Floodplain succession pattern in Khorsor region of Budhi Rapti River, Barandabhar Corridor, Chitwan, Nepal

A DISSERTATION SUBMITTED FOR THE PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE M.Sc. IN BOTANY

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LETTER OF RECOMMENDATION

This is to recommend that the dissertation entitled "**Floodplain Succession Pattern in Khorsor Region of Budhi Rapti River, Barandabhar Corridor, Chitwan, Nepal",** has been carried out by Mr. Dhiraj Chhetri Kunwar. This is his original research work and has been carried out under my supervision. To the best of my knowledge, this dissertation work has not been submitted for any other degree in any institutions. I therefore recommend this dissertation to be accepted for the partial fulfillment of the M.Sc. degree in Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal.

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LETTER OF APPROVAL

The M.Sc. dissertation entitled "**Flood Plain Succession Pattern in Khorsor Region of Budhi Rapti River, Barandabhar Corridor, Chitwan, Nepal",** submitted by Mr. Dhiraj Chhetri Kunwar to the Central Department of Botany, Tribhuvan University has been accepted for the partial fulfillment of the requirements for the M.Sc. in Botany.

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15 November, 2015

ABSTRACT

Riverine floodplain forms ecosystem that has great significance in ecosystem services. But frequent change in river course disturbed this floodplain. Budhi-Rapti River formed quite stable floodplain ecosystem nearby Khorsor zone (Barandabhar corridor). As such understanding the process of ecosystem development in the Budhi Rapti river floodplain holds great significance. This study was designed to understand plant colonizing pattern, variation in species richness and composition at the floodplain along the distance based gradient from river bank to the mature forest. Plot size of 20 × 20 m^2 (subdivided into 4 subplots) were established along the two transect (200m apart from each other). First plot was set 200m away from the bank of river and each plot were 50 m apart. A total of 20 plots were sampled along one transect thereby altogether 40 plots were sampled. All vascular plants occurred inside each plot was recorded (0 or 1). The species richness and composition was calculated. Richness for each plant life form i.e. herbs, shrubs and trees were also calculated. Altogether 158 plants (60 families and 136 genera) were recorded; Gramineae being richest followed by Leguminosae, Asteraceae and Cyperaceae. Succession was considered as main variable and measured indirectly through the first axis sample score value after indirect ordination i.e. NMDS. NMDS1 and NMDS2 scores were regressed against species richness as well as species composition variables. Here, total species richness was negatively correlated with the NMDS1 (temporal gradient) which showed convergent pattern of succession. However, herbs and shrubs species richness pattern were negatively correlated with NMDS1 but positive correlation was found with trees and climbers species richness. RDA analysis showed that herbs like *Anisomeles indica* and *Cynodon dactlylon* as an early successional species and tree species like *Ficus hispida* and *Bauhinia purpurea* as late successional species. This study suggests that flood plain succession is convergent type.

Keywords: Primary succession, convergence, species richness, floodplain, NMDS (Non-metric Multidimensional Scaling) axis, RDA.

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ABBREVIATION AND ACRONYMS

asl	Above sea level
BCC	Biodiversity Conservation Centre
CNP	Chitwan National Park
DBH	Diameter at Breast Height
DCA	Detrended Correspondence Analysis
DNPWC	Department of National Park and Wildlife Conservation
e.g.	For example
et al.	and others
GAM	Generalized Additive Model
GLM	General Linear Model
KATH	National Herbarium and Plant Laboratries
NMDS	Non-metric Multidimensional Scaling
^{o}C	Degree Celsius
RDA	Redundancy Analysis
TUCH	Tribhuvan University Central Herbarium

CHAPTER 1: INTRODUCTION

1.1 Background

Mystery behind the development of plant life form and their gradual change is always remains as a paradox in a scientific world, what has been defined as ecological succession (Sousa, 1979; Pielou, 1966). From the early 19th century to the present date myriads of scientific research have been made to answer the question behind successional changes (Cowles, 1899; Pidgeon, 1940). The barren land created by volcano (Vitousek *et al.*1993; Walker *et al.* 2003; Nara *et al.* 2003), deglaciation (Dolezal *et al.* 2008; Chapin *et al.* 1994; Fastie, 1995), river basin (Johansson *et al.*1996; Salo *et al.* 1986), floodplains (Bryant, 1987; Schimel *et al.* 1996) etc. serve as a laboratory for succession research. Especially, these habitats are suitable for the study of primary succession that mimics the early development of plants in earth.

In general, ecological succession represents the gradual development of the plant and animal communities (Connell and Slatyer, 1977; Grubb, 1977). It is divided into two types *viz* primary and secondary succession. The former represents the plant and animal life forms and their gradual changes from barren land where no humic soil was found at earlier (Walker and Del Moral, 2003) and the later represent development of plant and animal communities on secondarily formed barren land where there is existence of previous life (Tilman, 1987).

Numbers of models have been defined to unravel the mechanisms behind the successional changes in plant life forms in the light of years long experimental studies (Kitayama *et al.* 1995; Wardle *et al.* 2004). Opportunistic model, facilitation model, tolerance model, inhibition model (Connell and Slatyer, 1977) are few of them explaining the machinery of succession. For instance, opportunistic model explains that a species becomes an "Opportunist" with broad dispersal powers and rapid growths to maturity usually arrives first and occupy empty space. These species cannot invade and grow in the presence of adults of their own or other species (Sigler *et al.* 2002). Similarly facilitation model suggested that entry and growth of the later species are dependent on existence of earlier species "preparing the ground"; only after which late coming species can colonize (Bruno *et al.* 2003). Briefly, all these models or additional hypotheses illustrate that there is a series of changes occur during succession. These changes either occur in terms of plant life form composition (Dolezal *et al.* 2008) and their richness (Alvarez *et al.* 2012) followed by changes in habitat condition (Tilman, 1985) like changes in soil physiochemical properties, soil nutrients (Carson and Barret, 1988), belowground microbial activity (Ohtonen, 1999) etc.

Occurrence of plant life forms from mat like lichens to the stands of trees is the characteristic feature of the primary succession (Grime, 1977) where herbs, sub-shrubs, shrubs are the intermediate stages (Wiegleb and Felinks, 2001; Zhang, 2005). It is obvious that there is a variation in species composition (Dzwonko and Loster, 1992) and richness (Grubb, 1977) of the plant life form in the temporal gradient during succession (Vetaas, 1994). Particularly, in term of the number of species changing through time primary succession is converging (Lichter, 1998; Fukami *et al.* 2005; Rydin and Borgegård, 1988) or diverging (Baniya, *et al.* 2009; Nicol *et al.* 2005; Sarmiento *et al.* 2003; Wood and Del, 1987) pattern. Convergence pattern exemplifies the condition where there is decrease in the total species richness along the temporal gradient (age) (Martínez *et al.* 2001; Tilman, 1987). In contrast, the divergence pattern represents the decrease in total species richness from early to late stage of succession (Glenn-Lewin and Van der Maarel, 1992). The plant life form species richness pattern might be different with that of total species richness along temporal gradient (Wardle *et al.* 1995). For instance, decreasing pattern of herbs species richness with increase in temporal gradient (Walker and Del Moral, 2003) and increasing tree species richness pattern with increase in temporal gradient (Nemergut *et al.* 2007). According to life-history strategy pattern, colonizing species has been classified into redural (*r*) and competitent (*k*) species. All early colonizing species are called redural species and late colonizing species are *k* selected species. Each of these colonizing species has specific physiological and ecological adaptive feature towards colonizing habitat.

Regarding the change in habitat condition; the successional changes is driven by series of modification in aboveground (McLendon and Redente, 1992; Lichter, 1998) and belowground parameters (Olff *et al.*1993). Changes in canopy cover (Pena□Claros, 2003; Pugnaire *et al.* 1996) takes place with variation in light condition i.e. from light rich condition to the light poor condition during succession. This pattern of changes primarily supports the higher life forms like trees and climbers but limits abundance and richness of herbs and shrubs (Grubb, 1977). Meanwhile, there are changes in belowground parameters such as physiochemical properties of soil and its fertility (Crews *et al.* 1995) as well as changes in soil microbial activities (Ohtonen, 1999) etc. River basin is an ecosystem where colonization pattern can be clearly visualized from early to late stage of succession. Low land Nepal is almost flat formed by rivers having many river basins.

River basin succession is one of unique successions where soil texture changes from sandy (nutrient poor, high moisture, high minerals, and low humus content) to alluvial soil (nutrient rich, low moisture, low minerals and high humus content) (Jones *et al.* 2003; Lichter, 1998; McLendon and Redente; 1992; Ohtonen, 1999; Vetaas, 1994). These respective changes facilitate the plant of different strategies i.e. *r*-selected and *k*-selected species (Grime, 1977). At the same time disturbance (fire, grazing etc) and seed dispersal also play pivotal role in river basin succession (Ward and Stanford, 1995; Salo *et al.* 1986; Turner, 1998).

Study of ecosystem development during river basin succession is an important matter of study. Respective study could serve as effective tools for habitat management, biodiversity conservation, sustainable use of natural resources etc. Apart from these, sites like river banks are equally important for such study, where daily lives of people directly connected to access of natural resources and many other ecosystem services. Changing courses of river guides not only life history strategy of plants but also adjoining people. High altitude glacial moraines are one of highly studied sites in the world. Most study focuses primary succession towards the high altitudes deglaciated terrain (Dolezal *et al.* 2008). Minimum numbers of research were made on the successional pattern along the basins and river banks (Johansson *et al.*1996).

Succession study is constrained by temporal measurement of habitat since the time of colonization. Shorter temporal gradient can be tracked by direct measurement. However, direct measurement of long temporal gradient will not be feasible. Regular biological and abiological phenomenon during succession is continuously moving ahead. Thus indirect measurement of succession by means of ordination is a good choice (Aikio *et al.* 2000; Caccianiga *et al.* 2006; Matthews, 1978; Mesquita *et al.* 2001; Vetaas, 1994). Space by time substitution method developed by Matthews, 1995 is a highly adopted method of measuring succession which will better to adopt in this study.

1.2 Justification

Fragile and dynamic nature of Nepalese river systems makes basins after entering lowland. Lowland ecosystems form in the river basin provides significant ecosystem services to its direct and indirect dependence. Chitwan National Park and the adjoining buffer zone area is one of them where Rapti and Budhi Rapti rivers traverse through different basins. Regarding all these instances succession study is not only important but also urgent. Thus this study of primary succession in the river basin has been initiated with these following objectives:

1.3 General objective

The general objective of this study was to know the succession pattern of colonizing species along Budhi-Rapti river basin at Barandabhar corridor, Chitwan National Park.

1.3.1 Specific objectives

- To find out the life form species richness pattern along the temporal gradient
- To evaluate the variation in the species composition and richness of *Shorea robusta* forest of Barandabhar corridor along a distance based gradient from river bank to the mature forest;
- To access the status of associated species and their present diversity along the temporal gradient.

1.4 Limitation of the study

This type of specio-temporal succession study gives relative phenomenon of successional pattern. For the conformation of the pattern long term monitoring study is required.

CHAPTER 2: LITERATURE REVIEW

Alvarez *et al.* (2012) suggested that species showed different patterns of abundance in relation to stand age, supporting the current model of succession. In time, diversity increased in a logistic manner toward an asymptotic value once vegetation cover surpassed 60 %. Species richness increased in a humped-back shape, also reaching a maximum peak at 60 % vegetation cover which illustrates the change in species composition with time (succession).

Mat-forming capacity, high litter production, an extensive root system, and snow-pressure tolerance enable A. fruticosa to maintain dominance without replacement by Betula ermanii. This potential climax species remains scattered on rock terraces and elevated locations above the valley basin where it escapes snow avalanches and accumulation, a factor responsible for the inversion of vegetation zones in this maritime region (Dolezal *et al.* 2008)

Dolezal *et al.* (2008) studied the course of primary succession following deglaciation at Koryto Glacier Valley on Kamchatka Pacific coast. They monitored the vegetation changes over 270-yrs chronosequence. They found that species poor communities dominated by alder and grasses like *Alnus fruticosa, Calamagrostis purpurea* occurred on the fine-grained substrate of moraine crests, while species rich communities dominated by legumes and forbs like *Oxytropis kamtschatica, Saxifraga* species developed on the coarse grained substrate of moraine flanks, and in depressions communities dominated by willows and sedges (*Salix arctica, Juncus beringensis*) developed. Similarly, they found that the plant-species richness was highest at 80-yrs-old moraine, but thereafter decreased as the rapid growth of tree like *Alnus* led to dense stands that dominated resources and inhibited colonization and growth of earlier, as well as later, successional species. Here, they concluded that the change in plant species composition with succession.

Mitsch *et al.* (2005) studied successional patterns in two created wetland for more than 10 years. They found that pattern of succession follows the macrophytes community diversity and net primary productivity, soil development, water quality changes, and nutrient retention for two basins. They also found the increase in organic matter content in surface soils in the wetlands by approximately 1% per 3-year period. On the other hand they also reported that plant diversity and species differences led to some differences in the basins in macrophyte productivity, carbon sequestration, water quality changes and nutrient retention.

Fukami *et al*. (2005) carried out 9 year grassland experiment where they manipulate initial plant composition on abandoned arable land and subsequently allowed natural colonization. From the study they found that the initial compositional variation caused plant communities to remain divergent in species identities, even through these same communities converged strongly in species trait, and mentioned the difference between species divergence and trait convergence cannot be explained by dispersal limitation or community neutrality alone.

Mitsch *et al.* (2005) observed that there is the change in the nutrient retention during ecological succession in wetland. And suggested that nutrient factor is the essential factor of ecological succession. They also found that Plant diversity and species differences led to some differences in the basins in macrophyte productivity, carbon sequestration, water quality changes and nutrient retention.

Jones *et al.* (2003) studied primary succession in a high artic environment at deglaciated terrain of the Twin Glacier foreland at Alexandra Fjord, Ellesmere Island. They observed the vegetation cover of mosses and vascular plants measured from 1994 to 1995 using a stratified random design and made a ordination analysis. They found that terrain age accounted most of the variation in species composition over the study area. The succession followed a direction-replacement series with four main stages of dominance in 44 years: mosses to graminoid, forb to deciduous, shrub-moss to evergreen dwarft shrub moss. They concluded that the change in plant species composition with succession.

Pena-Claros (2003) studied that the Change in forest structure and species diversity throughout secondary succession by using a chronosequence at two sites in the Bolivian Amazon. He found that Species diversity increased with stand age and varied among the forest layers, with the lowest diversity in the canopy. The results of the correspondence analysis indicated that species composition varies with stand age, forest layer, and site Finally he concluded that the species composition of mature forests recovered at different rates in the different forest layers, being the slowest in the canopy layer and Species showed different patterns of abundance in relation to stand age, supporting the current model of succession.

Slius (2002) mentioned the pattern of species richness and composition in re-created grassland of Fermi National Accelerator Laboratory near Chicago. He found that the species richness at several scales and non-metric multidimensional scaling ordination were used to assess trends in the vegetation. Species richness declined through time at all scales examined and was always less in the restored prairies than that found in the remnant prairies.

The microbial community composition in a primary successional chronosequences was observed by Ohtonen (1999) on the forefront of Lyman Glacier, Washington, United States. They sampled microbial communities in soil from non-vegetated areas and under the canopies of mycorrhizal and nonmycorrhizal plants from 20- to 80-year-old zones along the successional gradient. They found that over the successional gradient, the microbial community shifted from bacterial-dominated to fungal-dominated and also the microbial respiration increased while specific activity (respiration per unit biomass) decreased in nonvegetated soils over the successional gradient.

Clear pattern of species turnover and community convergence as well as successional changes in species diversity, aboveground biomass, aboveground litter production, net ecosystem production, nutrient pool and nutrient cycling have been reported by Lichter (1998), during the study in sand dune chronosequence bordering northern Lake Michigan. They observed that following colonization by conifers, soil acidification resulted in rapid leaching losses of calcium and magnesium, whereas phosphorus and potassium were cycled more tightly (Lichter, 1998).

Berendse (1998) confirmed from his experiment that the plant features greatly influence the increase in mineralization and the change in plant species composition during ecosystem development. They suggested that during the initial phases of succession on nutrient-poor, mineral substrates dead plant material accumulates rapidly in the soil and this accumulation of soil organic matter can result in a more than 10-fold increase in nitrogen mineralization within a few decades. These changes in soil features have important consequences for plant growth and the competition between plant species. During succession in heathlands an increase in nutrient mineralization leads to species with low maximum growth rates and low biomass loss rates being replaced by species with high potential growth rates and high biomass losses.

Junk *et al.* (1997) made a review on plant life in the floodplain with special reference to herbaceous plants in the Amazon floodplain and described that four major plant communities can be distinguished: algae (phytoplankton and periphyton), aquatic herbaceous plants, terrestrial herbaceous plants, and the floodplain forest. And they concluded that the distribution of the vegetation is influenced by many factors such as : the duration of the aquatic and terrestrial phases ;physical stability of the habitat influenced by sedimentation and erosion processes ;current and wave action, Successional processes, related to the life span of the plants and the age of the habitat; Human impact.

Johansson *et al.* (1996) evaluated the importance of dispersal for species frequencies and distribution by comparing dispersal properties of vascular plant species with their frequencies along river banks. They assumed that species with long-floating seeds would be more frequent than species with short-floating seeds. Their results indicate that water dispersal has a certain role in structuring the riparian flora, and provide a basis for explaining species distribution patterns from dispersal characteristics. They also suggest that continuous river corridors are important for maintaining regional biodiversity.

Pugnaire *et al.* (1996) examined the relationships between the shrub and the herbs underneath along a gradient of shrub age. They use a total of fifty individuals to fit five age classes and shrub characteristics, soil properties and flora under the canopy were examined along the estimated chronosequence. They found that all shrub size variables increased with time, as did the amount of nutrients stored by the shrub, but differences were often significant only between the three oldest classes. Similary they observed the concentration of nitrogen and phosphorus in photosynthetic stems remained constant, but nutrient pools in stem biomass increased with time. In addition to, these shrubs changed the soil environment under their canopies with age by ameliorating soil texture, nutrient content and capacitance of water. Plant diversity in the understorey increased with shrub age, likely due to a greater heterogeneity under larger canopies. And finally concluded that the indirect interactions between shrub and its understorey herbs could be considered as a two-way facilitation in which both partners benefit from their association

Ward and Stanford (1995) reported that the dynamic nature of alluvial floodplain river is a function of flow and sediment regimes interacting with the physiographic features and vegetation cover of the landscape. They found that ecological integrity in floodplain rivers is based partly on a diversity of water bodies with differing degrees of connectivity with the main river channel. They concluded that diversity is maintained by the balance between the trend toward terrestrialization and flow disturbances that renew connectivity and reset successional sequences.
Vetaas (1994) studied the vegetation data from five dated terminal moraines in southern Norway, created between 1750 and 1930 and found that successional sequence from cryptogam-mats to a health-phase which may then be over-grown by Betula shrubs that develop into subalpine Betula pubescens forest.

Olff *et al.* (1993) studied the vegetational changes for 18 years on bare soil on the Dutch island of Schiermonnikoog after the building of a sand dike. They construct permanent transects along a topographic gradient from a moist plain to dry dunes... The accumulation of nitrogen during the successional series is accompanied by an increased biomass, a decreased light penetration to the soil surface, a decreased root/shoot ratio, increasing dominance of tall species, and a decreasing abundance of small, short-lived species. These data suggest that the importance of light competition is increasing during succession.

McLendon and Redente (1992) studied the soil nitrogen (N) availability gradient induced on a disturbed sagebrush site in northwestern Colorado by fertilizing with nitrogen (high available N), applying sucrose (low available N), and applying neither nitrogen nor sucrose (control). Species composition was studied for 3 years. At the end of the study, they determine the N concentration of aboveground tissue of 3 major species. They found that the rate of species replacement was most rapid on plots receiving the sucrose treatment and was slowest on plots receiving the N treatment. And finally concluded that the supply of available soil N, and therefore the dynamics of N incorporation in perennial plant tissue, is a primary mechanism in controlling the rate of secondary succession within this semiarid ecosystem.

Carson and Barret (1988) investigated the effect of monthly nutrient applications on succession in two old- field plant communities. Succession was monitored for 3 yr in 1-yr (younger) and 4-yr (older) experimental plots. Here they found that the type of nutrient enrichment affected the older community in an opposite manner from the younger community. They concluded that the age and physiognomy of the old-field community, the type of nutrients applied, and the duration of enrichment, each influenced the course of succession; responses observed in the 1st yr of enrichment were not indicative of later trends.

Huston and Smith (1987) suggested that an approach based on competition among individual plants is presented as an explanation for species replacements during plant succession. They found that the classic successional pattern of species replacement results from a particular structure of correlations among life history and physiological characteristics. Finally they concluded that in both primary and secondary succession are modeled as non-equilibrium processes, capable of interacting with disturbances to produce steady-state communities whose properties depend on abiotic conditions, such as temperature and resource levels, and on the type and frequency of disturbances.

Salo *et al.* (1986) suggested that large scale natural forest disturvance and primary succession in lowland rainforests of the Peruvian Amazon is caused by lateral erosion and changes of meandering rivers. Their results indicate that in the upper Amazon region, primary succession on newly deposited riverine soils is a major mode of forest regeneration. They use the Landsat imagery analyses for analysis. Here they proposed that by causing high site turnover, disturbance and variation in forest structure, the river dynamics may be a major factor creating and maintaining the high beta diversity characterizing the upper Amazon.

In the review made by Tilman (1985) taking in account of resource-ratio-hypothesis suggested the characteristic changes in habitat condition and plant life form for primary succession. Where he mentioned that the early successional species have relatively short in height, short lived , low nutrient content and fast growing which grow in poor soil having high light availability where as the late successional species have the vice versa characteristics. And finally concluded that in successional process life history of a plant depend on light and soil resource as a limiting factor.

Succession in tropical forest of Eastern Guatemala have been reported to be correlated with the litter fall and leaf decomposition of the residing plants at the forest as illustrated by study of (Ewel, 1976).

Reiners *et al.* (1971) observed the plant diversity diversity in a chronosequence at Glacier Bay, Alaska to examine the changes in plant diversity during primary succession in that region. They sampled 8 sites of known age in the respective experiment, where the four strata--trees, tall shrubs, low shrubs-herbs, and bryoid-thalloids--were sampled independently. Their result suggested that the richness (species number) of communities increased rapidly in the first 100 years, then more gradually to reach a maximum in the muskeg steady state.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

This study has selected the Khorsor zone as the study site (Figure 1). This zone is the floodplain of the Budhi Rapti river.

3.1.1 Chitwan National Park

The Chitwan National Park (CNP) is one of the country's treasures of natural wonders. It is the first National Park of Nepal established in 1973. It is located towards the south-central part of the country and covers an area of 932 sq km (DNPWC, 2010a). It lies in sub-tropical lowland of the inner terai (Figure 1). The area comprises of diverse ecosystem of Churia hills, tropical forest, flood plains of Rapti, Reu and Narayani rivers. It ranges from 100 m above sea level (asl) in the river valley to 815 m asl in the Churia hills. Over 40 lakes have been identified within the park and the buffer zone Including the Beeshajari Tal which is listed as the Ramsite site. The Narayani-Rapti river system forms a natural boundary in north and west of the park. Vegetation of CNP varies from riverine forest of deciduous trees to hardwood sal (*Shorea robusta*) forest. These forests are vital as corridor to wildlife migration and movements. Presently, *Shorea robusta* forest covers 70% of the park, riverine and pine (*Pinus roxburghii*) forest cover 7% and 3% respectively (DNPWC, 2010b).

3.1.2 Barandhabhar Corridor

Barandabhar forest is a wildlife corridor connecting Chitwan National Park to the Mahabharat foothills of Nepal. This forest between Chitwan National Park (CNP) and Mahabharat Mountain range remained the only forest strip connecting two different ecological systems (Panwar, 1986). It serves as a wildlife corridor for some animals and alternative or seasonal/and temporal habitat for others (Litvaitis *et al.* 1996). The East-West National Highway passes across the Barandabhar forest mid way in the corridor, has been a highly disturbed spot and is under the most severe human pressure. It is also the weakest link of the corridor due to the township of Bharatpur. Barandabhar forest is highly potential alternative habitat to enable wildlife to move up to the Mahabharat foothills mainly during the rainy season (Aryal *et al.* 2012).

The role of a corridor is vital. It allows outward dispersal of individuals from a source population. It helps to overcome environmental stochasticity (Dhakal *et al.* 2011).). It also allows ecological separation and resource partitioning between different animal species. Most wildlife corridors have lost their effectiveness as a result of biotic pressures and developmental activities. Corridors allow access to refuges and sources of recolonization in the event of floods, fire or diseases (Noss, 1987).

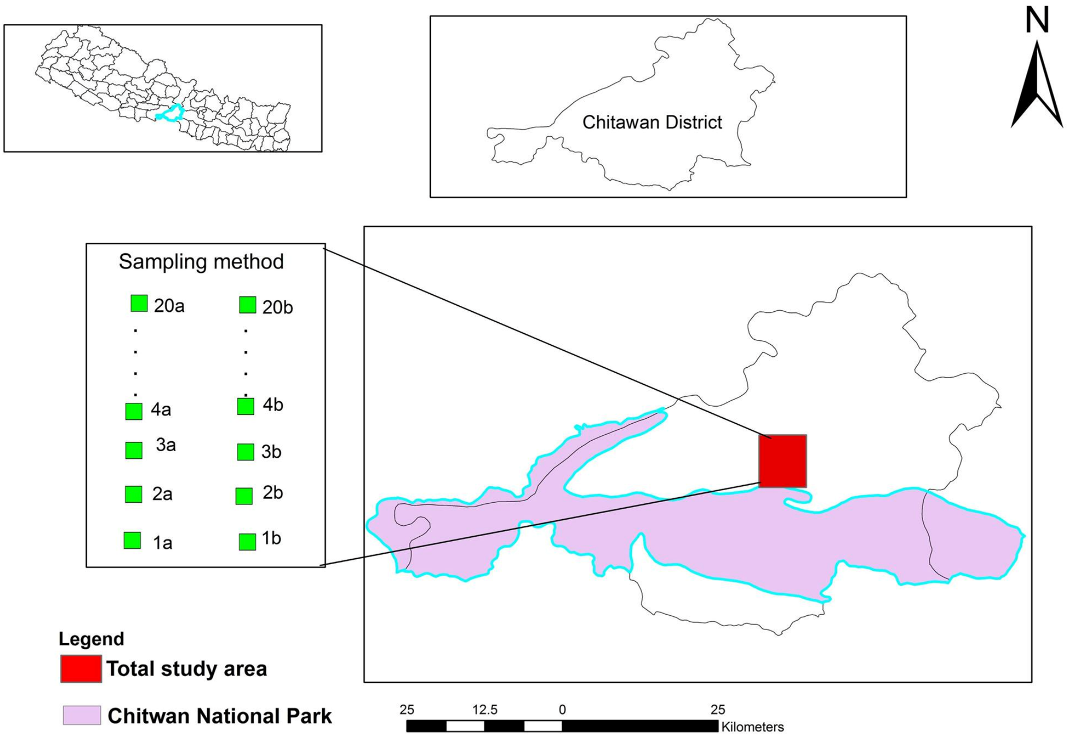


Figure 1: Map of the study area

3.1.3 Vegetation composition

This study area represents the tropical forest dominated by the sal (*Shorea robusta* Gaertn.) forest mixed with other tropical species such as *Litsea monopetala*, *Miliusa velutina*, *Mallotus philippensis*, *Maesa chisia, Murraya koenigii*, *Alstonia scholaris*, *Lagerstroemia parviflora*, *Trewia nudiflora*, *Terminalia alata, Albizia lucidior*, *Syzygium cumini*, *Terminalia bellirica*, *Clerodendrum viscosum*, *Dioscorea bulbifera*, *Hedychium ellipticum*, *Phyllanthus niruri*, *Costus speciosus*, *Pogostemon benghalensis*, *Corchorus aestuans*, *Mikania micrantha*, *Cyanotis vaga*, *Cyperus niveus*.

3.1.4 Climate

This study area falls under the tropical monsoon climatic zone. It has summer, rainy, winter and autumn seasons. Monthly average maximum temperature of the study area was 31.6°C and montly average minimum temperature was 16.3°C. An average annual rainfall recorded was 16.7mm for the year 2014 (Source: http://www.raonline.ch/pages/np/visin2/np_climate01.html accessed on 5th November 2015)

3.2 Data collection

3.2.1 Locating the sampling plot and measurement.

The field work for this study was conducted in June and October of 2014. Reconnaissance survey was done at first to obtain tentative idea of river flood plain and average distance away from the Budhi Rapti River. This distance was found to be 200 m.

Geographical location of river flood plain is also a determining factor to establish vegetation and its development. Thus park authorities were interviewed first, relevant literature was reviewed and local elderly people were also asked about past formation of the flood plain. Based on all these information, the flood plain towards the highway region where the Shorea forest, is the oldest flood plain formed by the Budhi Rapit in the past. Likewise, the flood plain towards Khorsor region, *Dalbergia sissoo* forest, is the youngest flood plain.

There were two transects placed parallel to each other with distance of separation was 200 m (Figure 2). A plot of 20 × 20 m^2 was established at the beginning of the transect from where the *Dalbergia sissoo* forest was started. The second plot was formed after 50 m away from the first. Reason behind the 200 m distance of separation of the transect was just a random believing that this distance will allow heterogeneity of vegetation formation. This study area represented the tropical forest. Thus having minimum area of a plot 20 × 20 m^2 is common to all vegetation study.

Each plot was divided into four subplots of 10 × 10 m^2 each to avoid biasness while counting. Subplots were marked as 1, 2, 3, and 4 in the clockwise direction. Presence and absence of species within each subplot was recorded in the form of 1 and 0 respectively. Each species present in a plot obtained abundance value from 4 to 1. For example if a species *Dalbergia sissoo* encountered in all four subplots it got abundance value 4. If it occurred in three subplots it received abundance value 3. Likewise, absence of a species from all four subplots denoted by 0. Thus two transects of 20 plots each were samped during this study. It represented 1.6 hector studied area.

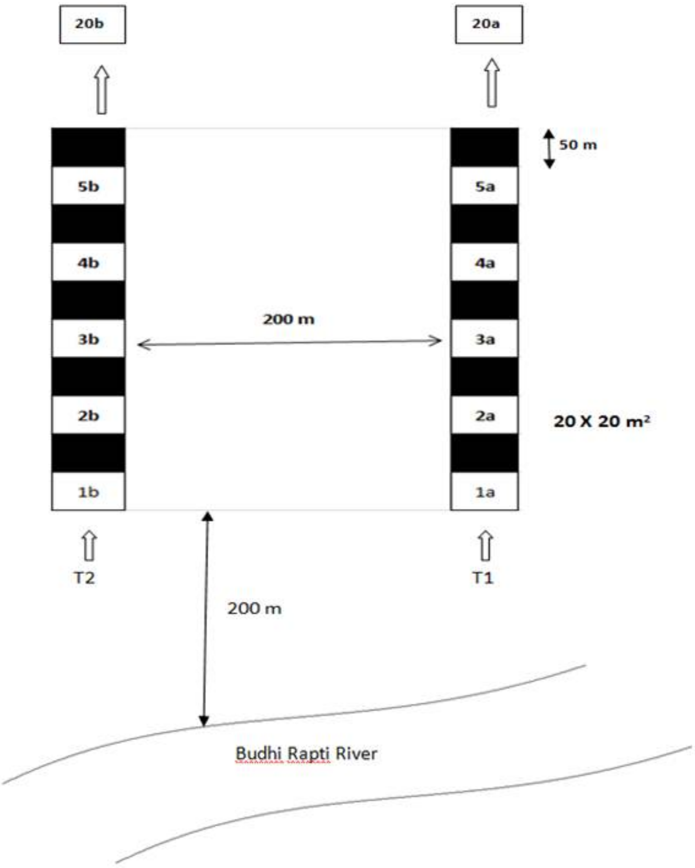


Figure 2: Sampling design

3.2.2 Plant collection, herbarium preparation and identification

All plant species encountered inside each plot were identified with the help of the field guides such as Polunin and Stainton (1984) and Stainton (1988). All species were collected at least once and dried properly. Preliminary sorting and identification of plant species was done after consulting expert from Biodiversity Conservation

Centre (BCC), Chitwan. Voucher specimens were made from properly dried plant specimens. Herbaria were made in the standard format as proposed by the Tribhuvan University Central Herbarium (TUCH). Further confirmation of each plant specimens was done after consulting preidentified herbaria that deposited at TUCH. Unidentified specimens were identified further after visiting the National Herbarium and Plant Laboratory (KATH), Godawari, Kathmanu. Some species such as *Vanda*, *Oberonia*, *Bulbophyllum* and *Carex* could not reach upto the species level. But they were different to each other by their species level. Such species were kept only upto generic level.

All valid scientific names for each species checked by using the www.plantlist.org website. All species were divided further into its own life-form such as herb, shrub, climber, tree, orchid and fern.

Nomenclature for all vascular angiosperms followed *the Annonated Checklist of the Flowering Plants of Nepal* (Press *et al.* 2000) while for ferns and fern allies followed *Ferns: the beauty of Nepalese Flora* (Gurung, 1991).

3.2.3 Measurement of temporal gradient

Temporal gradient was the main predictor variable of this study. The first axis sample score value after Non-metric Multidimensional Scaling of sample by species data was used as the successional gradient as Matthews, (1978). From this I believed that lower NMDS score represented early successional score and higher NMDS score represented late succession score. Likewise, zero NMDS first axis score represented mid succession. Matthews in 1978, use the NMDS ordination techniques for analyzing succession in high altitude of the Storbreen glacier foreland, Jotunheimen, Norway.

3.3 Numerical analysis

Information obtained from two plots of 20 x 20 m^2 each, equal distance away from the start, was averaged by total presence of species. For example, if a species named *Dalbergia sissoo* encountered in all 8 subplots, it will be recorded as 1 during this total averaging process. Likewise, all 7 to 1 time encountered species got equal abundance value *ie*., 1. Absence of species obtained zero value. Thus total species richness of this study is defined as the number of species per 800 m^2.

3.3.1 Pearson correlation coefficient

Pearson's correlation coefficient between response variables: total species richness and its derivatives (climber richness, fern richness, herb richness, orchid richness, shrub richness and tree richness) and predictors such as NMDS1, NMDS2 and Altitude were calculated. Correlation coefficient matrix was prepared with probability value (p) (Oksanen *et al.* 2015).

3.3.2 Normality and regression

Normality among response variables was sought prior to statistical tests. Normality among the response variables were checked by using Shapiro Wilcox test. Since all the data showed normal distribution, the Generalized Linear Model (GLM) (MacCullagh and Nelder, 1989) was used. The GLM upto second order was tested. The *F-statistics* was used to select the statistically best significant model ($p \leq 0.05$). The graphics was prepared from the best selected model.

3.3.3 Ordination: Nonmetric Multidimensional Scaling (NMDS)

Nonmetric multidimensional scaling (NMDS) is an indirect ordination method in which samples were ordered in an ordination space based on various types of distances (Euclidean distance in this case) of species. Its axes were representative of underlying gradients. This gradient has been used to map samples in simplified, two dimensional ordination space (Shepard, 1996).

Allocation of plots as gradient was not feasible due to flatness of the landscape of this study. Thus sample score values presented by NMDS1 and 2 utilized in this study as environmental variables as (Aikio *et al.* 2000; Caccianiga *et al.* 2006; Matthews, 1978; Mesquita *et al.* 2001 and Sahu *et al.* 2008). Between them NMDS1was highly correlated with sample scores that represented temporal gradient. Likewise, NMDS2 seemed to be the moisture gradient.

NMDS1 scores was used as temporal gradient for this study and regressed against total species richness and its derivatives.

3.3.4 Detrended correspondence analysis (DCA) and Redundancy analysis (RDA).

Zero inflation in this data matrix was first detected through changing pattern in axis length values during the detrended gradient analysis (DCA). This value was found higher in some of the higher axis. This error in the dataset may cause multi-collinearity. Thus these errors were corrected after removing only once and two times occurred species in the data set prior the multivariate analysis.

The Detrended correspondence analysis (DCA) resulted the first axis length value less than 2.5 sd units in the clean data set. This allowed to choose Redundancy Analysis (RDA). During RDA the best fitted statistically significant environment variables were chosen after regression, forward selection and 199 times permutations (Oksanen *et al.* 2015). Statistically significant results from the RDA were shown by graphics.

3.5 Software used

The Generalized Linear Model (GLM) was used by following MacCullagh and Nelder, (1989) Ordination was done by using vegan package (Oksanen *et al.* 2013). All the statistical analyses were done in R program (R Core Team 2015). Entering of data was done in Microsoft Excel and Writing was done in Microsoft Word.

CHAPTER 4: RESULTS

4.1 Plant species diversity

This study recorded 158 plant species under 60 families and 136 genera (Appendix I). Gramineae was the richest family followed by Leguminosae, Asteraceae, Cyperaceae, Labiatae, Euphorbiaceae, Verbenaceae (Appendix I). These recorded species were categorized under six life forms (herb, shrub, tree, climber, fern and orchid). Herb was the most dominant life forms with 66 species followed by tree (48), shrub (23), climber (12), fern (6) and orchids (3) (Figure 3).

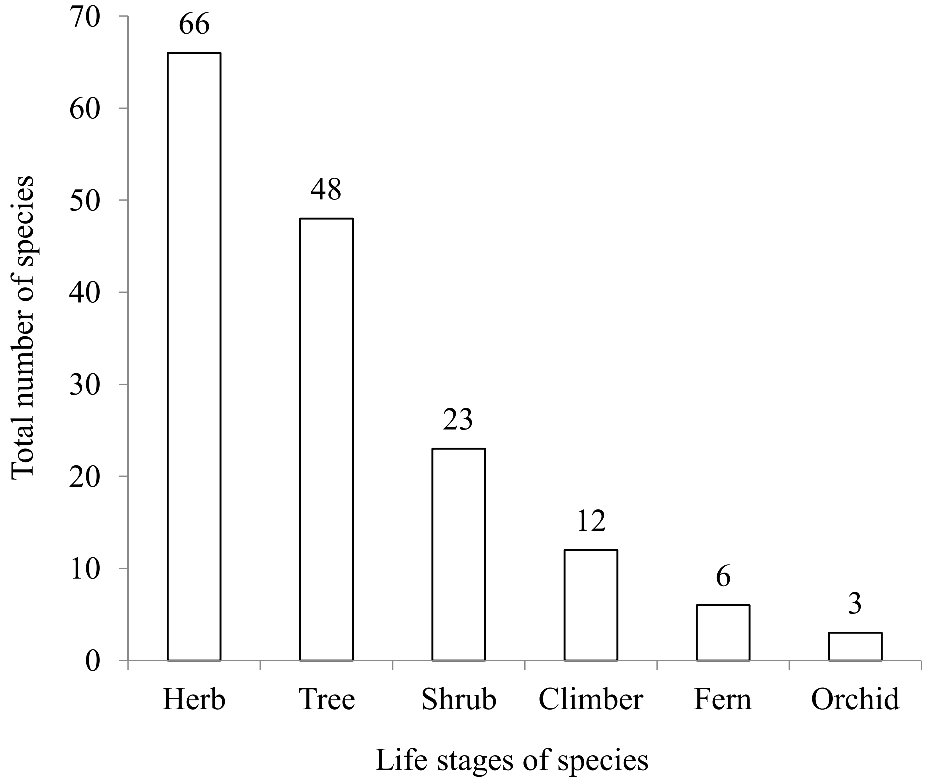


Figure 3: Species richness pattern with different life forms

This study included ten environmental variables (Table 1). The total species richness per plot (Sppn) was the counting response variable with the value ranged between 40 to 85 and 62 species as the mean total species richness for this study (Table 1). Similarly, tree species richness per plot (Tree_rich) was the counting variable varied from 14 to 21 species with mean number 17.2 (Table 1).

4.2 Pearson correlation coefficient among variables

The total species richness was found statistically significant ($p \leq 0.05$) and positive correlation with herb richness ($r^2= 0.94$) (Table 2). Likewise, the total species richness was found significant positive correlation to orchid richness ($r^2= 0.62$), shrub richness ($r^2= 0.56$) (Table 2). A negative correlation was found between NMDS1 with total species richness ($r^2=-0.69$), herb richness ($r^2= -0.58$), orchid richness ($r^2 = -0.78$) and shrub richness ($r^2=-0.72$) (Table 2). Similarly, statistically positive significant relation was found between orchid richness with herb richness ($r^2=0.5$) and shrub richness ($r^2= 0.58$) (Table 2).

Table 1: Name and summary of variables used during this study.

S.No.	Varibles	Short Form	Unit	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
1	Non-metric multidimensional scaling 1	NMDS1	Score	0.5	0.9	1.1	1.0	1.1	1.5
2	Non-metric multidimensional scaling 2	NMDS2	Score	0.8	0.8	0.9	1.0	1.2	1.4
3	Altitude	Alt	Metre	128.5	179.8	186	183	192	213
4	Total Species richness	Sppn	Number	40	55.8	62.5	61.7	68	85
5	Climber richness	Clim_rich	Number	3	5	5	5.55	6.25	8
6	Fern richness	Fern_rich	Number	2	4	4	4.25	5	6
7	Herb richness	Herb_rich	Number	11	21	25	24.9	30.3	41
8	Orchid richness	Orchid_rich	Number	0	0.0	1.0	0.9	1.3	3
9	Shrub richness	Shrub_rich	Number	4	7.8	9.0	9.3	0.3	6
10	Tree richness	Tree_rich	Number	14	15.8	17.0	17.2	19.0	21

Table 2: Pearson correlation coefficient matrix among variables

S. No.	Variables in short form	NMDS1	NMDS2	Alt	Sppn	Clim_rich	Fern_rich	Herb_rich	Orchid_rich	Shrub_rich	Tree_rich
1	NMDS1	1	0	-0.03	**-0.69***	0.06	0.38	**-0.58***	**-0.78***	**-0.72***	0.08
2	NMDS2		1	0.17	**-0.47***	0.02	-0.27	**-0.59***	0.03	0.28	-0.19
3	Alt			1	-0.13	0.03	0.3	-0.22	0.13	-0.13	0.22
4	Sppn				1	-0.12	0.03	**0.94***	**0.62***	**0.56***	0.21
5	Clim_rich					1	-0.11	-0.24	0	-0.04	-0.22
6	Fern_rich						1	0	-0.35	-0.32	0.38
7	Herb_rich							1	**0.5***	0.37	0.08
8	Orchid_rich								1	**0.58***	-0.04
9	Shrub_rich									1	-0.16
10	Tree_rich										1

Bold entry with '*' sign indicated statistical significant value ($p \leq 0.05$).

4.3 Regression Analysis

Total species richness was found statistically significant negative linear relationship (R^2 =1.0) with NMDS1and NMDS2 (Figures 4a and 4b, Appendix II).

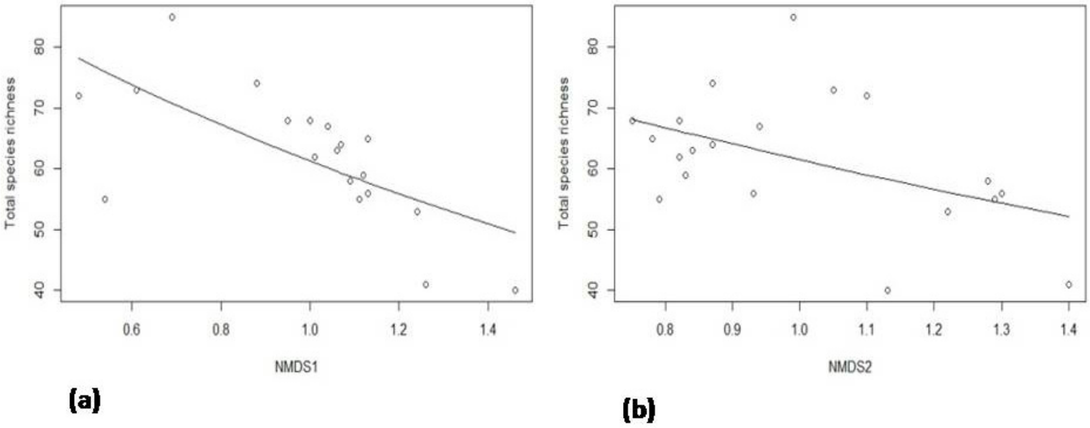


Figure 4: Total species richness vs NMDS1 (a) and NMDS2 (b)

Similarly, there was a statistical significant positive linear relationship (R^2 = 0.8) between climber species richness with NMDS1 and NMDS2 (Figures 5a and 5b).

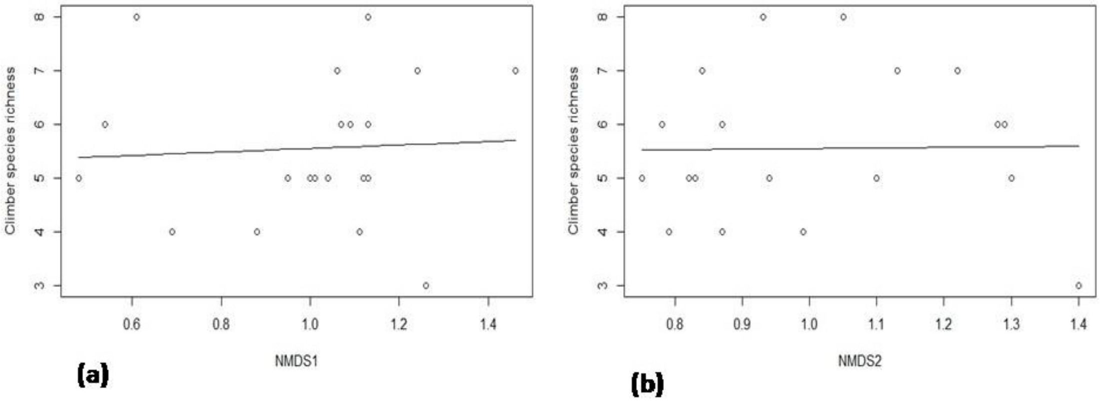


Figure 5: Climber species richness vs NMDS1 (a) and NMDS2 (b)

Fern species richness was found statistical significant positive linear relationship (R^2=0.8) With NMDS1 and significant negative linear relationship with NMDS2 (Figure 6a and 6b).

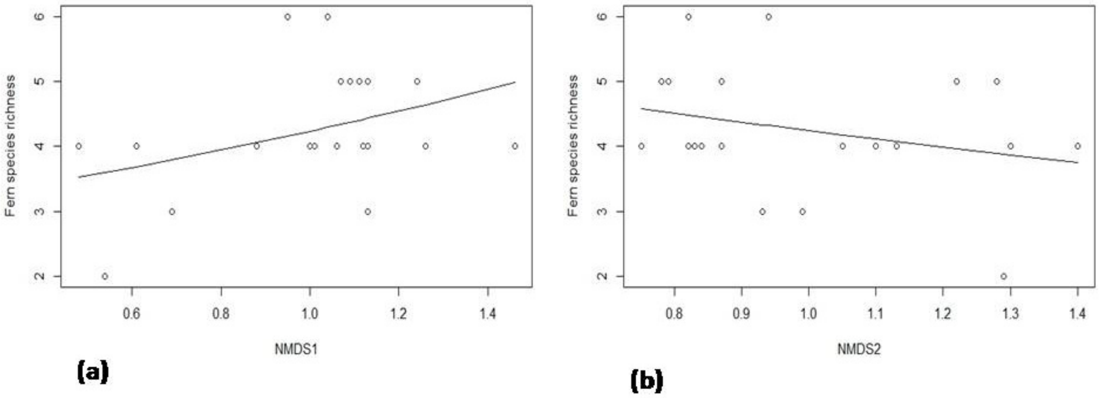


Figure 6: Fern species richness vs NMDS1 (a) and NMDS2 (b)

Similarly, herb species richness was found statistical significant negative linear relationship (R^2=1.0) between NMDS1 and NMDS 2 (Figure 7a and 7b).

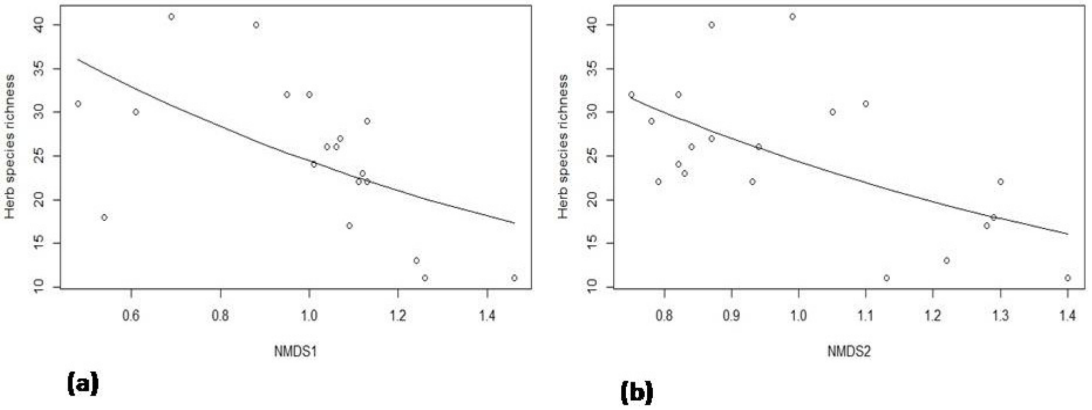


Figure 7: Herb species richness vs NMDS1 (a) and NMDS2 (b)

Orchid species richness was found as statistically decreasing relationship (R^2=0.3) between NMDS1 (Figure 8a) and significant positive linear relationship with NMDS2 (Figure 8b).

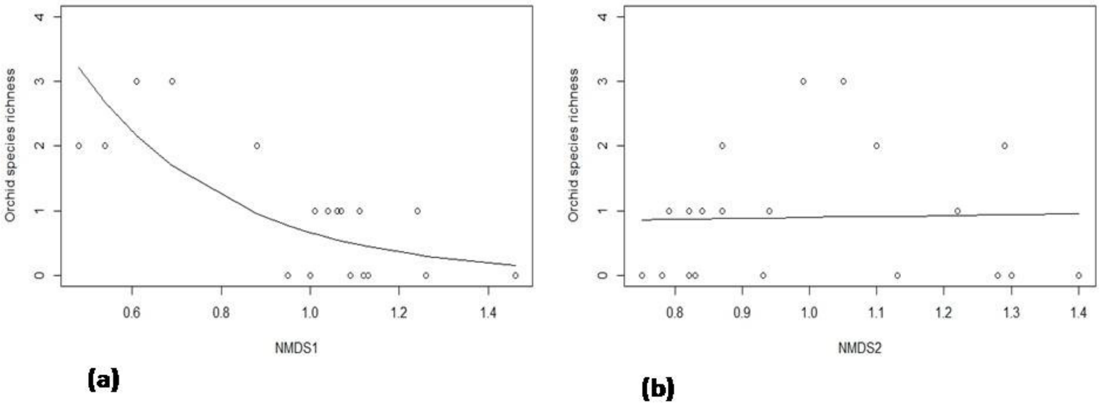


Figure 8: Orchid species richness vs NMDS1 (a) and NMDS2 (b)

Similarly, shrub species richness was found statistical significant negative linear relationship (R^2==0.9) with NMDS1 and significant positive linear relationship with NMDS2 (Figure 9a and 9b).

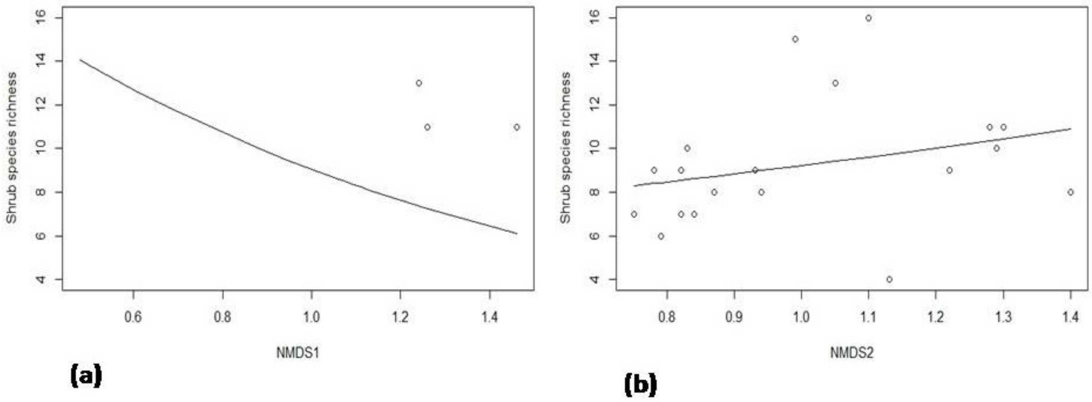


Figure 9: Shrub species richness vs NMDS1 (a) and NMDS2 (b)

Similarly, tree species richness was found statistical positive linear relationship (R^2=0.9) With NMDS1 and significant negative linear relationship with NMDS2 (Figure 10a and 10b).

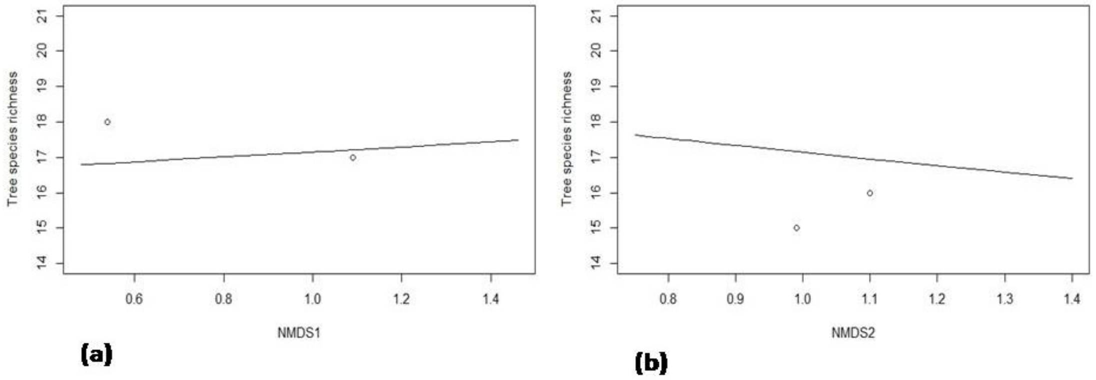


Figure 10: Tree species richness vs NMDS1 (a) and NMDS2 (b)

4.4 Ordination

4.4.1 DCA summary

The sample by species data matrix of this study showed shorter lengths of gradient, 1.7 standard deviation unit (SD unit) by the first axis of Detrended Correspondence Analysis (DCA) (Table 3). This length of gradient was found decreasing gradually with increasing axis. The variance explained by other axes was found gradually decreasing with increasing axis. That justified the normality in distribution. This DCA confirmed the linear pattern among species along the main gradient studied and allowed to choose linear direct ordination method which is Redundancy Analysis (RDA).

Table 3: DCA summary

	DCA1	DCA2	DCA3	DCA4
Eigen values	0.2	0.1	0.1	0.1
Decorana values	0.2	0.1	0.1	0.1
Axis lengths	1.7	1.5	1.2	1.0

4.4.2 RDA Analysis

Statistically significant axes were obtained by RDA. This redundancy analysis (RDA) gave two significant derived environmental variables *viz*. NMDS1 and NMDS2 after the permutations with species score. The number of permutation taken was 999 times. The NMDS1 represented significantly the first axis of RDA (Figure 4). Similarly NMDS2 denoted significant the second axis of RDA. Abundance of *Albizia lucidior and Miliusa velutina* was highly significant towards plots with the highest value of NMDS1. The highest abundance of *Dalbergia sissoo, Ficus religiosa, Parthenium hysterophorus* etc. towards the negative end of RDA first axis, were supported the plots with the least value of NMDS1. The abundance of *Breynia retusa, Smilax aspera* etc, towards the positive end of RDA first axis, were supported significantly the higher value of NMDS2. The abundance of *Commelina benghalensis* and *Hypoxis aurea* supported with the least value of NMDS2.

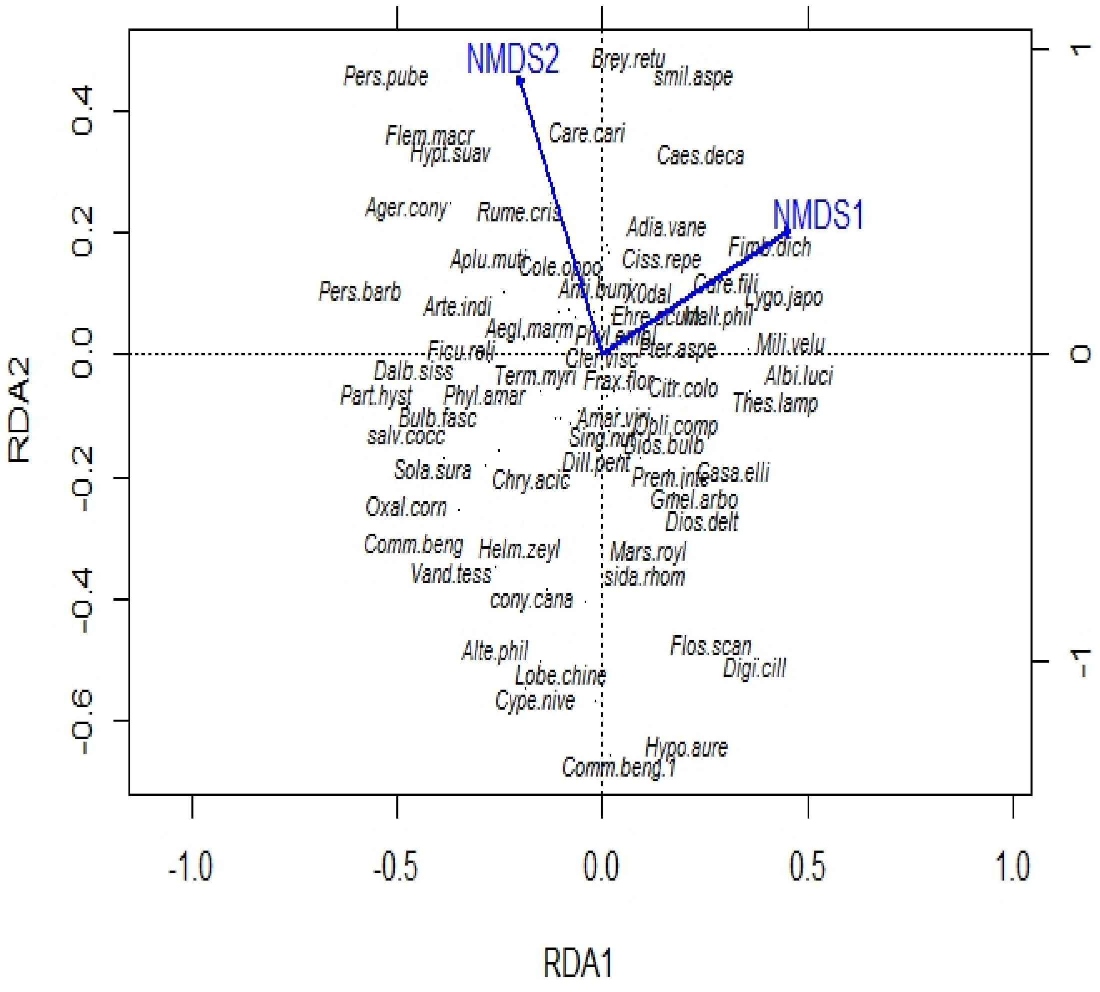


Figure 11: Species and environment biplot after Redundancy analysis (RDA). The full form of all abbreviated names included inside the figure were given in Appendix I.

4.5 Different life forms response to succession

4.5.1 Ferns species pattern along NMDS1 score (Temporal Gradient)

A total of 6 species of ferns were recored in the study. Species having negative NMDS1 score (species score) (Appendix III) were early successional species such as *Helminthostachys zeylanica* and *Dryopteris cochleata where* as species which have positive NMDS1 score were late successional species such as *Ophioglossum reticulatum* , *Adiantum capillus- veneri*s, *Lygodium japonicum, Pteris aspericaulis* And the species which have zero NMDS1 score were the intermediate species (Figure 12).

4.5.2 Climber species pattern along NMDS1 Score

This study found 12 species of climbers species .The climber species which have negative NMDS1 score(Appendix III) were early successional species such as *Trichosanthes anguina, Momordica cochinchinensis, Stephania japonica, Mikania micrantha* where as the species which have positive NMDS1 score were late succesional species succesional species such as *Butea buteiformis, Piper logum ,Caesalpinia decapetala* (Figure 13)

4.5.3 Orchid species pattern along NMDS1 Score

This study found 3 species of epiphytic orchids all have negative NMDS1 score (Appendix III) that means all orchids species were early successional species they are: *Bulbophyllum* sp, *Oberonia* sp ,*Vanda tessellata* (Figure 14).

4.5.4 Shrub species pattern along NMDS1 Score

This study recorded 23 species of shrubs. The species which have negative NMDS1 score (Appendix III) were early successional species such as: *Lantana camara, Leea crispa Salvia coccinea*. And the species which have positive NMDS1 score were late successional species such as: *Cassia occidentalis, Asparagus officinalis, Breynia retusa* (Figure 15).

4.5.5 Herb species pattern along NMDS1 Score

This study recorded 66 species of herbs. The species which have negative NMDS1 score (Appendix III) were early succesional species such as: *Anisomeles indica, Cynodon dactlylon, Typha angustifolia* . And the species which have positive NMDS1 score are late successional species such as: *Scutellaria discolor, Ludwigia hyssopifolia, Carex filicina* (Figure 16).

4.5.6 Tree species pattern along NMDS1 Score

This study found 48 species of trees. The species which have negative NMDS1 score (Appendix III) were early successional species such as: *Terminalia myriocarpa*, *Aegle marmelos, Mitragyna pravifolia Ficus religiosa, Dalbergia sissoo* etc and the species which have positive NMDS1 have late succcesional species such as *Ficus hispida, Bauhinia purpurea* , *Brassaiopsis glomerulata* (Figure 17).

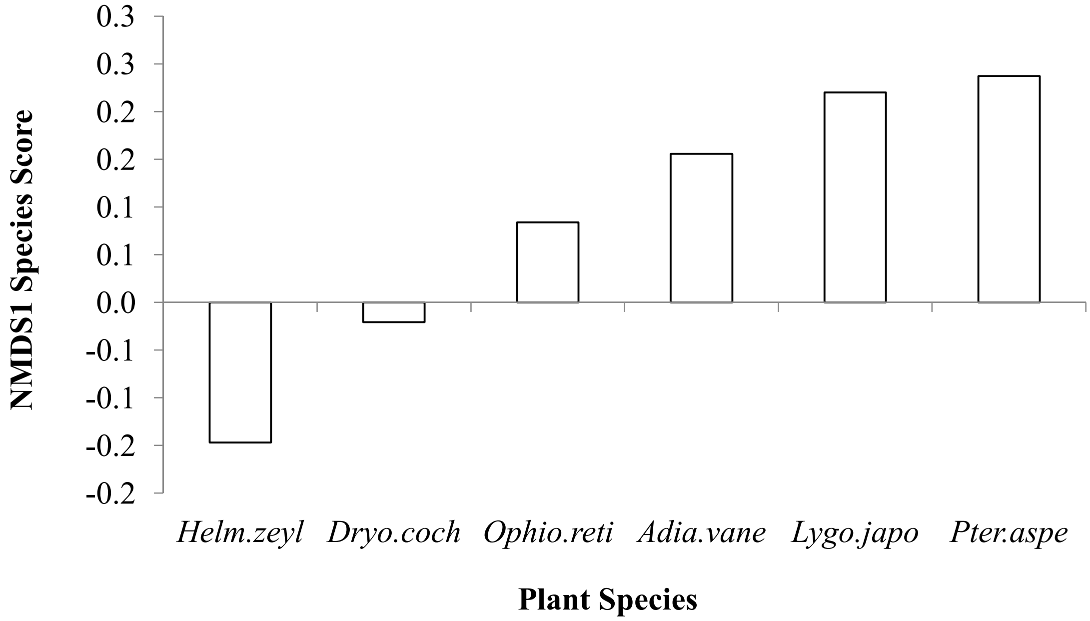


Figure 12 : Ferns species pattern along NMDS1 score

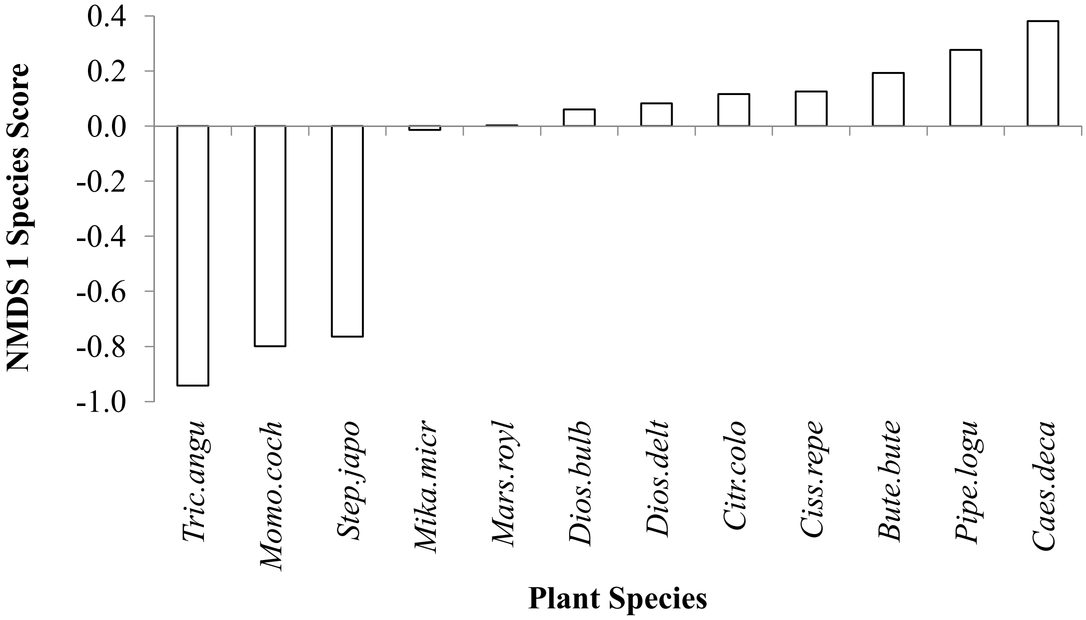


Figure 13: Climber species pattern along NMDS1 Score

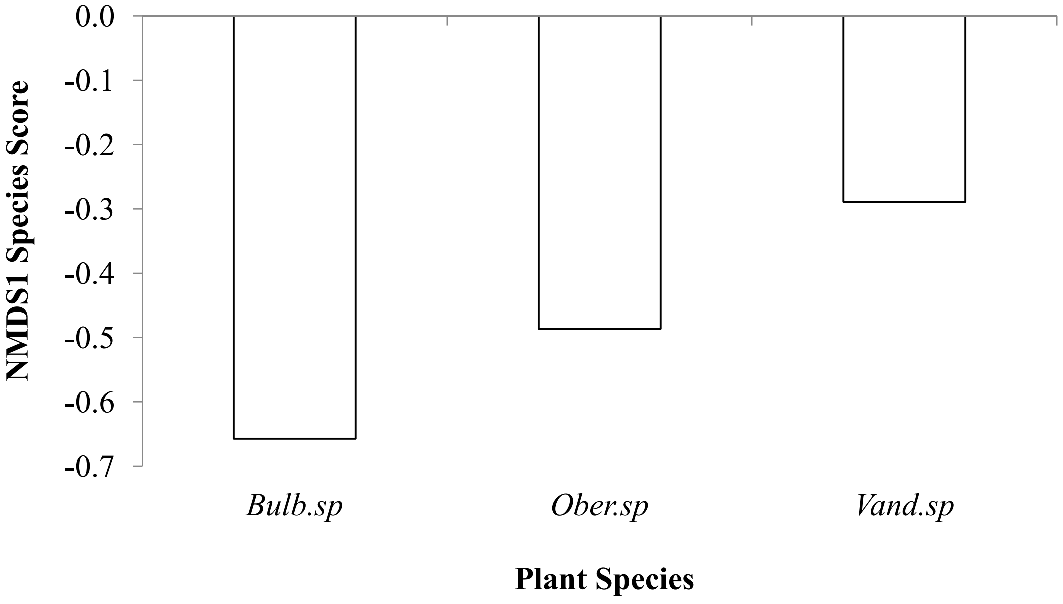


Figure 14: Orchid species pattern along NMDS1 Score

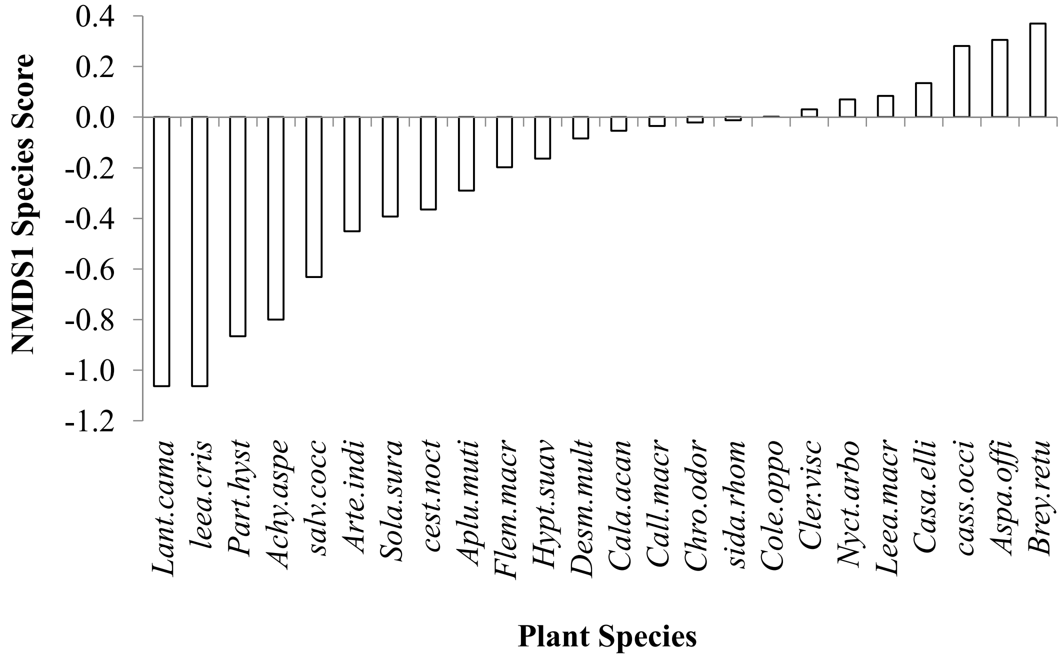


Figure 15: Shrub species pattern along NMDS1 Score

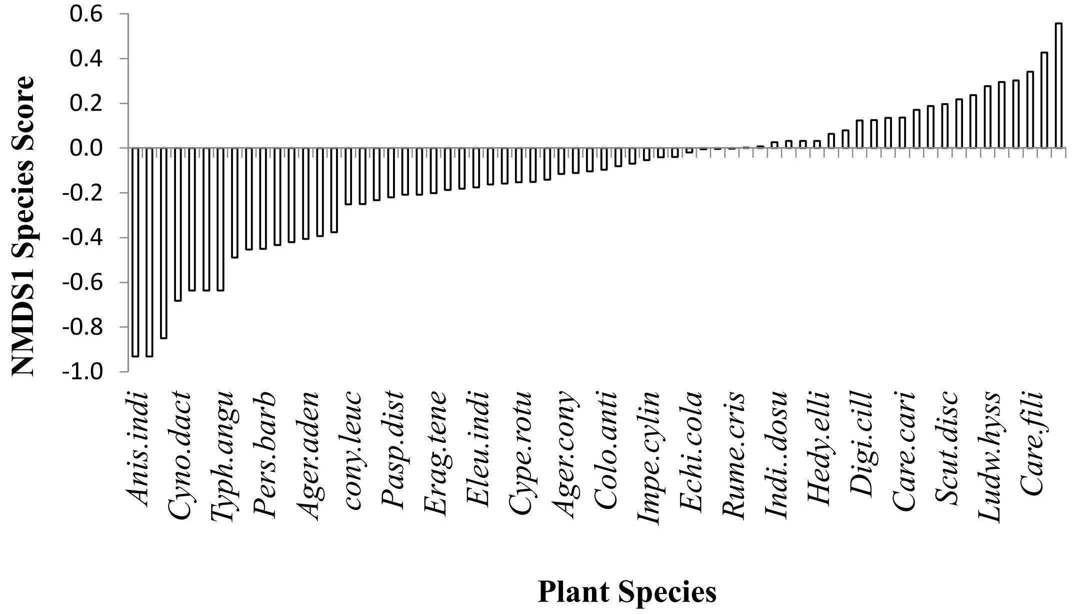


Figure 16: Herb species pattern along NMDS1 Score

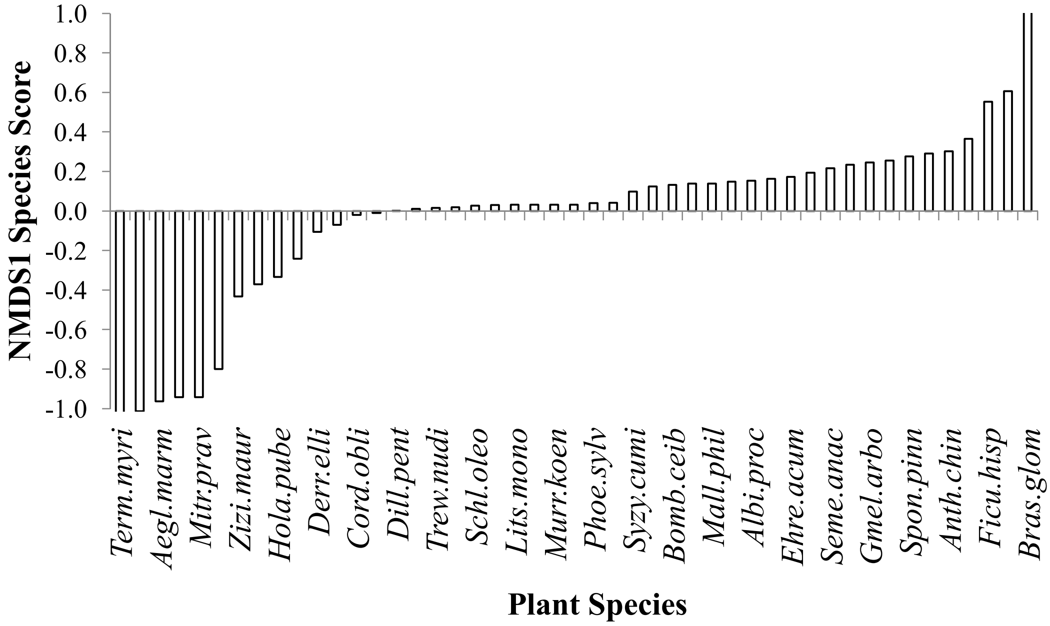


Figure 17: Tree species pattern along NMDS1 Score

CHAPTER 5: DISCUSSION

Succession is a universal and natural phenomenon. Flood plain formed by the Budhi Rapti river at Khorsor zone, Barandhabhar corridor, Chitwan National Park is no more exception. Plants of different life forms have found colonized in a definite pattern with characteristics of habitat as well as environment created by themselves. Here, I found deterministic but convergence type of succession pattern due to formation of matured Sal (Shorea) forest at the terminal end of the successional gradient for this moment. This could be changed to another type as Conell and Slatyer (1977). Most of the observed patterns in this study are matched with already established general patterns. There are also patterns with did not match with them. Thus justification will be searched at different local and regional scales and environment created by them.

The total herb species richness are found comparatively higher than other life forms such as trees, shrubs and climbers. The probable explanation of this result could be the environment created by soil of the study sites, *i.e.* the sand dunes formed nearby the river bank is relatively younger than further away. Younger sand dunes definitely would have lesser humus but high amount of mineral content which primarily favors the growth and establishment of short growing plants. Generally, these characters are shown by herb species with short life history, opportunistic, and are called *r*-selected species (Jones and Henry, 2003). Likewise, trees and shrubs are found colonized at matured sand dunes which justified these findings.

In Nepal, the tropical lowland (< 1000m) is generally flat with a gentle gradient. This study site also matches with it. Here, it is difficult to find out strongly distinct elevation gradient. Thus it needs rethinking of study design during gradient analysis. Measurement of succession gradient is almost impossible at short duration of observation. However, gradient is ubiquitous and succession is also not an exception (Huston, 1994). Measurement of succession is a matter of big challenge. Introduction of “Ordination” in community ecology (Aikio *et al.* 2000; Baniya *et al.* 2009; Caccianiga *et al.* 2006; Matthews, 1978; Mesquita *et al.* 2001; Vetaas, 1994) and implementation of Non-metric Multidimentional Scaling (NMDS) (Aikio *et al.* 2000; Caccianiga *et al.* 2006; Matthews, 1978; Mesquita *et al.* 2001) are great steps to overcome this shortcomings. The NMDS utilizes via *vegan*, a free community ecology analysis package (Oksanen *et al.* 2015). During NMDS samples and their species are presented on the basis of their abundance without bias. Sample score values of the NMDS first axis is always highly correlated with main gradient of study, that is succession in this case. Adoption of NMDS1 as succession gradient has been justified.

As the value of NMDS1 increases abundance of climax stage loving species are increasing. The second axis may represent the soil moisture gradient as having higher abundance of moisture loving species, alluvial soil loving species towards bank of the river side species. These two axes were taken as environmental variables to explain species richness, its derivatives and their composition.

The total species richness stood as the strongest variable in this study that showed the statistically significant ($p \leq 0.05$) but negative linear relationship with its functional group richness. Tree, herb, shrub, orchid, climber and fern richness indicated their major significant share to the total species richness. Herb and shrub species richness were found decreasing with increasing distance from the river bank.

Similarly, tree species richness was found increasing with NMDS1. High richness of tree species after a long time period in this study may facilitate higher canopy cover (Turner *et al.* 1988), high carbon biomass, high water table and low soil moisture (Olff *et al.* 1988). Conversely, more diversity and species richness were found towards the beginning of the NMDS1 or plots nearby river bank. In the course of succession the herb and shrub species are the early stage species with higher richness similarly at the climax stage tree species are also increasing. Due to higher canopy cover at climax stage there is less herbs and shrubs species. Due to high soil moisture at the beginning of this study or early succession stage there were higher number of invasive species (direct observation from the field). Thus the decreasing pattern of total species richness with NMDS1 is justified. This justification is also matched with justification given by Caccianiga *et al.* (2006), Aikio *et al.* (2000); Mesquita *et al.* (2001) in their study.

The observed successional changes in the species composition may also be associated with the seed dispersal of the respective plants which may be facilitated by the number of wild grazers in the park (Duncan and Chapman, 1999). The short living plants may increase richness after germination of short living plants after dropping off from fur of different animals while visiting water sources.

Total species richness is significantly correlated with herb species richness i.e. the total species richness is largely governed by the number of herb species in the study sites. Junk and Piedade (1997) found similar finding of higher number of terrestrial herbaceous species nearby Amazon floodplain.

Convergent pattern of total species richness is harmonious with number of previous studies done by Lichter (1998), Fukami *et al.* (2005) and Sluis (2002). Though the driving factor in this study are different than previous studies.

Decrease in total species richness can be explained by various factors that may change during successional stage (represented by NMDS1). Soil biophysical properties- soil characteristics (organic matter content, nutrient cycling (Carson and Barrett,1988) , microbial activity (Ohtonen *et al.* 1999), pH, moisture (Olff *et al.* 1988) aboveground vegetation- litter fall, canopy cover: disturbance (Turner *et al.* 1988) and other factors- fire, human encroachment, animal grazing etc may have resulted this model. However, the pattern of species richness for each life from differs on increasing gradient. For instance, in case of herbs richness, there is significant decrease in richness with increasing NMDS1. Changes in soil characteristics form sandy soil to the clay or alluvial Soil, decrease in soil nutrient content (Tilman, 1985; Mitsch *et al.* 2005; Vitousek and Reiners, 1975) on the other hand, increased canopy cover of tree species, may have similar results, which represents the changes in the habitat condition in process of succession Wiegleb and Felinks (2001) and Prach and Pyšek (2001).

Various factors like seed dispersal, animal movement and grazing may contribute to high species richness of herbs nearby river banks. Similar condition prevails in case of shrubs too. In contrast, the fern species richness and tree species richness increase simultaneously with increasing distance. Above mentioned reason may have resulted this pattern, like shady and moist condition of forest floor becomes suitable site for fern to flourish (Chapin *et al.* 1994: Yarranton *et al.* 1974), furthermore, disturbance factors (Turner *et al.*1998) like fire has little influence on the regeneration of these pteridophytes **(**Walker *et al.* 2010**)**. This phenomenon is quite common in this studied site. Likewise, the increased tree species richness may have facilitated by the high nutrient input, high microbial activity, efficient intake of nutrient by trees etc. meantime, frequent outbreak of fire, high canopy cover, litter fall also limit the growth and development of shrubs and herbs underneath the forest floor (Olff *et al.* 1993; Fukami *et al.* 2005). Consequently, habitat of increased tree species richness assisted the higher number of climbers in the respective habitat, resulting an increasing pattern of climber species richness with NMDS1. Herbs species such as *Anisomeles indica, Cynodon dactlylon, Typha angustifolia* etc. having negative NMDS1 score represents the early successional species. Likewise, tree species such as *Ficus hispida, Bauhinia purpurea*, *Brassaiopsis glomerulata* etc. having positive NMDS1 score represents the late successional species.

CHAPTER 6: CONCLUSION

This study concluded that the forest succession in Khorsor zone of Budhi-Rapti river basin is convergence type. Species richness pattern differed by life forms i.e. there is decrease in herb and shrub species richness with NMDS1 but increasing in trees species richness pattern with the NMDS1. Herbs represents plant life form of early successional stage and trees represents the late successional stage.

CHAPTER 7: RECOMMENDATION

Satellite imagery for the historical movement of flood plains can be a good tool to understand successional changes. Application of satellite imagery is highly recommended for future study.

Change in soil characteristics during primary succession in river banks can be a good study to explain biological phenomena further.

Measurement of disturbance during successional changes would result better information.

Long term monitoring of ecosystems will help further understanding of successional phenomenon.

REFERENCES

Aikio, S., Väre, H., & Strömmer, R. (2000). Soil microbial activity and biomass in the primary succession of a dry heath forest. *Soil Biology and Biochemistry*, *32*(8), 1091-1100.

Alvarez-Molina, L. L., Martinez, M. L., Perez-Maqueo, O., Gallego-Fernandez, J. B., & Flores, P. (2012). Richness, diversity, and rate of primary succession over 20 year in tropical coastal dunes. *Plant Eology* : An International Journal, *213*, 114-119.

Aryal, A., Brunton, D., Shrestha, T. K., Koirala, R. K., Lord, J., Thapa, Y. B., & Raubenheimer, D. (2012). Biological diversity and management regimes of the northern Barandabhar Forest Corridor: an essential habitat for ecological connectivity in Nepal. *Tropical Conservation Sciences*, *5*(1), 38-49.

Baniya, C. B., Solhøy, T., & Vetaas, O. R. (2009). Temporal changes in species diversity and composition in abandoned fields in a trans-Himalayan landscape, Nepal. *Plant Ecology*, *201*(2), 383-399.

Berendse, F. (1998). Effects of dominant plant species on soils during succession in nutrient-poor ecosystems. *Biogeochemistry*, *42*(1-2), 73-88.

Bruno, J. F., Stachowicz, J. J., & Bertness, M. D. (2003). Inclusion of facilitation into ecological theory. *Trends in Ecology & Evolution*, *18*(3), 119-125.

Bryant, J. P. (1987). Feltleaf willow-snowshoe hare interactions: plant carbon/nutrient balance and floodplain succession. *Ecology*, *15*, 1319-1327.

Carson, W. P., and Barrett, G. W. (1988). Succession in old-field plant communities: effects of contrasting types of nutrient enrichment. *Ecology*, *16*, 984-994.

Chapin, F. S., Walker, L. R., Fastie, C. L., & Sharman, L. C. (1994). Mechanisms of primary succession following deglaciation at Glacier Bay, Alaska. *Ecological Monographs*, *64*(2), 149-175.

Clements, F. E. (1916). Plant succession analysis of the development of vegetation. Carnegie Inst. Washington Pub. 242, 512 pp.

Conell , J.H. and Slatyer, R.O. (1977). Mechanism of succession in natural communities and their role in community stability and organization. *The American Naturalist*, *111* (982), 1110-1114.

Conover,W . J. (1971). Practical non parametric statistics. Wiley, NewYork. 642 pp.

Crews, T. E., Kitayama, K., Fownes, J. H., Riley, R. H., Herbert, D. A., Mueller-Dombois, D., & Vitousek, P. M. (1995). Changes in soil phosphorus fractions and ecosystem dynamics across a long chronosequence in Hawaii. *Ecology*, *76*(5), 1407-1424.

Dhakal, R. R., Kafle, G., & Yadava, J. N. (2011). Comparative assessment of floristic diversity in a buffer zone community forest and a community forest of Barandabhar corridor, Chitwan, Nepal. *Journal of Horticulture and Forestry*, *3*(8), 244-250.

DNPWC. (2010)a. Annual Report Chitwan National Park. Department of National Park and Wildlife Conservation, Government of Nepal, Kathmandu.

DNPWC. (2010)b. Annual Report Chitwan National Park. Department of National Park and Wildlife Conservation, Government of Nepal, Kathmandu.

Dolezal, J., Homma, K., Takahashi, K., Vyatkina, M. P., Yakubov, V., Vetrova, V. P., *et al*. (2008). Primary succession following deglaciation at Koryto Glacier Valley, Kamchatka. Arctic, Antartic, and Alpine Research , *40* (2), 309-322.

Dzwonko, Z., & Loster, S. (1992). Species richness and seed dispersal to secondary woods in southern Poland. *Journal of Biogeography*, 195-204.

Ewel, J. J. (1976). Litter fall and leaf decomposition in a tropical forest succession in Eastern Guatemala. *The Journal of Ecology*, *64* (1), 293-308.

Fastie, C. L. (1995). Causes and ecosystem consequences of multiple pathways of primary succession at Glacier Bay, Alaska. *Ecology*, *76*(6), 1899-1916.

Fukami, T., Martijn Bezemer, T., Mortimer, S. R., and Putten, W. H. (2005). Species divergence and trait convergence in experimental plant community assembly. *Ecology letters*, *8*(12), 1283-1290.

Glenn-Lewin, D. C., & van der Maarel, E. (1992). Patterns and processes of vegetation dynamics. *Plant succession*, *4*, 11-59.

Gobbi, M., Caccianiga, M., Cerabolini, B., Bernardi, F., Luzzaro, A., and Pierce, S. (2010). Plant adaptive responses during primary succession are associated with functional adaptations in ground beetles on deglaciated terrain. *Community Ecology*, *11*(2), 223-231.

Grime, J. P. (1977). Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. *American naturalist*, 1169- 1194.

Grubb, P. J. (1977). The maintenance of species-richness in plant communities: the importance of the regeneration niche. *Biol. Rev*, *52*(1), 107-145.

Gurung, V.L. (1991). *Ferns: The Beauty of Nepalese Flora.* Sahayogi Press, 234pp.

Heinselman, M. L. (1981). Fire and succession in the conifer forests of northern North America. In *Forest succession* (pp. 374-405). Springer New York.

Huston, M.A.(1994). Biological Diversity: The co-existence of species on changing landscapes. Cambridge University press, UK.

Johansson, M. E., Nilsson, C., and Nilsson, E. (1996). Do rivers function as corridors for plant dispersal?. *Journal of Vegetation Science*, *7*(4), 593-598.

Jones, G. A., and Henry, G. H. (2003). Primary plant succession on recently deglaciated terrain in the Canadian High Arctic. *Journal of Biogeography* , *30*, 277-296.

Junk, W. J., and Piedade, M. T. F. (1997). Plant life in the floodplain with special reference to herbaceous plants. In *The central Amazon floodplain* Springer Berlin Heidelberg. 147-185 pp .

Kitayama, K., Mueller-Dombois, D., & Vitousek, P. M. (1995). Primary succession of Hawaiian montane rain forest on a chronosequence of eight lava flows. *Journal of Vegetation Science*, *6*(2), 211-222.

Lichter, J. (1998). Primary succession and forest development on coastal lake Michigan sand dunes. *Ecological Monographs* , *68* (4), 487-510.

Litvaitis JA, Titus K, Anderson EM (1996). Measuring Vertebrate Use of Terrestrial habitats. In Research and Management techniques for Wildlife and Habitats (Bookhout, T.A. ed.) The Wildlife Society, Bethesda, USA. 254-274 pp.

MacCullagh, P. and Nelder, J.A. (1989). Generalized Linear Models. CRC Press.

Martínez, M. L., Vázquez, G., & Sánchez Colón, S. (2001). Spatial and temporal variability during primary succession on tropical coastal sand dunes.*Journal of Vegetation Science*, *12*(3), 361-372.

Matthews, J.A. (1978). An application of non-metric multidimensional scaling to the construction of an improved species plexus. *Journal of Ecology*, *66*: 157-173.

McLendon, T., and Redente, E. F. (1992). Effects of nitrogen limitation on species replacement dynamics during early secondary succession on a semiarid sagebrush site. *Oecologia*, *91*(3), 312-317.

Mesquita, R. C., Ickes, K., Ganade, G., and Williamson, G. B. (2001). Alternative successional pathways in the Amazon Basin. *Journal of Ecology*, *89*(4), 528-537.

Mitsch, W. J., Zhang, L., Anderson, C. J., Altor, A. E., and Hernandez, M. E. (2005). Creating riverine wetlands: Ecological succession, nutrient retention, and pulsing effects. *Ecological Engineering*, *25*(6),510-537.

Nara, K., Nakaya, H., Wu, B., Zhou, Z., & Hogetsu, T. (2003). Underground primary succession of ectomycorrhizal fungi in a volcanic desert on Mount Fuji. *New Phytologist*, *159*(3), 743-756.

Nemergut, D. R., Anderson, S. P., Cleveland, C. C., Martin, A. P., Miller, A. E., Seimon, A., & Schmidt, S. K. (2007). Microbial community succession in an unvegetated, recently deglaciated soil. *Microbial Ecology*, *53*(1), 110-122.

Nicol, G. W., Tscherko, D., Embley, T. M., & Prosser, J. I. (2005). Primary succession of soil Crenarchaeota across a receding glacier foreland. *Environmental Microbiology*, *7*(3), 337-347.

Noss 1987 Corridors in real landscape: a reply to Simberloff and Cox. Conserv. *Biological science*, *1*:159-164.

Odum E.P. and Barrett G.W. (2005). Fundamnental of Ecology Cengage Learning India Private Limited, Patparganj, New-Delhi, India.

Ohtonen, R., Fritze, H., Pennanen, T., Jumpponen, A., and Trappe, J. (1999). Ecosystem properties and microbial community changes in primary succession on a glacier forefront. *Oecologia*, *119*(2), 239-246.

Oksanen, J., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P. R., O'Hara, R. B., and Wagner, H. (2015). Package 'vegan'. *R Packag ver*, *254*, 20-8.

Olff, H., Huisman, J., & Van Tooren, B. F. (1993). Species dynamics and nutrient accumulation during early primary succession in coastal sand dunes. *Journal of Ecology*, 693-706.

Panwar HS 1986. Forest cover mapping for planning tiger corridors between Kanha and Bandhavgarh-a proposed project. In Proc. of the seminar-cum-workshop on wildlife habitat evaluation using Remote Sensing Techniques, Oct. 22-23. IIIRS and WII, Dehradun.

Pena-Claros, M. (2003). Changes in forest structure and species composition during secondary forest succession in the Bolivian Amazon1. *Biotropica*, *35*(4), 450-461.

Pidgeon, I. M. (1940). The ecology of the central coastal area of New South Wales. III. Types of primary succession. In *Proceedings of the Linnean Society of New South Wales*, *65*(6), 221-49.

Pielou, E. C. (1966). Species-diversity and pattern-diversity in the study of ecological succession. *Journal of theoretical biology*, *10*(2), 370-383.

Polunin, O. & Stainton, A. (1984). Flowers of the Himalaya, Oxford University Press, New-Delhi, India.

Prach, K., & Pyšek, P. (2001). Using spontaneous succession for restoration of human-disturbed habitats: experience from Central Europe. *Ecological Engineering*, *17*(1), 55-62.

Press, J.R, Shrestha,K.K. and Sutton, D.A. (2002). Annonated *checklist of the Flowering Plants of Nepal.* The Natural History Museum, London.UK.

Pugnaire, F. I., Haase, P., Puigdefábregas, J., Cueto, M., Clark, S. C., & Incoll, L. D. (1996). Facilitation and succession under the canopy of a leguminous shrub, *Retama sphaerocarpa*, in a semi-arid environment in south-east Spain. *Oikos*, 455-464.

R Core Team 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL, http://www.R-project.org/.

Reiners, W. A., Worley, I. A., & Lawrence, D. B. (1971). Plant diversity in a chronosequence at Glacier Bay, Alaska. *Ecology*, 55-69.

Rydin, H., & Borgegård, S. O. (1988). Primary succession over sixty years on hundred-year old islets in Lake Hjälmaren, Sweden. *Vegetatio*, *77*(1-3), 159-168.

Salo, J., Kalliola, R., Hakkinen, I., Makinen, Y., Niemela, P., Puhakka, M., *et al.* (1986). River dynamics and the diversity of Amazon lowland forest. Nature , *322*, 254-258.

Sarmiento, L., Llambi, L. D., Escalona, A., & Marquez, N. (2003). Vegetation patterns,regeneration rates and divergence in an old-field succession of the high tropical Andes. *Plant Ecology*, *166*(1), 145-156.

Schimel, J. P., Cleve, K. V., Cates, R. G., Clausen, T. P., & Reichardt, P. B. (1996). Effects of balsam poplar (Populus balsamifera) tannins and low molecular weight phenolics on microbial activity in taiga floodplain soil: implications for changes in N cycling during succession. *Canadian Journal of Botany*, *74*(1), 84-90.

Sigler, W. V., Crivii, S., & Zeyer, J. (2002). Bacterial succession in glacial forefield soils characterized by community structure, activity and opportunistic growth dynamics. *Microbial Ecology*, *44*(4), 306-316.

Singh J.S.,Singh S.P. and Gupta S.R. (2006). Ecology Environment and Resource conservation Anamaya Publishers Lada sarai, New-Delhi, India.

Sluis, W. J. (2002). Patterns of species richness and composition in re□created grassland. *Restoration Ecology*, *10*(4), 677-684.

Sousa, W. P. (1979). Experimental investigations of disturbance and ecological succession in a rocky intertidal algal community. *Ecological Monographs*, *49*(3), 227-254.

Tilman, D. (1985). The resource-ratio hypothesis of plant succession. *American Naturalist*, 827-852.

Tilman, D. (1987). Secondary succession and the pattern of plant dominance along experimental nitrogen gradients. *Ecological monographs*, *57*(3), 189-214.

Turner, M. G., Baker, W. L., Peterson, C. J., & Peet, R. K. (1998). Factors influencing succession: lessons from large, infrequent natural disturbances. *Ecosystems*, *1*(6), 511-523.

Uhl, C., Clark, H., Clark, K., and Maquirino, P. (1982). Successional patterns associated with slash-and-burn agriculture in the upper Rio Negro region of the Amazon Basin. *Biotropica*, 249-254.

Vetaas, O. R. (1994). Primary succession of plant assemblages on a glacier foreland-Bodalsbreen, southern Norway. *Journal of Biogeography*, 297-308.

Viereck L.A., Dryness C.T. and Force M.J. (1993). An overview of the vegetation and soils of the floodplain ecosystem of the Tanana River, Interior Alaska. Can.J.For.Res, *23*: 889-893.

Vitousek P.M. and Reiners W.A. (1975). Ecosystem succession and Nutrient Retention: A hypothesis Bioscience, *25*(6): 376-381.

Vitousek, P. M., Walker, L. R., Whiteaker, L. D., & Matson, P. A. (1993). Nutrient limitations to plant growth during primary succession in Hawaii Volcanoes National Park. *Biogeochemistry*, *23*(3), 197-215.

Walker, L. R., & Del Moral, R. (2003). *Primary succession and ecosystem rehabilitation*. Cambridge University Press.

Walker, L. R., Landau, F. H., Velazquez, E., Shiels, A. B., and Sparrow, A. D. (2010). Early successional woody plants facilitate and ferns inhibit forest development on Puerto Rican landslides. *Journal of Ecology*, *98*(3), 625-635.

Ward J.V. and Stanford J.A. 1995. Ecological Connectivity in Alluvial River ecosystem and its disriuption by flow regulation. Regulated Rivers : *Research and Management*,*11*:105-119.

Wardle, D. A., Walker, L. R., & Bardgett, R. D. (2004). Ecosystem properties and forest decline in contrasting long-term chronosequences. *Science*, *305*(5683), 509-513.

Wardle, D. A., Yeates, G. W., Watson, R. N., & Nicholson, K. S. (1995). Development of the decomposer food-web, trophic relationships, and ecosystem properties during a three-year primary succession in sawdust. *Oikos*, 155-166.

Wiegleb, G., and Felinks, B. (2001). Primary succession in post-mining landscapes of Lower Lusatia—chance or necessity. *Ecological Engineering*, *17*(2), 199-217.

Wood, D. M., & Del Moral, R. (1987). Mechanisms of early primary succession in subalpine habitats on Mount St. Helens. *Ecology*, 780-790.

Yarranton, G. A., and Morrison, R. G. (1974). Spatial dynamics of a primary succession: nucleation. *The Journal of Ecology*, 417-428.

Zhang, J. T. (2005). Succession analysis of plant communities in abandoned croplands in the eastern Loess Plateau of China. *Journal of Arid Environments*, *63*(2), 458-474.

APPENDICS

APPENDIX I: List of species encountered during this study their life form, short form and frequency.

S.N.	Scientific name	Family	Life form	Short form	Frequency
1	*Achyranthes aspera* L.	Amaranthaceae	Herb	Achy aspe	5
2	*Adiantum capillus- veneri*s L.	Pteridaceae	Fern	Adia capi	39
3	*Aegle marmelos* (L.) Corr.	Rutaceae	Tree	Aegl marm	1
4	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Asteraceae	Herb	Ager aden	5
5	*Ageratum conyzoides* (L.) L.	Asteraceae	Herb	Ager cony	44
6	*Albizia lucidior* (Steud.) I.C.Nielsen	Leguminosae	Tree	Albi luci	28
7	*Albizia procera* (Roxb.) Benth.	Leguminosae	Tree	Albi proc	6
8	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	Tree	Alst scho	78
9	*Alternanthera philoxeroides* (Mart.) Griseb	Amaranthaceae	Herb	Alte phil	27
10	*Alternanthera sessilis* (L.) R.Br. ex DC	Amaranthaceae	Herb	Alte ses	31
11	*Amaranthus viridis* L.	Amaranthaceae	Herb	Amar viri	2
12	*Anisomeles indica* (L.) Kuntze	Labiatae	Herb	Anis indi	3
13	*Anogeissus latifolius* (Roxb. ex DC.) Bedd.	Combretaceae	Tree	Anog lati	1
14	*Anthocephalus chinensis* (Lam.)Walp	Rubiaceae	Tree	Anth chin	1
15	*Antidesma bunius* (L.) Spreng.	Euphorbiaceae	Tree	Anti buni	2
16	*Apluda mutica* L.	Gramineae	Shrub	Aplu muti	11
17	*Ariopsis peltata* Nimmo	Araceae	Herb	Ario pelt	8
18	*Artemisia indica* Willd.	Asteraceae	Shrub	Arte indi	4
19	*Artocarpus lakoocha* Roxb.	Moraceae	Tree	Arto lako	1
20	*Asparagus officinalis* L.	Liliaceae	Shrub	Aspa offi	2
21	*Bauhinia purpurea* L.	Leguminosae	Tree	Bauh purp	2
22	*Bombax ceiba* L.	Bombacaceae	Tree	Bomb ceib	1
23	*Brachiaria kurzii* (Hook. f.) A. Camus	Gramineae	Herb	Bras kurz	19
24	*Brassaiopsis glomerulata* (Blume) Regel	Araliaceae	Tree	Bras glom	2
25	*Breynia retusa* (Dennst.) Alston	Euphorbiaceae	Shrub	Brey retu	12
26	*Bulbophyllum* sp.	Orchidaceae	Orchid	Bulb spp	11
27	*Butea buteiformis* (Voigt) Mabb.	Leguminosae	Shrub	Bute bute	2
28	*Caesalpinia decapetala* (Roth) Alston	Leguminosae	Climber	Caes deca	14
29	*Calamus acanthospathus* Griff.	Arecaeae	Shrub	Cala acan	5
30	Callicarpa macrophylla Vahl	Verbenaceae	Shrub	Call macr	48
31	*Carex filicina* Nees.	Cyperaceae	Herb	Care fili	17
32	*Carex inanis* Kunth	Cyperaceae	Herb	Care inan	3
33	*Carex nivalis* Boot	Cyperaceae	Herb	Care niva	7

34	*Carex* sp.	Cyperaceae	Herb	Care spp	9
35	*Careya arborea* Roxb.	Lecythidaceace	Tree	Care arbo	7
36	*Casearia elliptica* Willd.	Flacourtiaceae	Shrub	Casa elli	27
37	*Cassia occidentalis* L.	Leguminosae	Shrub	Cass occi	1
38	*Cassia tora* L.	Leguminosae	Herb	Cass tora	25
39	*Centella asiatica* (L.) Urban	Umbelliferae	Herb	Cent asia	9
40	*Cestrum nocturnum* L.	Solanaceae	Shrub	Cest noct	6
41	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Asteraceae	Shrub	Chro odor	79
42	*Chrysopogon aciculatus* (Retz.) Trin	Gramineae	Herb	Chry acic	8
43	*Cissus repens* Lam.	Vitaceae	Climber	Ciss repe	29
44	*Citrullus colocynthis* Schrad.	Cucurbitaceae	Climber	Citr colo	33
45	*Cleistocalyx operculatus* (Roxb.) Merr. & L.M.Perry	Myrtaceae	Tree	Clei oper	77
46	*Clerodendrum viscosum* Vent.	Verbenaceae	Shrub	Cler visc	134
47	*Colebrookea oppositifolia* Sm.	Labiatae	Shrub	Cole oppo	16
48	*Colocasia esculenta* (L.)Schott.	Araceae	Herb	Colo escu	44
49	*Commelina benghalensis* L.	Commelinaceae	Herb	Comm beng	19
50	*Conyza canadensis* (L.) Crong.	Asteraceae	Herb	Cony cana	23
51	*Conyza leucantha* (D. Don) Ludlow & Raven	Asteraceae	Herb	Cony leuc	5
52	*Corchorus aestuans* L.	Tiliaceae	Herb	Corc aest	65
53	*Corchorus capsularis* L.	Tiliaceae	Herb	Corc caps	87
54	*Cordia dichotoma* Forster	Cordiaceace	Tree	Cord dich	1
55	*Costus speciosus* (Koenig.) Sm.	Zingiberacceae	Herb	Cost spec	84
56	*Curcuma domestica* Valeton.	Zingiberaceae	Herb	Curc dome	4
57	*Cyanotis vaga* (Lour.) J. A & J. H. Schult	Commelinaceae	Herb	Cyan vaga	58
58	*Cynodon dactlylon* (L.) Pers	Gramineae	Herb	Cyno dact	10
59	*Cyperus compressus* L.	Cyperaceae	Herb	Cype comp	35
60	*Cyperus niveus* Retz.	Cyperaceae	Herb	Cype nive	55
61	*Cyperus rotundus* L.	Cyperaceae	Herb	Cype rotu	42
62	*Dalbergia sissoo* DC.	Leguminosae	Tree	Dalb siss	11
63	*Derris acuminata* Benth.	Leguminosae	Tree	Derr elli	9
64	*Desmodium multiflorum* DC.	Leguminosae	Shrub	Desm mult	33
65	*Desmostachys bipinnata* (L.) Stapf	Gramineae	Herb	Desm bipi	10
66	*Digitaria ciliaris* (Retz.) Koeler	Gramineae	Herb	Digi cill	23
67	*Dillenia pentagyna* Roxb.	Dilleniaceae	Tree	Dill pent	88
68	*Dioscorea bulbifera* L.	Dioscoreaceae	Climber	Dios bulb	99
69	*Dioscorea deltoidea* Wall. ex Griseb.	Dioscoreaceae	Climber	Dios delt	42
70	*Dryopteris cochleata* (D.Don) C.Chr.	Aspidiaceae	Fern	Dryo coch	74

71	*Dysoxylum binectariferum* (Roxb.) Hook.f.ex Bedd.	Meliaceae	Tree	Dyso bine	5
72	*Echinochloa colona* (L.) Link	Gramineae	Herb	Echi cola	1
73	*Ehretia acuminata* R.Br.	Cordiaceae	Tree	Ehre acum	9
74	*Eleocharis retroflexa* (Poir.) Urb.	Cyperaceae	Herb	Eleo retr	2
75	*Elephantopus scaber* L.	Asteraceae	Herb	Elep scab	44
76	*Eleusine indica* (L) Gaertn	Gramineae	Herb	Eleu indi	3
77	*Eragrostis tenella* (L.) Beauvois ex Roem.& Sch	Gramineae	Herb	Erag tene	4
78	*Ficus hispida* L.f.	Moraceae	Tree	Ficu hisp	2
79	*Ficus racemosa* L.	Moraceae	Tree	Ficu race	1
80	*Ficus religiosa* L.	Moraceae	Tree	Ficu reli	2
81	*Fimbristylis dichotoma* (L.)Vahl.	Cyperaceae	Herb	Fimb dich	27
82	*Flemingia macrophylla* (Willdenow) Merrill	Leguminosae	Shrub	Flem macr	15
83	*Floscopa scandens* Lour.	Commelinaceae	Herb	Flos scan	20
84	*Fraxinus floribunda* Wall.	Oleaceae	Tree	Frax flor	7
85	*Garuga pinnata* Roxb.	Burseraceae	Tree	Garu pin	5
86	*Gmelina arborea* Roxb.	Verbenaceae	Tree	Gmel arbo	9
87	*Hedychium ellipticum* Buch.-Ham. ex Sm.	Zingiberaceae	Herb	Hedy elli	97
88	*Helminthostachys zeylanica* L.	Ophioglossaceae	Fern	Helm zeyl	43
89	*Holarrhena pubescens* Wall. ex G.Don	Apocynaceae	Tree	Hola pube	8
90	*Hypoxis aurea* Lour.	Hypoxidaceae	Herb	Hypo aure	44
91	*Hyptis suaveolens* (L.) Poit.	Labiatae	Herb	Hypt suav	11
92	*Imperata cylindrica* (L.) Raeusch.	Gramineae	Herb	Impe cylin	49
93	*Indigofera dosua* Buch.-Ham. ex D. Don	Leguminosae	Shrub	Indi dosu	3
94	*Lactuca sativa* L.	Asteraceae	Herb	Lact sati	3
95	*Lagerstroemia parviflora* Roxb.	Lythraceae	Tree	Lage prav	61
96	*Lantana camara L.*	Verbenaceae	Shrub	Lant cama	3
97	*Leea crispa* L.	Leeaceae	Shrub	leea cris	2
98	*Leea macrophylla* Roxb. Ex Hornem	Leeaceae	Shrub	Leea macr	82
99	*Leucas indica* (L.) R. Br. ex Vatke	Labiatae	Herb	lecu indi	2
100	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	Tree	Lits mono	112
101	*Lobelia chinensis* Lour.	Lobeliaceae	Herb	Lobe chine	40
102	*Ludwigia hyssopifolia* (G.Don)Exell	Onagraceae	Herb	Ludw hyss	2
103	*Lygodium japonicum* (Thunb.) Sw.	Schizaeaceae	Fern	Lygo japo	68
104	Maesa chisia *Buch.-Ham. ex D. Don*	Myrsinaceae	Tree	Maes chis	80
105	*Mallotus philippensis* (Lam.) Muell.	Euphorbiaceae	Tree	Mall phil	82
106	*Marsdenia roylei* Wight	Asclepiadaceae	Climber	Mars royl	18
107	*Mentha spicata* L.	Labiatae	Herb	Ment spic	1

108	*Mikania micrantha* Kunth.	Asteraceae	Climber	Mika micr	60
109	*Miliusa velutina* (Dunal.)Hook	Meliaceae	Tree	Mili velu	96
110	*Mitragyna pravifolia* (Roxb.)Korth.	Rubiaceae	Tree	Mitr prav	3
111	*Momordica cochinchinensis* (Lour.) Spreng.	Cucurbitaceae	Climber	Momo coch	4
112	*Murraya koenigii* (L.) Spreng.	Rutaceae	Tree	Murr koen	78
113	*Oberonia* sp.	Orchidaceae	Orchid	Ober spp	6
114	*Ophioglossum reticulatum* L.	Ophioglossaceae	Fern	Ophio reti	66
115	*Oplismenus compositus* (L.) P.Beauv	Gramineae	Herb	Opli comp	10
116	*Oxalis corniculata* L.	Oxalidaceae	Herb	Oxal corn	21
117	*Parochetus communis* D.Don	Leguminosae	Herb	Paro comm	8
118	*Parthenium hysterophorus* L.	Asteraceae	Herb	Part hyst	9
119	*Paspalum distichum* L.	Gramineae	Herb	Pasp dist	33
120	*Persicaria barbata* (L.) Hara	Polygonaceae	Herb	Pers barb	15
121	*Persicaria pubescens* (Blume) H. Hara	Polygonaceae	Herb	Pers pube	20
122	*Phoenix sylvestris* Roxb.	Palmae	Tree	Phoe sylv	33
123	*Phyllanthus amarus* Thonn.	Euphorbiaceae	Herb	Phyl amar	5
124	*Phyllanthus emblica* L.	Euphorbiaceae	Tree	Phyl embl	3
125	*Phyllanthus niruri* L.	Euphorbiaceae	Herb	Phyl niru	93
126	*Pilea symmeria* Wedd.	Urticaceae	Herb	Pile symm	3
127	*Piper logum* L.	Piperaceae	Climber	Pipe logu	15
128	*Pogostemon benghalensis* (Burm. f.) Kuntze	Labiatae	Shrub	Pogo beng	66
129	*Pouzolzia hirta* Blume ex Hassk	Urticaceae	Herb	Pouz hirt	50
130	*Premna integrifolia* L.	Verbenaceae	Tree	Prem inte	4
131	*Pteris aspericaulis* Wall.ex.J.Agardh	Pteridaceae	Fern	Pter aspe	15
132	*Rumex dentatus* L.	Polygonaceae	Herb	Rume dent	1
133	*Rumex vesicarius* L.	Polygonaceae	Herb	Rume vesi	41
134	*Saccharum procerum* Roxb.	Gramineae	Herb	Sacc proc	11
135	*Salvia coccinea* Buc'hoz ex Etl.	Labiatae	Shrub	Salv cocc	16
136	*Schleichera oleosa* (Lour) Oken.	Sapindaceae	Tree	Schl oleo	4
137	*Scutellaria discolor* Colebr.	Labiatae	Herb	Scut disc	33
138	*Semecarpus anacardium* L.f.	Anacardiaceae	Tree	Seme anac	2
139	*Setaria pallidefusca* Hubb.	Gramineae	Herb	Seta pall	15
140	*Shorea robusta* Gaertn.	Dipterocarpaceae	Tree	Shor robu	116
141	*Sida acuta* Burman Fil.	Malvaceae	Tree	Sida acut	17
142	*Sida rhombifolia* L.	Malvaceae	Shrub	sida rhom	18
143	*Smilax aspera* L.	Liliaceae	Climber	Smil aspe	5
144	*Solanum surattense* Burm.f.	Solanaceae	Shrub	Sola sura	11
145	*Spondias pinnata* (L.f.) Kurz.	Anacardiaceae	Tree	Spon pinn	16

146	*Stephania japonica* (Thunb.) Miers	Menispermaceae	Climber	Step japo	9
147	*Strobilanthes atropurpureus* Nees	Acanthaceae	Herb	Stro atro	18
148	*Syzygium cumini* (L.) Skeels	Myrtaceae	Tree	Syzy cumi	19
149	*Terminalia alata* Heyneex. Roth	Combretaceae	Tree	Term alat	41
150	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	Tree	Term bell	10
151	*Terminalia myriocarpa* Heurck. & Muell. Arg	Combretaceae	Tree	Term myri	2
152	*Themeda arundinacea* (Roxb.) A.Camus	Gramineae	Herb	Them arun	8
153	*Thespesia lampas* (Cav.) Dalz	Malvaceae	Tree	Thes lamp	12
154	*Trewia nudiflora* L.	Euphorbiaceae	Tree	Trew nudi	42
155	*Trichosanthes anguina* L.	Cucurbitaceae	Climber	Tric angu	10
156	*Typha angustifolia* L.	Typhaceae	Herb	Typh angu	1
157	*Vanda tessellata* sp.	Orchidaceae	orchid	Vand tess	28
158	*Ziziphus mauritiana Lam.*	Rhamnaceae	Tree	Zizi maur	3

APPENDIX II: Regression Table for Variables

S.N	Variable	Resid.df	Resid.dev	Deviance	R^2	F-value	Pr(>F)
1	Sppn ~ NMDS1	19	2204.2				
		18	20.01	2184.2	1.0	2038.2	< 2.2e-16 ***
2	Climb_rich~NMDS1	19	34.95				
		18	6.314	28.636	0.8	82.204	3.946e-08 ***
3	Fern_rich~NMDS1	19	17.75				
		18	3.7559	13.994	0.8	67.787	1.624e-07 ***
4	Herb_rich~NMDS1	19	1342.55				
		18	38.41	1304.1	1.0	638.58	1.643e-15 ***
5	Orchid_rich~NMDS1	19	19.8				
		18	13.471	6.3289	0.3	10.74	0.004187 **
6	Shrub_rich~NMDS1	19	159.75				
		18	8.229	151.52	0.9	334.8	4.448e-13 ***
7	Tree_rich~NMDS1	19	80.55				
		18	4.655	75.895	0.9	292.85	1.394e-12 **
8	Alt~NMDS1	19	5407.2				
		18	31.2	5376	1.0	3278.3	< 2.2e-16 ***
9	Sppn~NMDS2	19	2204.2				
		18	28.42	2175.8	1.0	1367	< 2.2e-16 ***
10	Climb_rich~NMDS2	19	34.95				
		18	6.333	28.617	0.8	81.913	4.051e-08 ***
11	Fern_rich~NMDS2	19	17.75				
		18	4.0383	13.712	0.8	63.097	2.711e-07 ***
12	Herb_rich~NMDS2	19	1342.55				
		18	36.35	1306.2	1.0	626.7	1.937e-15 ***
13	Orchid_rich~NMDS2	19	19.8				
		18	25.274	-5.4744	-0.3		
14	Shrub_rich~NMDS2	19	159.75				
		18	15.406	144.34	0.9	165.66	1.62e-10 ***
15	Tree_rich~NMDS2	19	80.55				
		18	4.518	76.032	0.9	301.33	1.094e-12 ***
16	Alt~NMDS2	19	5407.2				
		18	30.4	5376.8	1.0	3366.5	< 2.2e-16 ***

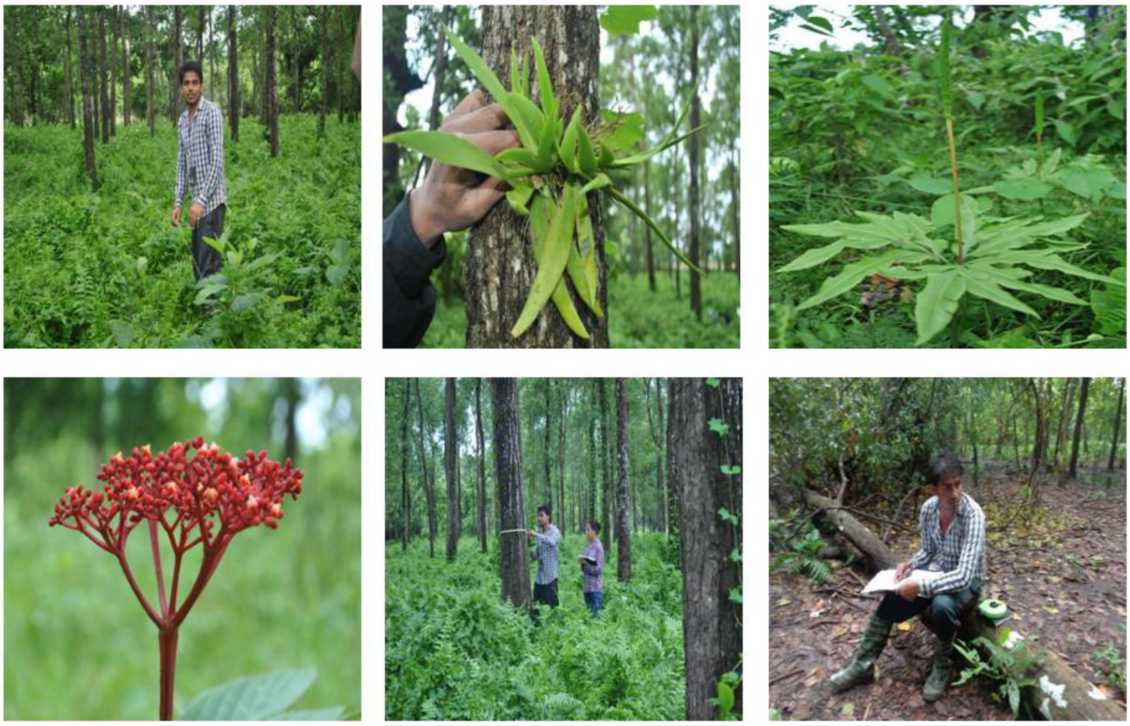
APPENDIX III : Different life forms response to succession.

S.N.	Life forms	Name	NMDS1	S.N.	Life forms	Name	NMDS1
1	Climber	Tric.angu	-0.9	80	Herb	Opli.comp	0.3
2	Climber	Momo.coch	-0.8	81	Herb	Rume.dent	0.3
3	Climber	Step.japo	-0.8	82	Herb	Care.fili	0.3
4	Climber	Mika.micr	0.0	83	Herb	Pile.symm	0.4
5	Climber	Mars.royl	0.0	84	Herb	Smil.aspe	0.6
6	Climber	Dios.bulb	0.1	85	orchid	Bulb.sp	-0.7
7	Climber	Dios.delt	0.1	86	Orchid	Ober.sp	-0.5
8	Climber	Citr.colo	0.1	87	orchid	Vand.tess	-0.3
9	Climber	Ciss.repe	0.1	88	Shrub	Lant.cama	-1.1
10	Climber	Bute.bute	0.2	89	Shrub	Leea.cris	-1.1
11	Climber	Pipe.logu	0.3	90	Shrub	Part.hyst	-0.9
12	Climber	Caes.deca	0.4	91	Shrub	Achy.aspe	-0.8
13	Fern	Helm.zeyl	-0.1	92	Shrub	Salv.cocc	-0.6
14	Fern	Dryo.coch	0.0	93	Shrub	Arte.indi	-0.5
15	Fern	Ophio.reti	0.1	94	Shrub	Sola.sura	-0.4
16	Fern	Adia.vane	0.2	95	Shrub	Cest.noct	-0.4
17	Fern	Lygo.japo	0.2	96	Shrub	Aplu.muti	-0.3
18	Fern	Pter.aspe	0.2	97	Shrub	Flem.macr	-0.2
19	Herb	Anis.indi	-0.9	98	Shrub	Hypt.suav	-0.2
20	Herb	Phyl.amar	-0.9	99	Shrub	Desm.mult	-0.1
21	Herb	Lact.sati	-0.8	100	Shrub	Cala.acan	-0.1
22	Herb	Cyno.dact	-0.7	101	Shrub	Call.macr	0.0
23	Herb	Lecu.indi	-0.6	102	Shrub	Chro.odor	0.0
24	Herb	Ment.spic	-0.6	103	Shrub	Sida.rhom	0.0
25	Herb	Typh.angu	-0.6	104	Shrub	Cole.oppo	0.0
26	Herb	Oxal.corn	-0.5	105	Shrub	Cler.visc	0.0
27	Herb	Casi.tora	-0.5	106	Shrub	Nyct.arbo	0.1
28	Herb	Pers.barb	-0.5	107	Shrub	Leea.macr	0.1
29	Herb	Care..inan	-0.4	108	Shrub	Casa.elli	0.1
30	Herb	Comm.beng	-0.4	109	Shrub	cass.occi	0.3
31	Herb	Ager.aden	-0.4	110	Shrub	Aspa.offi	0.3
32	Herb	Chry.acic	-0.4	111	Shrub	Brey.retu	0.4
33	Herb	Them.arun	-0.4	112	Tree	Term.myri	-1.1
34	Herb	cony.leuc	-0.3	113	Tree	Ficu.reli	-1.0
35	Herb	Stro.atro	-0.2	114	Tree	Aegl.marm	-1.0
36	Herb	Cony.cana	-0.2	115	Tree	Dalb.siss	-0.9
37	Herb	Pasp.dist	-0.2	116	Tree	Mitr.prav	-0.9
38	Herb	Alte.phil	-0.2	117	Tree	Ficu.glom	-0.8
39	Herb	Seta.pall	-0.2	118	Tree	Zizi.maur	-0.4
40	Herb	Erag.tene	-0.2	119	Tree	Garu.pinn	-0.4

41	Herb	Cent.asia	-0.2	120	Tree	Hola.pube	-0.3
42	Herb	Pouz.hirt	-0.2	121	Tree	Sida.acut	-0.2
43	Herb	Eleu.indi	-0.2	122	Tree	Derr.elli	-0.1
44	Herb	Pers.pube	-0.2	123	Tree	Arto.lako	-0.1
45	Herb	Cype.nive	-0.2	124	Tree	Cord.obli	0.0
46	Herb	Cype.rotu	-0.2	125	Tree	Term.bell	0.0
47	Herb	Sing.nut	-0.2	126	Tree	Dill.pent	0.0
48	Herb	Lobe.chine	-0.1	127	Tree	Clei.oper	0.0
49	Herb	Ager.cony	-0.1	128	Tree	Trew.nudi	0.0
50	Herb	Bac.mili	-0.1	129	Tree	Lage.prav	0.0
51	Herb	Cype.comp	-0.1	130	Tree	Schl.oleo	0.0
52	Herb	Colo.anti	-0.1	131	Tree	Dyso.bine	0.0
53	Herb	Comm.beng.1	-0.1	132	Tree	Lits.mono	0.0
54	Herb	Sacc.proc	-0.1	133	Tree	Maes.chis	0.0
55	Herb	Impe.cylin	-0.1	134	Tree	Murr.koen	0.0
56	Herb	Amar.viri	0.0	135	Tree	Shor.robu	0.0
57	Herb	Ario.pelt	0.0	136	Tree	Phoe.sylv	0.0
58	Herb	Echi.cola	0.0	137	Tree	Care.arbo	0.0
59	Herb	Hypo.aure	0.0	138	Tree	Syzy.cumi	0.1
60	Herb	Phyl.niru	0.0	139	Tree	Anog.lati	0.1
61	Herb	Rume.cris	0.0	140	Tree	Bomb.ceib	0.1
62	Herb	Cost.spec	0.0	141	Tree	Alst.scho	0.1
63	Herb	Desm.bipi	0.0	142	Tree	Mall.phil	0.1
64	Herb	Indi..dosu	0.0	143	Tree	Frax.flor	0.1
65	Herb	Corc.aest	0.0	144	Tree	Albi.proc	0.2
66	Herb	Corc.caps	0.0	145	Tree	Phyl.embl	0.2
67	Herb	Hedy.elli	0.0	146	Tree	Ehre.acum	0.2
68	Herb	Elep.scab	0.1	147	Tree	Term.alat	0.2
69	Herb	Flos.scan	0.1	148	Tree	Seme.anac	0.2
70	Herb	Digi.cill	0.1	149	Tree	Anti.buni	0.2
71	Herb	Alte.ses	0.1	150	Tree	Gmel.arbo	0.2
72	Herb	Care.niva	0.1	151	Tree	Mili.velu	0.3
73	Herb	Care.cari	0.1	152	Tree	Spon.pinn	0.3
74	Herb	Paro.comm	0.2	153	Tree	Albi.luci	0.3
75	Herb	Prem.inte	0.2	154	Tree	Anth.chin	0.3
76	Herb	Scut.disc	0.2	155	Tree	Thes.lamp	0.4
77	Herb	Curc.dome	0.2	156	Tree	Ficu.hisp	0.6
78	Herb	Fimb.dich	0.2	157	Tree	Bauh.purp	0.6
79	Herb	Ludw.hyss	0.3	158	Tree	Bras.glom	1.0

(+) value = Old succession species, (-) value= Early succession species, (0) value= Intermediate species

SOME PHOTO PLATES



From left to right: sampling plot, *Vanda* sp, *Helminthostachys zeylanica*, *Leea macrophylla*, Measuring DBH of Sissoo tree, Entering data

From left to right: Eating lunch during fieldwork, Entering data, near Budhi-Rapti river, Identifying plants with BCC experts and herbarium preparation, With wild-life technician, BCC family.