,* (2015) finds the same result in a case study from Lumbini collaborative forest, Rupandehi. The dominance of *Shorea robusta* in the studied forest might be due to the proper community management practices in Sal forest due to its high timber value.

In riverine forest *Trewia nudiflora* (147 pl/ha) is most dominant species with the IVI of 100.76 followed by *Albizia lucidior* (47 pl/ha), *Dalbergia sissoo* (26 pl/ha) and *Acacia catechu* (28 pl/ha) with the IVI of 53.91, 34.74 and 23.91 respectively. This shows that *T. nudiflora* plays a crucial role in shaping the structure and dynamics of the riverine ecosystem. Since the studied riverine forest is near to Khagari river system, it has been enriched by alluvial deposits over time, making them particularly suitable habitats for riverine species like *T. nudiflora*. This species is notably abundant in such forests, as observed by Khadka and Lamichhane, (2020) in the Chitwan National Park, Nepal, and by Poudel *et al.*, (2021) in the forests of Hetauda near riverbanks. Poudel *et al.*, (2021) found *T. nudiflora* (50 pl/ha) as one of the dominant species in the forest of Hetauda near the river side. *T. nudiflora* plays a crucial role in the ecosystem, with its fruits being consumed by chital, which aids in seed dispersal and regeneration.

However, the abundance of *Trewia nudiflora* in these areas is threatened by human activities. Locals use it as fodder, preventing its fruits from reaching maturity and affecting its regeneration. Despite its ecological importance, this species receives less attention due to its low timber value. Consequently, without proper management, *T. nudiflora* faces the risk of decline in the near future. Local communities need to develop conservation strategies to ensure the preservation of this vital species in the riverine forests.

Diversity indices, including Shannon's and Simpson's indices, provided quantitative measures of species diversity and evenness within each forest type. Sal forest exhibited lower diversity indices compared to riverine forest, indicating a less diverse plant community and potential dominance of a few species. This might be due to the dominance of *Shorea robusta* in sal forest. Conversely, riverine forest showed higher diversity indices, reflecting a more even distribution of species and greater species richness. Analysis of diversity indices at a spatial level indicated differences in species distribution among various plots within both Sal and riverine forests. Some plots showed higher diversity indices than others, this might be due to heterogeneity in environmental conditions or management practices influencing plant community structure at a local scale.

5.2 Plant Invasion

In Sal forest 9 IAPS were recorded whereas in riverine forest 11 IAPS were recorded. Invasion of IAPS is high in riverine forest as compare to Sal forest, this might be due to high level anthropogenic activity in riverine forest as compare to Sal forest. Riverine forest is near to the roadside as well as local community, and the people of this community highly depend on this riverine forest site for timber and fodder plant collection, so it is highly disturbed, which might be the cause of high invasive species richness. The cover of riverine forest is also low as compare to Sal forest. Furthermore, the high richness of IAPS in riverine forest might be favored by the flood which helps in seed dispersal of this species.

In the Sal forest, *Chromolaena odorata* emerges as the dominant invasive species, with a staggering frequency of 80%, followed by *Mikania micrantha*, with a frequency of 75%. Whereas, in Riverine forest, also *M. micrantha* maintains its dominance with a frequency of 75%, followed by *C. odorata* with a frequency of

55%. This consistency in dominance across different forest types underscores the adaptability and resilience of *M. micrantha* and *C. odorata* in invading diverse habitats. Furthermore, high frequency suggests that *C. odorata* and *M. micrantha*, has successfully established itself and is rapidly spreading within the ecosystem. The dense growth and aggressive nature of this plant could outcompete native vegetation, leading to habitat degradation and loss of biodiversity (Ratnayake, 2014). Thapa *et al.,* (2016) also reported 10 IAPS in tropical sal forest (Panchakanya community forest) of Chitwan in which *C. odorata* was dominant species, which is similar to our finding. Likewise, Pandey *et al.,* (2021) reported *M. micrantha* as dominant species followed by *C. odorata* and *Lantana camara* in the urban forest of Hetauda, which is similar to our finding from riverine forest. Similarly Chaudhary *et al.,* (2020) documented 14 IAPS from Parsa National Park in which *C. odorata* has high frequency and coverage similar to our finding. Moreover, as outlined by Shrestha *et al.,* (2021), Chitwan National Park (CNP, 2018) documented the presence of over 16 Invasive Alien Plant Species (IAPS). However, our study revealed a less number of IAPS. These variations could be attributed to differences in study design and coverage area; specifically, our current study exclusively focused on the forested areas of Bhimwali Community Forest. The findings highlight the urgent need for proactive management and control measures to mitigate the spread of invasive alien plant species in both Sal and Riverine forests.

5.3 Population structure and Regeneration

Forests are dynamic environments that undergo transformations over time and space, and their characteristics can be delineated in terms of their composition, function, and structure (Franklin *et al.*, 1981).The health and growth of the forest are influenced by the presence of seedlings and sprouting mechanisms, as mentioned by Pratt *et al.,* (2012). In our study, the Sal forest showed a robust regeneration status, with a notable count of 2944 seedlings/ha, 454 saplings/ha, and 398 mature trees/ha. In contrast, the riverine forest had fewer seedlings 229/ha, saplings 204/ha, and trees 309/ha. In a different study by Sharma *et al.,* (2020) in the *Shorea robusta* forest of central Nepal, they found higher numbers with 12,589 seedlings/ha, 2643 saplings/ha, and 1979 trees/ha for all species. This difference in results may be attributed to factors like species composition, habitat, adaptability of individual species, and climatic conditions.

In Sal forest, overall forest including all trees as well as *Shorea robusta* as a dominating species shows a reverse J-shaped pattern with the highest number of seedlings followed by saplings. The distribution of trees across different life stages follows a pattern where the number of seedlings is higher than saplings, saplings are more abundant than adult trees, and adult trees outnumber old trees. This suggests a healthy and ongoing regeneration process, with a continuous cycle of younger trees replacing older ones, contributing to the overall sustainability and vitality of the forest ecosystem.

In Riverine forest, overall forest regrowth follows a reverse J-shaped curve, with more young, narrower trees than adult ones. *Trewia nudiflora* as a dominant species followed by *Albizia lucidior* both shows reverse J-shaped curve. But most of the tree of *T. nudiflora* was looped by the local people as it is used as a fodder plant to feed their cattle's. So the seedlings of *T. nudiflora* was fewer than saplings, this might effect on regeneration to some extent. Likewise *Acacia catechu* and *Dalbergia sissoo* shows bell shape curve. Acacia catechu lacked seedlings and saplings, with a peak in tree numbers at dbh class 15-25, sharply decreasing afterward, and no trees above dbh class 55cm. *D. sissoo* also had no seedlings or saplings, with more adult trees than old ones, indicating poor regeneration in both species. Most of the adult tree was in dead stage, this might be due to diseases or plant invasion because we have observed that every dead tree was invaded by *Mikania micrantha*. In case of A*cacia catechu* neither seedling nor sapling was observed. The numbers of tree between dbhclass 15-25 was observed high and after that it drastically decreases and no tree was observed above dbh class 55cm. In case of *D. sissoo* also no seedling and sapling was observed and number of adult tree was high than old trees. This shows that there was poor regeneration in *A. catechu* and *D. sissoo*. If the current situation continues there will be no existence of *A. catechu* and *D. sissoo* in Bhimwali community forest after 10-20 years.

5.4 Impact of invasive alien plants in forests

The results of the impact of Invasive Alien Plant Species (IAPS) on forest ecosystems, as revealed by regression analysis, underscore several significant findings. Firstly, there is a consistent negative relationship between IAPS richness and various indicators of forest health across both Sal and Riverine forest types. The decrease in seedling density and sapling density with increasing IAPS richness suggests that the presence of invasive plants hampers the regeneration and growth of native tree species, indicating potential challenges for forest regeneration and overall biodiversity. Additionally, the negative correlation between IAPS richness and canopy cover implies that invasive plants might outcompete native vegetation for sunlight, leading to a reduction in forest canopy density. Interestingly, while there is an insignificant negative relationship between IAPS richness and tree richness in Sal forest, a positive relationship is observed in Riverine forest, indicating a potential difference in the susceptibility of different forest types to invasion. Furthermore, the decrease in ground vegetation with increasing IAPS cover emphasizes the detrimental impact of invasive species on the overall biodiversity and ecosystem functioning. Chaudhary *et al.,* (2020) also reported a similar result in Parsa National Park (PNP) of central Nepal. Similarly research conducted by Thapa *et al.,* (2016) also reveales negative impact of IAPS in seedling germination of *Shore arobusta* in Panchakanya Community forest of Chitwan.

Comparing two site of the forest riverine forest is experiencing high number of IAPS as well as it is facing huge negative impact as compare to Sal forest. This might be because riverine forest is near to road and human settlements. Human-induced activities and the movement of animals in proximity to human settlements can contribute to the introduction and spread of invasive alien plant species (IAPS) propagules, as noted by Hobbs and Huenneke in 1992. Research conducted by Karki in 2009 also revealed that the extent of invasion tends to decrease with reduced human activities in peri-urban zones.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study conducted in Bhimwali Community Forest revealed distinct characteristics in the composition, diversity, invasive alien plant species (IAPS) richness, and population structure between the riverine and sal forests. The sal forest exhibited dominance of *Shorea robusta*, with a robust regeneration pattern and comparatively lower IAPS presence. In contrast, the riverine forest showed higher IAPS richness, especially near human settlements, impacting seedling and sapling density negatively. The population structure and regeneration dynamics varied, with the sal forest demonstrating a robust regeneration process, while the riverine forest showed signs of poor regeneration, particularly in *Acacia catechu* and *Dalbergia sissoo*. *Trewia nudiflora* dominated the riverine forest but faced challenges in regeneration due to anthropogenic activities. The study emphasizes the importance of understanding forest dynamics, species interactions, and the impact of human activities for effective conservation and sustainable management of community forests. Further research and conservation efforts are warranted, particularly in the context of the potential long-term implications of IAPS invasion on the regeneration potential of key tree species in Bhimwali Community Forest.

6.2 Recommendations

On the basis of the results of this study following recommendations are suggested:

1. Effective invasive alien plant species (IAPS) management strategies, especially in the riverine forest should be implemented, to control their negative impact on seedling germination and sapling growth.
2. Conservation efforts on species with poor regeneration, such as *Acacia catechu* and *Dalbergia sissoo*, should be focused to ensure their sustained presence in Bhimwali Community Forest.
3. Anthropogenic activities should be monitored and regulated to reduce the introduction and spread of invasive species.
4. Further research is needed to conduct in order to understand the specific factors influencing regeneration patterns and invasive species dynamics in Bhimwali Community Forest.

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APPENDICES

Appendix I: Field data sheet used for vegetation sampling

Investigators'Name:…………………………Phone:…………………Campus:………… ………………..Email:…………………… Date and time:…………………... Gaupalika/Nagarpalika:……...…………… Locality:……………… District:……… Slope................. Aspect:……………... Land use type ………………………… Altitude(m):…..................…Latitude(N):…………………Longitude(E):……………Dist urbancelevel (0,1,2,3) Forest type:………………Date of estd.....…………Canopy cover (%) (Average of three):………………….Soil moisture (%)……………. Soil pH…………………soil temperature…………….Transect:…………Plot no:…………Size of Plot: 20m×20m

SN	Species	DBH(cm) Or CBH(cm)	Height(m)	Remarks (Tree condition: dead, cut, diseased, fallen, lopped etc.)

Note: *For tree, measure DBH ≥ 5cm and height >1.37m.Tree with multiple stems are considered and inventoried as multiple individuals if the stem split below 1.37m in height (along the stem).*

For shrubs, saplings and invasive plants

Transect no:………… Plot no:……………. Plot size: 5m × 5m plot inside the main plot.

SN	**Species**	**Number**	**Height (m)**	**Cover (%)**	**Remarks** Any observable characters

Note: S*hrub and tree sapling are the individuals with height > 50 cm to DBH < 5cm*

Don't forget to collect soil sample from every plot

Collect soil sample from 10-15 cm depth from four corners and centre, mix them homogenously and take about 400-500 gm. Label properly (plot no., locality, forest type etc.) in zipper log bag. Dry the soil sample in air for 24 hrs in room temperature as soon as possible. **Note field weight and air dry weight of soil**.

For herb (including Pteridophytes)

Establishthree1m × 1m square plots diagonally (two opposite corner and centre) inside the main plot.

Transect: ………… **Main Plot no:** ………………. **Size of Plot:** 1 m x 1m

SN	Species	Number in sub-plots			Cover (%) in sub-plots		
		1	2	3	1	2	3

Note: *Tree and shrub seedlings are with height<50cm. Count Tree seedling in main plot if the seedlings are absent in1m X1m plots.*

Appendix II: Plot characteristics

a) **Sal forest**

Plot	**Longitude**	**Latitude**	**Altitude (m)**	**Aspect (ᵒ)**	**Slope**	**Canopy cover (%)**	**Invasive cover (%)**
1	84ᵒ28′ 42″	27ᵒ41′ 55″	220	127 SE	Plane	75	10
2	84ᵒ28′ 48″	27ᵒ41′ 60″	230	45 SW	Plane	70	10
3	84ᵒ28′ 50″	27ᵒ42′ 0″	230	163 S	Plane	25	45
4	84ᵒ28′ 55″	27ᵒ42′ 2″	230	194 S	Plane	75	15
5	84ᵒ28′ 58″	27ᵒ42′ 3″	227	203 SW	Plane	75	7
6	84ᵒ28′ 55″	27ᵒ42′ 6″	227	140 SE	Plane	80	7
7	84ᵒ28′ 52″	27ᵒ42′ 5″	230	333 N	Plane	55	30
8	84ᵒ28′ 47″	27ᵒ42′ 6″	230	242 SW	Plane	45	40
9	84ᵒ28′ 42″	27ᵒ42′ 2″	230	278 W	Plane	60	25
10	84ᵒ28′ 39″	27ᵒ42′ 3″	225	201 S	Plane	80	30
11	84ᵒ28′ 42″	27ᵒ42′ 7″	223	210 S	Plane	60	25
12	84ᵒ28′ 45″	27ᵒ42′ 8″	230	240 SW	Plane	50	25
13	84ᵒ28′ 48″	27ᵒ42′ 10″	230	300 NW	Plane	65	20
14	84ᵒ28′ 51″	27ᵒ42′ 9″	230	228 SW	Plane	25	60
15	84ᵒ28′ 55″	27ᵒ42′ 13″	220	251 SW	Plane	45	30
16	84ᵒ28′ 50″	27ᵒ42′ 15″	232	296 SW	Plane	65	0
17	84ᵒ28′ 46″	27ᵒ42′ 15″	230	224 SW	Plane	60	0
18	84ᵒ28′ 43″	27ᵒ42′ 14″	230	147 SE	Plane	55	10
19	84ᵒ28′ 38″	27ᵒ42′ 13″	228	208 SW	Plane	70	0
20	84ᵒ28′ 50″	27ᵒ42′ 2″	230	225 SW	Plane	35	45

b) Riverine forest

Plot	Longitude	Latitude	Altitude (m)	Aspect (°)	Slope	Canopy cover (%)	Invasive cover (%)
1	84° 28′ 42″	20° 40′ 58″	210	160 S	Plane	30	50
2	84° 28′ 45″	27° 40′ 59″	208	264 W	Plane	10	75
3	84° 28′ 49″	27° 40′ 59″	210	267 W	Plane	35	40
4	84° 28′ 53″	27° 40′ 59″	210	265 W	Plane	30	40
5	84° 28′ 42″	27° 41′ 7″	215	142 SE	Plane	35	35
6	84° 28′ 46″	27° 41′ 8″	215	123 SE	Plane	45	35
7	84° 28′ 50″	27° 41′ 9″	210	139 SE	Plane	40	10
8	84° 28′ 55″	27° 41′ 9″	215	120 SE	Plane	60	25
9	84° 29′ 0″	27° 41′ 12″	215	189 S	Plane	50	30
10	84° 28′ 46″	27° 41′ 22″	210	172 S	Plane	70	30
11	84° 28′ 52″	27° 41′ 21″	211	191 S	Plane	65	25
12	84° 28′ 56″	27° 41′ 20″	210	210 SW	Plane	65	5
13	84° 29′ 2″	27° 41′ 21″	215	221 SW	Plane	40	0
14	84° 28′ 56″	27° 41′ 31″	212	179 S	Plane	15	45
15	84° 28′ 50″	27° 41′ 35″	210	160 S	Plane	55	0
16	84° 29′ 24″	27° 41′ 58″	220	262 W	Plane	45	0
17	84° 29′ 31″	27° 42′ 21″	222	295 NW	Plane	15	20
18	84° 29′ 34″	27° 42′ 27″	222	266 W	Plane	25	20
19	84° 29′ 39″	27° 42′ 38″	225	268 W	Plane	75	0
20	84° 29′ 45″	27° 42′ 35″	225	236 W	Plane	50	25

Appendix III: List of tree species found in Bhimwali Community Forest

a) Sal forest

S.N	**Tree Species**	**Family**	**Local name**
1	*Alstonia scholaris* - (L.) R. Br.	Apocynaceae	Saatpaat
2	*Terminalia bellirica* - (Gaertn.) Roxb.	Combretaceae	Barro
3	*Terminalia alata* - Heyne ex Roth	Combretaceae	Saaj
4	*Dillenia pentagyra* - Roxb.	Dilleniaceae	Tatari
5	*Shorea robusta* - Gaertn. f.	Dipterocarpaceae	Sal
6	*Trewia nudiflora* - L.	Euphorbiaceae	Bheller
7	*Butea monosperma* - (Lam.) Taub.	Fabaceae	Palas
8	*Cassia fistula* - L.	Fabaceae	Rajbrikshya
9	*Careya arborea* - Roxb.	Lecythidaceae	Kumbhi
10	*Lagerstroemia parviflora* - Roxb.	Lythraceae	Botdhayaro
11	*Toona ciliata* - M. Roem.	Meliaceae	Tuni
12	*Syzygium nervosum* - (DC.) A. Cunn. ex DC.	Myrtaceae	Kyamuno
13	*Neolamarckia cadamba* - (Roxb.) Bosser	Rubiaceae	Kadam

b) Riverine forest

S.N	Tree species	Family	Local Name
1	*Mangifera indica* - L.	Anacardiaceae	Aam
2	*Ehretia laevis* - Roxb.	Boraginaceae	Dhatrung
3	*Garuga pinnata* - Roxb.	Burseraceae	Dabdabe
4	*Terminalia chebula* - Retz.	Combretaceae	Harro
5	*Trewia nudiflora* - L.	Euphorbiaceae	Bheller
6	*Tamarindus indica* - L.	Fabaceae	Imli
7	*Dalbergia sissoo* - Roxb.	Fabaceae	Sissoo
8	*Acacia catechu* - (L.f.) Willd.	Fabaceae	Khair
9	*Albizia lucidior* - (Roxb.) Benth.	Fabaceae	Seto Siris, Padkey
10	*Cassia fistula* - L.	Fabaceae	Rajbrichya
11	*Gmelina arborea* - Roxb.	Lamiaceae	Khamari
12	*Premna bengalensis* - Roxb.	Lamiaceae	Gineri
13	*Careya arborea* - Roxb.	Lecythidaceae	Kumbhi
14	*Lagerstroemia parviflora* - Roxb.	Lythraceae	Botdhayaro
15	*Bombax ceiba* - L.	Malvaceae	Semal
16	*Aphanamixis polystachya* - (Wall.) R. Parker	Meliaceae	Tut, Rohituka
17	*Melia azedarach* - L.	Meliaceae	Bakaino
18	*Syzygium cumini* - (L.) Skeels	Myrtaceae	Jamun
19	*Nyctanthes arbor-tristis* - L.	Oleaceae	Parijat
20	*Phyllanthus emblica* - L.	Phyllanthaceae	Amla
21	*Adina cordifolia* - Roxb.	Rubiaceae	Karam
22	*Aegle marmelos* - (L.) Corrêa	Rutaceae	Bel

Appendix IV: List of IAPS found in Bhimwali Community Forest

a) Sal forest

S. N	Invasive Plant Name	Family	Local Name
1	*Ageratina adenophora* - (Spreng.) R.M. King & H. Rob.	Asteraceae	Banmara, Kalijhar
2	*Chromolaena odorata*-(L.) R.M. King & H. Rob.	Asteraceae	Aule banmara
3	*Ageratum conyzoides* - L.	Asteraceae	Seto gandhe
4	*Ageratum houstonianum* - Mill.	Asteraceae	Nilo gandhe
5	*Bidens pilosa* - L.	Asteraceae	Kalo kuro
6	*Mikania micrantha* - Kunth.	Asteraceae	Lahare banmara
7	*Mimosa pudica* L.	Fabaceae	Lajjawati
8	*Hyptis suaveolens* - (L.) Poit.	Lamiaceae	Ban silam
9	*Spermacoce alata* - Aubl.	Rubiaceae	Alu pate

b) Riverine forest

S.N	Invasive Plant Name	Family	Local Name
1	*Mikania micrantha*–Kunth	Asteraceae	Lahare banmara
2	*Chromolaena odorata* - (L.) R.M. King & H. Rob.	Asteraceae	Aule banmara
3	*Ageratum houstonianum* - Mill.	Asteraceae	Nilo gandhe
4	*Ageratum conyzoides* - L.	Asteraceae	Seto gandhe
5	*Bidens pilosa* - L.	Asteraceae	Kalo kuro
6	*Xanthium strumarium* - L.,	Asteraceae	Bhende kuro
7	*Senna tora* - (L.) Roxb.	Fabaceae	Sano tapre
8	*Mimosa pudica* - L.	Fabaceae	Lajjawati
9	*Senna occidentalis* - (L.) Link	Fabaceae	Thulo tapre
10	*Hyptis suaveolens* - (L.) Poit.	Lamiaceae	Ban silam
11	*Lantana camara* - L.	Verbenaceae	Banphada kanda

Appendix V: Relative frequency, Relative density, Relative Basal Area, and IVI of tree species

a) Sal forest

S. N	Tree species	Fre (%)	RF	D/Ha	RD	BA/ Ha	RBA	IVI (RD+RF+ RBA)
1	*Trewia nudiflora*	10	3.70	8.75	2.19	0.44	0.80	6.69
2	*Cassia fistula*	10	3.70	2.5	0.63	0.06	0.11	4.44
3	*Lagerstroemia parviflora*	35	12.96	13.75	3.44	0.44	0.80	17.20
4	*Shorea robusta*	100	37.04	331.25	82.81	50.61	92.48	212.33
5	*Syzygium nervosum*	60	22.22	28.75	7.19	0.76	1.39	30.80
6	*Toon aciliata*	5	1.85	2.5	0.63	0.12	0.23	2.70
7	*Butea monosperma*	5	1.85	1.25	0.31	0.06	0.11	2.27
8	*Careya arborea*	5	1.85	1.25	0.31	0.07	0.13	2.30
9	*Neolamarkia cadamba*	5	1.85	2.5	0.63	0.02	0.03	2.51
10	*Dillenia pentagyra*	10	3.70	1.25	0.31	0.05	0.09	4.10
11	*Terminalia bellirica*	5	1.85	1.25	0.31	1.11	2.03	4.19
12	*Terminaliya alata*	15	5.56	3.75	0.94	0.88	1.61	8.10
13	*Alstonia scholaris*	5	1.85	1.25	0.31	0.10	0.19	2.35
	TOTAL	**270**	**100**	**400**	**100**	**54.72**	**100**	**300**

Note: Fre = Frequency, RF = Relative Frequency, D = Density, RD= Relative Density, BA= Basal Area and RBA= Relative Basal Area

b) Riverine Forest

S. N	Tree species	Fre (%)	RF	D/Ha	RD	BA/ Ha	RBA	IVI (RD+RF +RBA)
1	*Tamarindus indica*	5	1.33	1.25	0.38	0.10	0.49	2.21
2	*Magnifera indica*	5	1.33	1.25	0.38	0.06	0.31	2.03
3	*Bombax ceiba*	15	4.00	5	1.54	1.71	8.28	13.82
4	*Dalbergia sissoo*	40	10.67	26.25	8.07	3.31	16.00	34.74
5	*Aegle marmelos*	5	1.33	1.25	0.38	0.03	0.14	1.86
6	*Acacia catechu*	35	9.33	27.5	8.46	1.27	6.12	23.91
7	*Trewia nudiflora*	95	25.33	147	45.20	6.25	30.23	100.76
8	*Phylanthus emblica*	5	1.33	5	1.54	0.24	1.18	4.05
9	*Albizia lucidior*	60	16.00	47	14.45	4.85	23.46	53.91
10	*Aphanamixis polystachya*	10	2.67	12.5	3.84	0.07	0.35	6.86
11	*Gmelina arbarea*	10	2.67	17.5	5.38	1.26	6.10	14.15
12	*Nyctanthes arbor*	10	2.67	2.5	0.77	0.04	0.20	3.63
13	*Premna bengalensis*	10	2.67	3.75	1.15	0.01	0.04	3.86
14	*Garuga pinnata*	5	1.33	1.25	0.38	0.01	0.06	1.78
15	*Cassia fistula*	10	2.67	6.25	1.92	0.06	0.31	4.90
16	*Melia azedarach*	5	1.33	1.25	0.38	0.01	0.06	1.78
17	*Careya arborea*	5	1.33	1.25	0.38	0.18	0.88	2.59
18	*Lagerstroemia parviflora*	10	2.67	3.75	1.15	0.41	1.98	5.80
19	*Syzygium cumini*	10	2.67	3.75	1.15	0.16	0.76	4.58
20	*Terminalia chebula*	5	1.33	1.25	0.38	0.39	1.89	3.61
21	*Adina cordifolia*	5	1.33	2.5	0.77	0.01	0.04	2.15
22	*Ehretia laevis*	15	4	6.25	1.92	0.23	1.11	7.03
	TOTAL	**375**	**100**	**325.25**	**100**	**20.69**	**100.00**	**300.00**

Note: Fre = Frequency, RF = Relative Frequency, D = Density, RD= Relative Density, BA= Basal Area and RBA= Relative Basal Area

Appendix VI: Density of Seedlings, Saplings and Adults (stem/plot)

Plot	**Sal forest**			**Riverine forest**		
	Seedlings	**Saplings**	**Adults**	**Seedlings**	**Saplings**	**Adults**
1	50	36	21	5	0	14
2	120	42	23	6	11	6
3	16	11	6	5	8	10
4	90	15	27	4	4	8
5	70	10	33	14	15	7
6	20	14	30	16	10	9
7	40	20	21	4	3	8
8	20	30	9	6	7	9
9	210	12	7	8	3	14
10	120	46	33	8	21	18
11	336	13	9	4	12	15
12	240	9	8	22	11	13
13	294	17	7	14	13	12
14	1	3	7	0	0	10
15	9	7	9	18	17	10
16	128	11	11	5	3	15
17	260	24	9	3	3	25
18	282	25	16	38	10	21
19	42	13	27	0	0	10
20	7	5	5	3	12	11
Total/Ha	**2944**	**454**	**398**	**229**	**204**	**306**

Appendix VII: Diversity of Native, Naturalized and Invasive plant species

Plot	**Sal forest**			**Riverine forest**		
	Native	**Non-Native**		**Native**	**Non-Native**	
		Naturalized	**Invasive**		**Naturalized**	**Invasive**
1	10	0	3	13	3	5
2	14	0	2	7	1	4
3	10	0	7	10	3	5
4	12	2	3	13	2	8
5	14	1	2	11	3	3
6	12	2	2	11	1	5
7	12	1	2	15	1	3
8	7	0	4	12	1	4
9	11	1	4	11	1	3
10	13	1	4	13	1	4
11	15	1	3	14	1	3
12	10	1	5	14	2	1
13	11	0	3	11	0	0
14	8	1	5	14	1	7
15	12	0	2	14	2	0
16	18	0	0	12	1	0
17	11	0	0	8	1	4
18	12	1	2	10	0	2
19	14	2	0	10	0	0
20	7	0	4	17	1	3
Total	**50**	**5**	**9**	**68**	**9**	**11**

Appendix VIII: Plot wise IAPS richness and coverage

Plot	Sal forest		Riverine forest	
	IAPS richness	**IAPS cover (%)**	**IAPS richness**	**IAPS cover (%)**
1	3	10	5	50
2	2	10	4	75
3	7	45	5	40
4	3	15	8	40
5	2	7	3	35
6	2	7	5	35
7	2	30	3	10
8	4	40	4	25
9	4	25	3	30
10	4	30	4	30
11	3	25	3	25
12	5	25	1	5
13	3	20	0	0
14	5	60	7	45
15	2	30	0	0
16	0	0	0	0
17	0	0	4	20
18	2	10	2	20
19	0	0	0	0
20	4	45	3	25
Total	**9**	**21%**	**11**	**26%**

Appendix IX: Soil characteristics

Plot	Sal forest			Riverine forest		
	Soil temperature (^{o}C)	**Soil moisture (%)**	**Soil PH**	**Soil temperature (^{o}C)**	**Soil moisture (%)**	**Soil PH**
1	23	17.9	5.66	26	12.37	7.15
2	22	12.37	6.14	24	16.86	7.72
3	23	15.52	5.22	25	21.6	6.4
4	23	14.11	6.28	26	15	6.06
5	24	114.77	5.76	23	18.34	6.29
6	23	15.19	5.89	23	18.98	6.05
7	22	14.54	5.65	26	17.25	7.06
8	23	12.76	5.8	27	17.08	6.91
9	23	19.18	4.93	26	21.16	7.1
10	22	15.53	5.23	23	21.17	6.59
11	23	18.59	5.26	23	18.72	6.03
12	23	12.79	5.13	25	17.4	6.05
13	22	14.3	5.4	24	20.5	6.54
14	23	14.6	6.5	24	18.15	6.02
15	23	14.87	6.18	24	21.88	7.94
16	22	15.06	5.56	23	20.52	8.13
17	23	9.37	5.62	23	36.59	7.02
18	23	16.54	4.92	24	33.68	6.2
19	22	12.64	5.54	23	15.33	7.44
20	22	14.36	5.12	24	3.83	7.67
Mean	**22.7**	**14.75**	**5.58**	**24.3**	**19.32**	**6.81**

Appendix X: Photo Plates

A. Plot Establishment

B. DBH Measurement

C. Soil Collection

D. Soil PH Measurement

E. Local people collecting timbers

F. Local people collecting Sal leaf

G. Group photo with Supervisor, friends and forest guard

H. Photo with forest guard of Bhimwali Community Forest

वागमती प्रदेश सरकार
वन तथा वातावरण मन्त्रालय
वन निर्देशनालय

डिभिजन वन कार्यालय चितवन

भरतपुर, चितवन, नेपाल

प.सं.: २०७९/८० (योजना)
च.नं. ४००

मिति: २०७९/०७/१४

विषय: आवश्यक सहयोग गरिदिनु हुन।

श्री भीमवली सा.व.उ.स. कालिका न.पा.-५ चितवन ।
श्री पदमपुर सा.व.उस., कालिका न.पा.-५ चितवन ।
श्री उदयपुर सा.व.उ.स., कालिका न.पा.-७ र ८ चितवन ।

प्रस्तुत विषयमा, त्रिभुवन विश्वविद्यालय अनतरगत अमृत क्याम्पसका स्नातकोत्तरमा अध्ययनरत विद्यार्थी निरज खनालले "Status and Impact of invasive Plant Specioes in difforent land use types of kalika Municipality" शिर्षकमा अध्ययन गर्न लागेको र सो को लागि उक्त क्याम्पसको शिफारिस पत्र समेत राखी यस कार्यालयमा निवेदन दिनुभएकोले त्याहाँ सामुदायिक वनमा अध्ययन अनुसन्धान कार्यका लागी आवश्यक सहयोग गरिदिनु हुन अनुरोध छ ।

०७९।७।१४

अधिकृत स्तर आठौं (प्रा.)

वोधार्थ:
निरज खनाल
कालिका न.पा.-५ – उपरोक्त वमोजिम सामुदायिक वनहरुमा सम्पर्क राखी अध्ययन अनुसन्धान गर्नु हुन ।
९८४५६७४२०४

फोन नं. 056-520215 Email- divisionchitwan2020@gmail.com

द.नं. ७५/०६७/०६८

सम्पर्क नं.: ९८४५२१८...

श्री भीमवली सामुदायिक वन उपभोक्ता समूह

कालिका ५, चितवन

प.सं.
च.नं.२६/ ०८० /०८१

मिति: ....२०८०।०७।२४

श्री ....जो जस संग सम्वन्ध छ ।

सिफारिस गरिएको सम्वन्धमा ।

विषय:

प्रस्तुत विषयको सम्वन्धमा कालिका नगरपालिका वार्ड नं. ५, यस भिमवली सामुदायिक वन उपभोक्ता समूहको कार्य क्षेत्रमा त्रिभुवन विश्वविद्यालय त्रिचन्द्र वहुमुखि क्याम्पस वनस्पति विभागका शिक्षक उपप्रध्यापक श्री कृष्णप्रसाद शर्माको नेतृत्वमा एम.एस. सी. थेसिस विधार्थी निरज खनाल,सिजन पण्डित, विवेक पाण्ड र दुई जना सहयोगीको टोलीले यसै सामुदायिक वनमा मिति २०८०।०७।१२ देखि २०८०।०७।२४ गते सम्म अध्ययन तथा अनुसन्धान को कार्य सम्पन्न गरेको व्यहोरा जानाकारि गरिन्छ ।

अध्यक्ष
अध्यक्ष जयचन्द्र प्रशाद चौधरी

श्री जयचन्द्र प्रसाद चौधरी