EFFECT OF DISTURBANCE ON PLANT SPECIES DIVERSITY, FOREST STRUCTURE AND REGENERATION IN COMMUNITY FORESTS OF DEUKHURI, DANG, NEPAL

A THESIS

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DECLARATION

I, Rita Khatri, hereby declare that the thesis work entitled **"Effect of Disturbance on Plant Species Diversity, Forest Structure and Regeneration in Community Forests of Deukhuri, Dang, Nepal"** is a genuine work done by me and has not been published elsewhere for the award of any degree. All the information cited in this piece of work is specifically acknowledged and credited to the respective authors or institutions as references.

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ACCRONYMS AND ABBREVIATION

AGB	Above Ground Biomass
Alt	Altitude
asl.	Above sea level
DBH	Diameter breast height
BGB	Below Ground Biomass
°C	Degree Celsius
CFUGs	Community forest user's groups
cm	Centimeter
DDC	District Development Committee
DF	Disturbed Forest
et al.	And others
GHGs	Greenhouse gases
GPS	Global Positioning System
ha.	Hectare
IVI	Important value index
K	Potassium
Kg/m^2	Kilogram per meter square
m	Meter
NTFPs	Non-timber forests products
p (rho)	Wood density
Sd	Seedlings
SOC	Soil organic matter
Sp	Saplings
Tr	Tree
Spp.	Species
t/ha	Tons per hector
UDF	Undisturbed forest

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ABSTRACT

Disturbance are the major drivers of forest ecosystem. Disturbance both natural and human disturbances affect forest characteristics and biodiversity of the local area. This study investigated the effect of disturbance in plant species diversity, forest structure and regeneration in Durga community forest (undisturbed) and Mahadewa community forest (disturbed) of Deukhuri, Dang Nepal. Disturbance was estimated by visual observation of the study area on the basis of different disturbance parameters. Altogether 60 plots were laid for the study. Each of 30 quadrats of 20m×20m for tree, 2 sub plots of 5m×5m for shrubs and 3 sub plots of 2m×2m for herbs within each tree plot were laid in disturbed and undisturbed forest. A total of 106 plant species under 44 families were recorded from study area. Among the recorded species, 69 plant species under 35 families were found in undisturbed forest and 81 plant species under 35 families were found in disturbed forest. Whereas, 44 species under 26 families were common to both. Fabaceae was the richest family in undisturbed forest while Poaceae dominated in disturbed forest. *Shorea robusta* was the dominant tree species in both forests with higher IVI value (i.e, 212.127 in undisturbed and 256.201 in disturbed). The grasses like *Cynodon dctylon Eragrostis* sp., *Cyperus rotundus, Imperata cylindrica* etc. dominated disturbed forest while *Hemidesmus indicus, Dioscorea alata, Cynodon dactylon* etc were found more in undisturbed forest. Some of the herb and shrub species were added up during rainy season. Shrub *Clerodendrum infortunatum* dominated both forest types. The overall plant biodiversity was higher in disturbed forest. The herb density (per hectare) was higher in disturbed forest while the tree and shrub density was higher in undisturbed forest during both (rainy and dry) season. The Diameter- density relation was reverse J shape i.e, with increase in diameter the number of trees decreases which show that trees are at intermediate stage of growth. Similarly, the height class distribution showed that in disturbed forest highest frequency was at 20-25m with very few young trees while in undisturbed forest there were more frequency at 15-20m height. The regeneration pattern in undisturbed forest was comparatively good as the number of seedlings were higher followed by number of saplings and trees. Whereas, in disturbed forest there were more trees than seedlings and saplings. *Shorea robusta* had the higher regeneration compared to other species in both forest.

Keywords: *Grazing, Biodiversity, Churia region, Shorea robusta, Chlerodendron infortunatum.*

CHAPTER 1: INTRODUCTION

1.1 Background

Disturbance either natural or anthropogenic are major drivers of forest ecosystem (Lorimer and White, 2003). Forest disturbances are events that change the structure and composition of the forest ecosystems, their functions, and resources availability in the ecosystems (White and Pickett, 1985). Disturbances, both natural and human disturbances affect forest characteristics and biodiversity of local area (Hubbell et al., 1999). These disturbances vary in frequency and intensity in changing ecosystem (White and Jentsch, 2001). Disturbances are ecosystem process that play important role in maintenance of ecosystem services and conservation of biodiversity (Siebert and Belsky, 2014). In general, there is very important role of disturbance in maintaining plant species diversity, changing vegetation structure and regeneration pattern of forest ecosystem (Sagar et.al, 2003). Forest ecosystem has three major attributes i.e., structure, composition and function and disturbances are the major ecological force that changes these attributes (Gogoi and Sahoo, 2018).

Generally, the changes in diversity, structure and regeneration of species are related to the characteristic of disturbance factor like intensity, frequency and scale of disturbance (Kennard et al., 2002). Most of the study highlighted a single disturbance factor, e.g., selective logging to explain structural attributes of forests (Sapkota et al., 2009). However, multiple factors (e.g., livestock grazing, browsing, fodder and fuel wood collection) have simultaneous role in altering ecosystem functioning. Similarly, it has also been argued that species richness and diversity are invariably affected by frequent and fluctuating disturbances of low-intensity e.g., grazing and browsing, firewood and fodder extraction suggesting the importance of combined effect of various low-intensity factors (Sagar et.al, 2003).

Biodiversity is essential for human survival and economic wellbeing (Zhu et al., 2007). Species diversity is a key determinant of ecosystem functioning like productivity, stability and nutrient dynamics (Gautam and Mandal, 2018). Diversity of forests in Terai is being reduced due to various disturbances. It also decreases the number of endemic, endangered and threatened species in an ecosystem. Forest degradation due to different disturbance factors results in loss of biodiversity and it also affects ecosystem function and livelihood of local people (Gautam and Mandal, 2018).

Disturbance can impact forest both positively and negatively by altering the environmental condition (Gautam et al, 2016). Disturbance has a positive role on diversity, as an intermediate level of disturbance increases forest diversity and also supports community co-existence (Sheil and Burslem, 2003). However, under extensive disturbance species diversity normally decline which leads to the loss of late successional species, whereas very low level disturbance leads to the removal of species adapted to colonize ecosystems immediately after disturbance (Sheil and Burslem 2003). Hubbell et al. (1999) argued that dispersal and recruitment limitations normally outweigh the role of disturbance.

The effect of disturbance on soil properties is less understood than above ground effects. Some researcher (Pandey and Singh, 1991; Sahani and Behera, 2001) found the negative impact of disturbance on clay content and soil organic carbon content. Forest cover opening due to disturbances result in erosion of soil and further removal of tree biomass lead to loss of soil nutrients and less carbon content in soil. With increase in trampling there is an increase in the bulk density and less water holding capacity (Liu et al., 2023).

Forest structure and regeneration processes have also been affected by human disturbances, especially through selective thinning and pruning of vegetation (Sapkota et al., 2009). The selective thinning and pruning of plant species have unseen effect on plant diversity as it eventually leads to single species dominance. Both high and low disturbance reduces the regeneration, but at intermediate disturbance, there is presence of more seedling and saplings (Kennard et al., 2002) due to availability of sun light and more space. Tree regeneration can be predicted by the structure of their populations and density (Khan et al., 1987). The presence of sufficient numbers of seedlings, saplings and young trees in a given population indicates successful regeneration (Khan et al., 1987). A sustained regeneration and growth of all species in the presence of older plants is required for the growth of any plant community (Taylor and Zisheng, 1988). Tree regeneration patterns in the forest gaps has been found to be dependent upon the history of the forest community, seed availability and the biology of the species (Hubbell and Froster, 1992). Forest regeneration is a natural mechanism of restoring forest vegetation and retaining lost bio diversity. The response of species to natural regeneration decrease with increase in disturbance (Gogoi and Sahoo 2018).

In Nepal approximately 40.36 % of the total land is covered by forest (DFRS, 2015). Human settlement in terai of Nepal have existed from thousands of years with large scale human intervenes over 100 years (Subedi, 2006).Tremendous pressure has been exerted on country's natural resources due to population expansion and increasing agroforestry (Zobel et al.,1995). In general, farmers use forest products as fodder, fuel wood, leaf litter and timber (Singh and Singh, 1997). Although, Churiya region has the highest forest disturbance, the disturbance due to tree cutting and lopping, forest encroachment and illegal timber harvesting is a major concern in terai forest (DFRS, 2015). Historically, almost 75% of the terai region in central and western Nepal was covered by forest area (Timilsina et. al, 2007). This cover is decreasing every year due to various disturbances factors. Deukhuri valley is one of the largest valley in South Asia and the patches of sal (*Shorea robusta*) forests in this area serves as home to many wild lives. However, these forests are disturbed by multiple disturbance factors. Therefore, this study intend to understand effect of disturbance in plant species diversity, forest structure and forest regeneration in Dang, Deukhuri, Nepal. This work will be seen as reference for planning, management and conservation of these forests.

1.2 Rationale of the study

There are large numbers of research works related to plant species diversity, forest structure and forest regeneration in various parts of Nepal. There are very few research works related to effect of disturbance on plant species diversity, forest structure and forest regeneration in mid-western region of Nepal. So, this study will help to fulfill this gap and will give the idea on effect of disturbances on plant species diversity, forest structure and forest regeneration status in mid-western region of Nepal. Thus, this study will establish the baseline information about effect of disturbance and will be helpful in planning, management and conservation strategies of disturbed and undisturbed forests at community, regional or national level.

1.3 Justification

Deukhuri valley of Dang is capital of Lumbini province and the second largest valley of Asia surrounded by Siwalik Hills and Mahabharat range. The forests in the valley acts as the biological corridor for animals and birds and also supports genetic pool exchange from Banke National Park and Bardiya National Park within Terai Arc Landscape (TAL) of Nepal and Suhelwa Wildlife Sanctuary of India. Similarly, these foothill forests of

Deukhuri valley are of great important because they are within Lamahi bottleneck area (TAL, 2015). However, the common natural and anthropogenic disturbances like burning, grazing, browsing, timber harvesting, fodder and fuel extraction etc. have widely been reported from forests of Dang, Deukhuri area. The forest encroachment by local people after the Rapti river flood and the migrated people from hilly region is very high in this area. Similarly, the local community people are highly dependent on forest products such as firewood collection for local wine production, collection of NTFPs like bamboo, thakal for basket making and medicinal purpose are often reported. However, it is not known whether the biodiversity of these forests increased or decreased due to disturbance. Therefore, present study analyze the plant species diversity, forest structure and forest regeneration in disturbed and undisturbed forests of Deukhuri, Dang Nepal.

1.4 Research Questions

i) What are the variations in species composition, forest structure and regeneration status of the forest that experience multiple disturbances in comparison to undisturbed one?

ii) Do tree biomass and soil parameters differ in disturbed and undisturbed sites?

1.5 Objectives

The main objective of the study was to understand the effect of disturbance on plant species diversity, structure and regeneration of forest in Deukhuri.

The study has following specific objectives;

- To determine the plant species diversity of disturbed and undisturbed areas
- To compare the plant community structure of disturbed and undisturbed forest areas.
- To compare regeneration pattern of tree species in disturbed and undisturbed forests.
- To compare the soil properties of disturbed and undisturbed sites.

1.6 Limitations

Canopy cover was estimated by the visual method, in lack of instrument and soil samples were collected during dry season only due to high laboratory cost.

CHAPTER 2: LITRATURE REVIEW

2.1 Plant Diversity and Disturbance

Disturbances is a factor that can change plant species diversity either by removing disturbance-sensitive species, or by adding new species in the area through opening up growing space and resources for use by colonizing species. Thus disturbance helps to maintain species richness by slowing or preventing competitive exclusion, and alter spatial heterogeneity in plant community (Huston, 1994). The intermediate disturbance hypothesis (IDH) (Connell, 1978; Huston, 1994) predicts that species diversity will be maximized at intermediate disturbance as it will provide space for the new species. The changes in species number, tree density, basal area and diversity are caused by both natural and anthropogenic disturbances (Rao *et al*., 1990). Natural disturbance like fire, flood and drought also acts as external factor that strongly affect the composition of plant communities (Crutzen and Goldammer, 1993, Danthu et al., 2003). Human disturbance like unsustainable development activities and encroachment in forest area have also caused loss of biodiversity (Regmi and Weber, 2000). The daily needs of people such as animal fodder, leaf litter for composting, fuel wood extraction, timer collection and grazing etc are the main reasons for the forest destruction (Bhuyan *et al.,* 2003*;* Uniyal *et al.,* 2010).

Species diversity is the key factor for the stability of ecosystem but the increasing disturbances affect the functioning of ecosystem of the forest. Disturbance either natural or human induced is an ecological force that affects both forest structure and functioning (Gogoi and Sahoo, 2018). Diversity of tropical forests is being reduced due to natural and anthropogenic disturbances. It also decreases the number of endemic, endangered and threatened species in an ecosystem. Biodiversity loss is major consequences of forest degradation as it affects ecosystem function and livelihood of local people (Gautam and Mandal 2018).

The common anthropogenic disturbances like burning, grazing, browsing, timber harvesting, fodder and fuel extraction etc have widely been reported from forests of Nepal and India (Pande 1999, Pandey and Shukla 2001, Sagar et al., 2003). Human disturbances, particularly from the overexploitation of biological resources, generally have negative impacts on species diversity at a global scale (Goudie, 2000). Many researchers have tested the impact of anthropogenic disturbances on plant species diversity; most of them

(Busssmann, 2004, Rahman et al., 2009, Shrestha et al., 2013) have agreed that there is positive role medium level disturbance on maintaining the heterogeneity of plant species. Although the relationship between disturbance and species richness has extensively been explained (Vetaas, 1997; Vandermeer et al., 2000; Molino and Sabatier, 2001; Sheil and Burslem, 2003), the studies that describe how disturbances influence stand structure, species composition and regeneration of tree species are very limited (Sapkota et al., 2009).

2.2 Effect of Disturbance on Forest Structure

Forest structures play many roles in ecosystem, for example large leaf area intercept radiation and precipitation, gaps in tree canopy allows trees, shrubs and herbs to regenerate and large live and dead trees provide specialized habitat for many species (Franklin et al., 1981). However due to various disturbances the forest structure and its function has been changed in recent years. Illegal timber cutting, fuel wood extraction harvesting and over-exploitation of forest resources may lead to species-specific changes in the population structure and can alter the structure and composition of the forests. Forest structure is both a product and driver of ecosystem processes and biodiversity. The tree mean canopy cover, basal area, tree density, tree height represent the forest structure (Kumar and Shahabuddin 2005).

The selective logging, thinning and pruning of plant species results in single species dominance, which eventually alter the forest structure (Baral and Katzensteiner 2009). The diameter and height distributions revealed that the low disturbed forest type comprised a mixture of very young to giant trees, while the medium and highly disturbed forest types contained only young trees (Rahman et al. 2009). Natural disturbance like fire strongly influenced density, basal area, and spatial structure of tree population (Taylor 2010). Tropical forests are amongst the highly disturbed forest ecosystems in the world which, are predominantly distributed over the developing countries (Gautam and Mandal 2018).

2.3 Effect of Disturbance Regeneration

Forest regeneration patterns following natural or anthropogenic disturbances are determined by interactions between the disturbance regime (i.e., intensity, frequency, scale) and the biology of species (i.e., life history, physiology, behavior) (Pickett and White, 1985). Regeneration and establishment of plants in the forest are regulated by various factors like drought, pest infestation or forest fire. Plants do have some resistance mechanism to fight against drought and pest to some extent and may help them to persist in nature. But the fire event is disastrous to plants as it burns leaves and kills stem tissues of seedlings and saplings. Besides this the heat generated during fire events increase the soil temperature and is sufficient to kill roots and seeds near the soil surface. Following disturbance shifts in species composition can arise from differences in species-specific modes of persistence through disturbances. Both high and low disturbance reduces the regeneration, but at intermediate disturbance, there is presence of more seedling and saplings may be due to availability of sun light and more space (Kennard et al., 2002). Natural regeneration is a central component of tropical forest ecosystem and is essential for preservation and maintenance of biodiversity (Rahman et al. 2009). Successful regeneration of a tree species can be predicted by the structure of their overall populations as well as sufficient numbers of seedlings, saplings, and adults (Saxena et al. 1984; Pala et al., 2013).

2.4 Effect of Disturbance on Tree biomass

The terrestrial ecosystem, especially forest ecosystem are natural carbon sinks as they can hold carbon in their biomass. The tropical forests, which store up about 46% of the world's terrestrial carbon pool and about 11.55% of the world's soil carbon pool, play a key role in the global carbon cycle and constant sink of atmospheric carbon (Brown and Lugo, 1982; Soepadmo, 1993). But due to fire events, deforestations, urbanization and commercial farming, tropical forests are now considered as the main contributors to terrestrial carbon cycling. Forest biomass is an important tool in accessing forest productivity and carbon sequestration (Gautam and Mandal, 2016). Different disturbance factors often lead to changes in vegetation composition, forest structure and forest biomass. Forest disturbances like fire and excessive harvest can lead to replacement of the whole tree stand of the forest (Pugh et al., 2019). Though researches on carbon cycling are going on but its exact quantification of Carbon emission contribution by tropical forests are is still challenging (Golley and Lieth, 1972; Chave et al., 2008). Studies of forest biomass often can relate to access the effect of disturbance on forest structure, regeneration and soil nutrient dynamics (Gautam and Mandal 2018).

2.5 Effect of Disturbance on Soil Properties

Both natural and human disturbance causes the substantial pressure on forest resource base. Livestock grazing followed by fuel wood/fodder extraction and annual low intensity fires opens up the forest area promoting the grass species used locally as fodder or household articles (Saha, 2002). Livestock grazing, fuel wood/fodder extraction and burning are recognized as ‘chronic disturbance’ (Singh, 1998) that can have substantial impacts on the entire forest ecosystem including impacts on vegetation (Tilman and Lehman, 2001), fauna (Bawa and Seidler, 1998) and soils (Bruijnzeel, 2004). Some researches on the impacts on soils confirms the negative impacts of disturbance on clay content, organic matter and soil moisture (Pandey and Singh, 1991; Sahani and Behera, 2001).The removal of biomass and increased erosion results in a net loss of nutrients and organic matter. Compaction due to trampling can increase the bulk density and reduce infiltration, causing an increase in surface runoff and increased soil aridity.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study area

Two community forests of Gadhawa rural municipality of Dang, Nepal which are adjacent to each other namely Durga community forest that is not disturbed visually and experience no fire (after here called undisturbed forest UDF) and Mahadewa community forest which is visually more disturbed and experience fire more often (after here called disturbed forest DF) were selected for study purpose. The study was carried out during February (Dry season) and during September (Rainy season). These forests were selected by visiting the forests prior to study and by interviewing the local people and community forests committees. These forests lie 10-12 km away from east-west highway. The elevation of these Community Forests ranges between 100 m to 500 m above the sea level (asl). Durga Community Forest covered an area about 418 hectares and Mahadewa Community forest covered an area of 256 hectares. This study falls in the Deukhuri valley of Dang District. The major community living here are Tharu, Magar, Bhraman and Chhetri. These forests are highly disturbed by human settlements. Grazing, firewood collection, timber cutting and forest fire are major disturbance which highly affect the biodiversity of these forests. Soil is clay and sandy loam in these areas.

Gadhawa Rural Municipality is located in Deukhuri valley of Dang district of Lumbini Province, Nepal. It is the capital of Lumbini Province located in the Inner Terai of mid-western Nepal. It lies from 195 meter to 885 meter above sea level. According to the preliminary report of population census 2078, Gadhawa Rural Municipality has 46275 population where male and female comprises 22650 (48.95%) and 23625 (51.05%) population respectively. This rural municipality has a 358.57 square km area and is divided into 8 wards. It is surrounded by Arghakhanchi and Kapilvastu districts from the east, Rajapur Rural Municipality from the west, Lamahi Municipality and Rapti Rural Municipality in the north, and India in the south direction (www.gadhawamun.gov.np). Map of the study area (Figure 1) was prepared using ArcGIS.

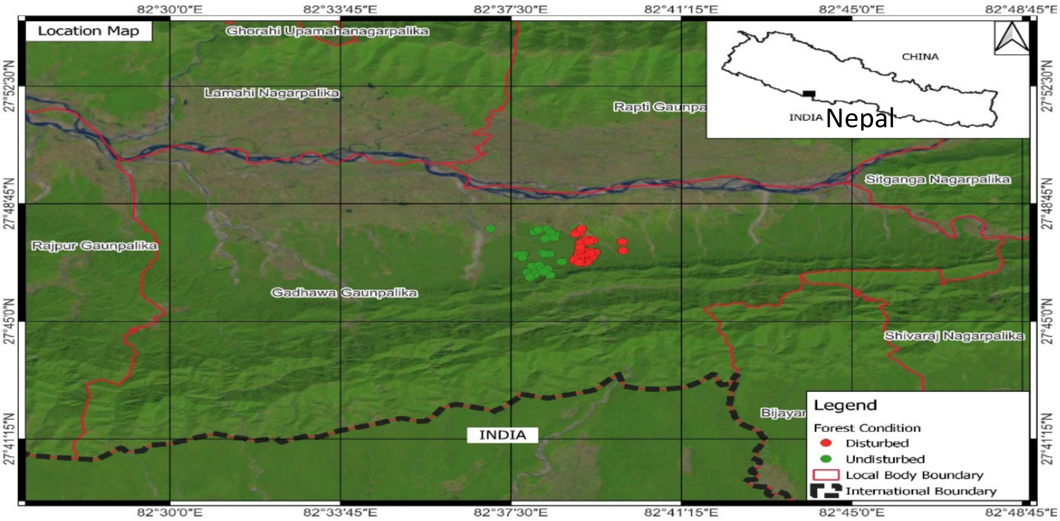

Figure 1 Map of study area

3.1.1 Climate and Hydrology

Dang is located at 180 m above sea level. The climate of the Dang district is distinguished into three types: lower tropical (below 300 m and occupy 18.1 %), upper tropical (300 to 1000 m and occupy 69.9 %) and subtropical zone (1000 to 2000 m and occupy 12.0 %). The summer season of this region is very hot and winter is very cold. In summer the temperature rises to 38°C and in winter the temperature falls below 4.8°C. The average annual temperature was 29°C and the average annual rainfall was 139 mm of Dang. As shown in the graph the average maximum temperature was 34.6 °C in May and the minimum temperature was 6.3°C in January. Maximum rainfall was 448.8 mm in July and minimum rainfall was 0.1mm in November (Figure 2).

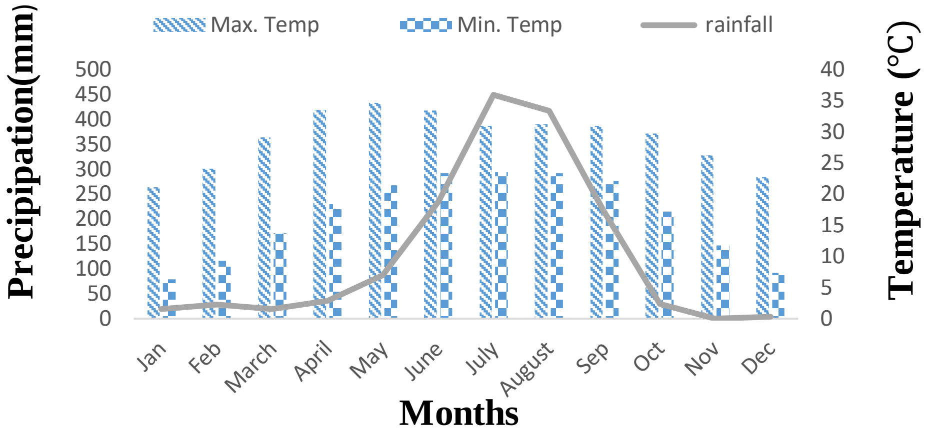

Figure 2: Variation in monthly average (minimum and maximum) temperature and precipitation of last 11 years (2010-2020) at Dang.

(Source: climatedata.org)

3.1.2 Vegetation

The major vegetation of this area is tropical dry deciduous forest. The sal forests along with patches of khayer - sisau mixed degraded forests are present here. Although the exact extent of remaining forest is unknown, these forests may still retain a significant portion of Churia hill forests. Sal is a major species which are found dense and deciduous in this forest. The other associated tree species are *Dalbergia sissoo, Acacia catechu, Terminalia tomentosa, Syzygium cumini* etc in a very small number. *Berberis* sp., *Clerodendrum infortunatum, Cycas pectinata* etc. are some understory shrub species. Degraded grasslands occur along the Rapti River. The grass species like *Cynodon dactylon, Cyperus rotundus, Saccharum spontaneum* etc are also found in study area.

3.2 Sampling Design

A stratified random sampling method was used for locating the sampling plots; the forest blocks designated by the CFUGs were considered strata. Square quadrat of 20 m × 20 m was defined with the help of clinometers (for maintaining aspect so that each corner of the plot is 90◦ to each other) and rope at each earlier randomly selected location. Each tree and shrub species enrooted inside the plots were recorded. Trees on the border were included if ≥ 50% of their basal area fell within the plot and excluded if < 50% of their basal area fell inside the plot. Altogether 30 quadrats of 20 m × 20 m were laid in undisturbed forest (Durga community forest) and of the same size in disturbed forest (i.e Mahadewa community forest) for trees. Within each quadrat of 20m x20m, 2 sub-plots of 5m ×5m were laid for shrubs and 3 plots of 2m × 2m were laid for herbs. For regeneration individual plants were categorized into seedling (ht < 1.3 m), saplings (dbh < 10 cm and ht > 1.3 m) and trees (dbh > 10 cm ht >3m). The sampling was done twice in the same year and in the same quadrate especially during dry season and rainy season. For which all the previously sampled quadrates were identified by GPS records as well as they were marked by painting color on tree trunk and ribbon. All the process was repeated, the quadrate for trees were exactly same but the quadrates laid for shrubs and herbs might not be the same.

3.2.1 Measurements

Tree height (H > 137 cm) and Diameter at breast height (DBH, 137 cm) of all individuals of tree species were measured. While measuring the DBH of trees of unusual shape (like trees with forked stems, trees with a bulged or curved stem at 137 cm, trees inclined in-ground etc.), a standard forestry practice of MacDicken (1997) was adopted. DBH tape was used for measuring the diameter and a clinometer was used to estimate the tree height. The geographical location (latitude, longitude, and elevation) of each quadrate (20m × 20m) was recorded using an altimeter from the center of the plot. Slope and aspect were measured by clinometers. The canopy cover for each plot was estimated by the visual estimation method from the center of the plot. The sample field data sheet used for geographical location has been presented in Appendix I.

3.2.2 Plant Identification

Most of the plants were identified at the time of quadrat study with the help of field guides (members of the community forest) and consulting with local experts. Unidentified species were collected tagged and pressed with the help of a newspaper and these unidentified specimens were identified with the help of experts, relevant books (Polunin and Stainton, 1984) and by comparing the herbarium of National Herbarium and Plant Laboratories (KATH), Godhawari, Kathmandu.

3.2.3 Scaling Disturbance

Based on visual observation of litter present on floor, trampling, tree lopping and felling, grazing and record of fire and flood occurrence within 5 year disturbance was estimated (Baral and Katzensteiner, 2009).

3.2.4 Soil sampling

For bulk density and moisture content, soil samples were collected below 15 cm to 30 cm from 4 corners and center of each quadrat using a steel ring of 15cm height with internal diameter of 2.2 cm. The soil samples were collected separately for bulk density and then packed in air-tight plastic bags wrapped in aluminum foil for laboratory analysis. Soil samples for Humus content, organic matter, nitrogen, phosphorus, potassium were collected from the quadrat then dried in shade for a week and finally packed in airtight plastic bags until laboratory analysis. All together 60 soil samples were collected from study area (i e, 30 in undisturbed forest and 30 in disturbed forest).

3.3 Laboratory work conduct

The bulk density is calculated after drying in a hot air oven at 105▫C for 24 hours and by taking the final weight of the soil. Soil pH was determined by calibrating the pH meter with buffer solutions of known pH (pH 4 and 7). Humus content of soil was calculated using crucible method. The texture of soil was determined by sieving the soil in different size of sieve. Organic matter was calculated by Walkey-Black's rapid titration method. Water holding capacity (WHC) was determined according to funnel method. The water holding capacity, organic matter, humus content, moisture content and bulk density were examined using book by Zobel et. al. (1987) in the lab of Amrit Science Campus, Botany Department. While soil nitrogen, phosphorus and potassium were examined in the lab of Central Department of Environmental Science, Kirtipur. Total nitrogen was estimated by micro-kjeldahl method (Jackson, 1958). Total phosphorus was determined calorimetrically by ammonium molybdate-stannous chloride blue color method after digesting the soil in triacid mixture of HClO4, HNO3 and H2SO4 in the ratio of 1:5:1 (Jackson, 1958). Potassium was estimated by atomic absorption spectrophotometer.

3.4 Statistical Analysis

Field data were entered into the excel 2013, followed by mathematical calculations and further statistical analysis was carried out following the standard formula from literatures as described below. Final graphical presentation were prepared in same worksheet as possible. The correlation between soil parameters and plant diversity was carried out for both UDF and DF using IBM SPSS Statistics 25.

3.4.1 Vegetation parameters

3.4.1.1 Importance Value Index

For the vegetation analysis, different parameters such as density, frequency, relative density, relative frequency, importance value index (IVI), and diversity index were calculated for the species. Vegetation analyses were carried out using Zobel *et al*., (1987).

$$\text{Density}=\frac{\text{Total no. of species occurred}}{\text{Total no. quadrat studied}}\times\frac{1}{\text{area of quadrat}}$$

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

$$\text{Frequency}=\frac{\text{No. of quadrat in which species occurred}}{\text{Total no. of quadrat studied}}\times 100\%$$

$$\text{Relative frequency}=\frac{\text{Frequency of individual species}}{\text{Total frequency of all species}}\times 100\%$$

$$\text{Average coverage}=\frac{\text{Total coverage of species}}{\text{Total no. of quadrat}\times\text{Area of quadrat}}\times 100\%$$

$$\text{Relative coverage}=\frac{\text{Coverage of individual species}}{\text{total coverage of all species}}\times 100\%$$

The important value index is a measure of how dominant a species is in a given forest area. In this research work, it was calculated by the following formula.

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

(Where, RD=Relative density; RF=Relative frequency; RC=Relative coverage)

3.4.1.2 Diversity Indices

A plant diversity index is defined as the number of plants and abundance of each plant that lives in a particular location. The plant species diversity was calculated based on the Shannon diversity index and Simpson diversity index. Shannon diversity index was calculated using the general formula.

$H = -\sum pi \times \ln pi$ (Shannon and Weiner 1963)

Where, H = Shannon's diversity index, Pi = Species proportion, Ln = natural logarithm

The Simpson's diversity index was calculated using the following formula;

Ds = 1-D (Ds value ranges between 0 and 1) Where, D = Simpson's index

Simpson's index (D) = $\frac{\Sigma n(n-1)}{N(N-1)}$ (Simpson, E.H., 1949)

Where N = total no. of individual species (all species)

n = no. of individuals of a particular species

3.4.1.3 Forest Structure and Regeneration

Forest structure is the physical geography of the forest. It refers to vertical arrangement of canopy layers and plants of different life forms. To estimate the forest structure, the DBH size class distribution and height class distribution of trees were determined.

To estimate the regeneration status of the forest, the density of seedling, sapling, and tree of each species were determined separately following the method described by Zobel *et al.*, (1987). The density was estimated by the following equation;

$$\text{Density (stem/ha)} = \frac{\text{Total no.of individuals in each life form}}{\text{Total number of plots studied} \times \text{size of plot} (m^2)} \times 10000$$

Density of individual species was calculated by the following equation;

$$\text{Density(stem/ha)} = \frac{\text{Total no. of individual of each species in each life form}}{\text{total number of plots studied} \times \text{size of plot} (m^2)} \times 10000$$

Total counts of plants were obtained by summation of the number of plants from all sampling plots.

3.4.1.4 Estimation of tree biomass

The algometric equation (model) developed by Chave *et al*., (2005) was used for estimating the above and below ground tree biomass.

ABG = $0.0509 \times \rho D^2 H$……for moist forest stand

Where, AGB = above ground biomass (kg) Where, ρ = wood density (g/cm^3), H = height of tree (m) and D = diameter of tree at breast height (cm).

3.4.1.5 Wood density

It was measured by the wood density index given by Reyes et al (1992). For the name of species and wood density (APPENDIX VI).

CHAPTER 4: RESULTS

4.1 Vegetation

A total of 106 plant species under 45 families were recorded from study area (APPENDIX II). Among the recorded species, 69 plant species under 35 families were found in undisturbed forest and 81 plant species under 35 families were found in disturbed forest. Whereas, 44 species under 26 families were common to both. Some of the common species were *Shorea robusta*, *Cassia fistula*, *Clerodendrum infortunatum*, *Cycas pectinata*, *Cynodon dactylon*, *Cyperus rotundus* etc. The richest family was Fabaceae with 8 plant species followed by Poaceae (7 plant species) and Asteraceae (6 plant species) in undisturbed forest. While in disturbed forest, the richest family was Poaceae with 18 plant species followed by Asteraceae with 12 plant species and Fabaceae with 8 plant species (figure 2). Only 62 plant species under 30 families and 52 species under 29 families were recorded from disturbed and undisturbed forest respectively during dry season. However, some species were added during rainy season and 72 plant species under 31 families were recorded from disturbed forest and 63 plant species under 32 families were recorded from undisturbed forest (figure 3).

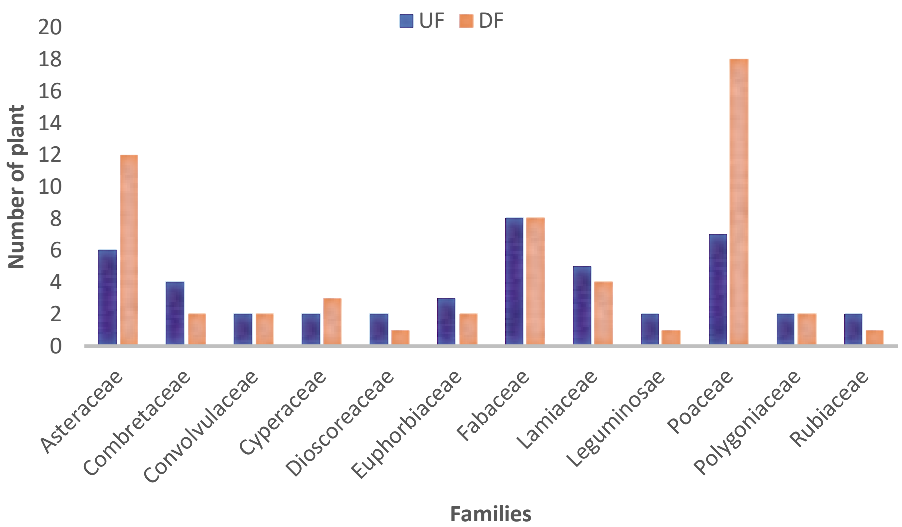

Figure 3: Major families present in disturbed and undisturbed forest

In this study, 17 tree species from undisturbed forest and 9 tree species from disturbed forest were recorded during both rainy and dry season. In undisturbed forest, 7 shrub species and 39 herb species were found during rainy season. While in disturbed forest 13 shrub species and 50 herb species were recorded at the same time. At dry season, there were

6 shrub species and 30 herb species in undisturbed forest where as in disturbed forest there were 9 shrub species and 44 herb species (Figure 4). The number of tree species was higher in undisturbed forest while the number of understory species (shrub and herb species) was higher in disturbed forest during both season.

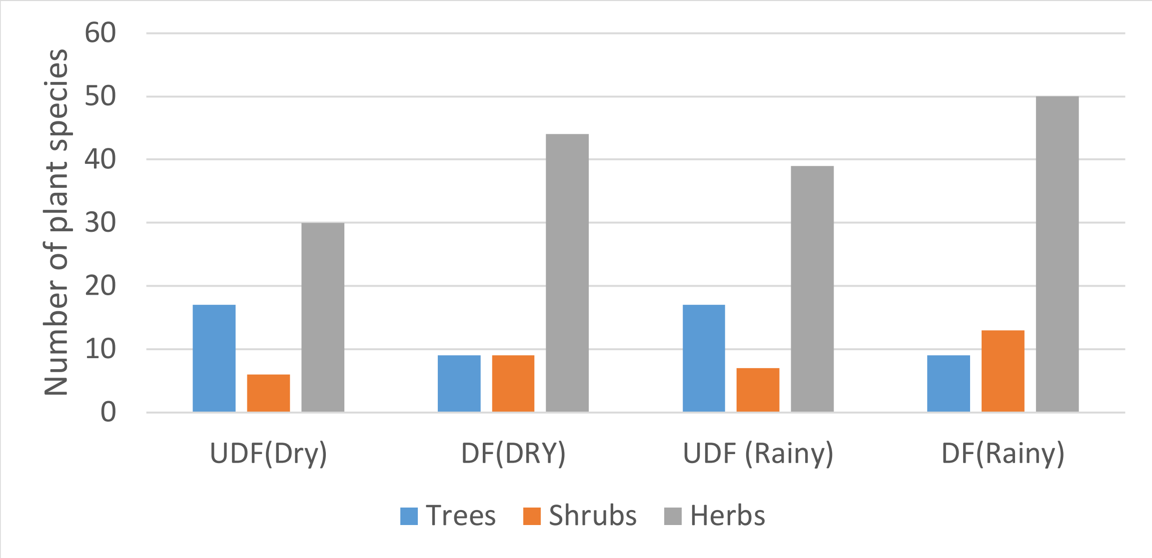

Figure 4: Total number of plant species on the basis of life form.

Tree species like *Aegle marmelos, Largestroemia parviflora* and *Syzygium cumini* were only found in disturbed forest while tree species like *Acacia catechu, Cassia fistula, Madhuca longifolia* and *Shorea robusta* were common to both disturbed and undisturbed forest. The shrub species like *Annona squamosa, Berberis aristata, Clerodendrum infortunatum, Colebrookea oppositifolia* and *Cycas pectinata* were common to undisturbed and disturbed forest during both season. Some of the herb species like *Ageratum conyzoides, Ageratum haustoniaum, Conyza* sp., *Parthenium* sp., *Oxalis* sp., *Saccharum spontaneum* and *Setaria viridis* etc were found only in disturbed forest. Similarly, herb species like *Adiantum* sp., *Asplenium* sp., *Dioscorea deltoidea, Drymaria cordata* and *Eclipta prostrata* etc were found only in undisturbed forest.

4.2 Important Value Index (IVI)

During rainy season, in undisturbed forest and disturbed forest altogether, 39 and 50 herbs species were recoded respectively. Among them *Hemidesmus indicus* had the highest IVI (29.551) and *Hyparrhenia hirta* had the lowest IVI (1.135) in undisturbed forest. Where as in disturbed forest, the highest IVI was of *Eragrostis* sp. (24.634) and lowest was *Achyranthes aspera* (0.97). During dry season, 30 herb species were listed in undisturbed forest and 44 herb species were recorded from disturbed forest. In undisturbed forest, *Sida* sp. had the highest IVI (24.246). In disturbed forest, *Oxalis* sp. had the highest IVI and *Adiantum* sp. had the lowest IVI (APPENDIX III).

During rainy season, in undisturbed and disturbed forest, 7 and 13 shrub species were found respectively. *Clerodendrum infortunatum* had the highest IVI in both forest. However *Zizyphus jujuba* had the lowest IVI in undisturbed forest while *Jusminum* sp. had lowest IVI in disturbed forest. During dry season, 6 and 9 shrub species were recorded from undisturbed and disturbed forest respectively. *Clerodendrum infortunatum* had the highest IVI in both forest but *Tinospora cordifolia* and *Urena lobata* had the lowest IVI in undisturbed and disturbed forest respectively (Table 1).

Table 1: IVI of shurb species present in disturbed and undisturbed forest during rainy and dry season.

		IVI (Rainy Season)		IVI (Dry Season)	
S.N	**Name of Shrubs**	**UDF**	**DF**	**UDF**	**DF**
1	*Annona squamosa*	2.96273	16.4908	11.9267	13.2356
2	*Bauhinia* sp.	6.06416			
3	*Berberis aristata*	2.75382	43.3597	6.44289	50.4267
4	*Carissa spinarum*		10.1143		
5	*Clerodendrum infortunatum*	228.868	83.7412	204.126	78.1428
6	*Colebrookea oppositifolia*	4.0752	63.8575	16.579	67.5263
7	*Cycas pectinata*	52.6617	15.1036	57.0871	28.0014
8	*Fraxinus* sp.		7.99158		28.5378
9	*Jatropa curcus*		5.30943		
10	*Jasminum*sp.		4.77055		
11	*Piper longum*		11.3887		
12	*Senna accidentalis*		10.2888		8.91051
13	*Tinospora cordiflora*			3.83837	
14	*Urena lobata*		11.2347		7.28598
15	*Zizyphus jujuba*	2.61454	16.3491		17.9329

As the tree species were same for dry and rainy season, there were recorded 17 and 9 tree species from undisturbed and disturbed forest (APPENDIX IV). *Shorea robusta* had the highest IVI in both forests (i.e, 212.127 in undisturbed and 256.201 in disturbed). Whereas, *Terminalia bellirica* and *Terminalia tomentosa* had the lowest IVI in undisturbed forest and *Aegle marmelos* has the lowest IVI in disturbed forest (Figure 5).

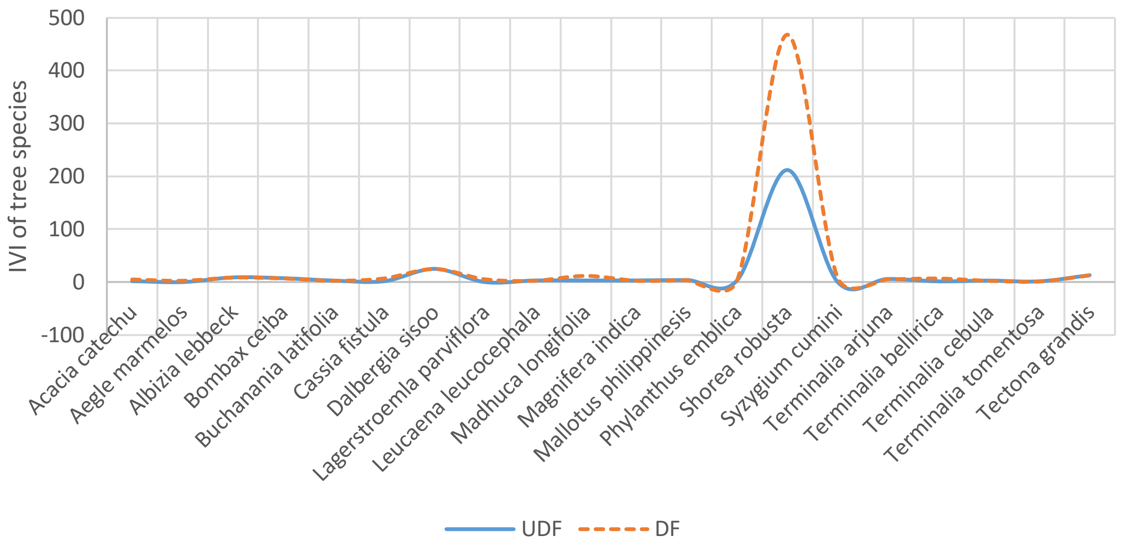

Figure 5: IVI of tree species in disturbed and undisturbed forest.

4.3 Diversity Indices

During rainy season, the Shannon's diversity index (H) value of tree and herb was found higher in undisturbed forest while the Shannon's diversity index value of shrub was higher in disturbed forest. Whereas, the Simpson's diversity index (D) value of herb, shrub and tree was found higher in disturbed forest. During dry season, the Shannon's diversity index value of tree was higher in undisturbed forest while the Shannon's diversity index value of herb and shrub was higher in disturbed forest. Similarly, the Simpson's diversity index value of tree was higher in disturbed forest and the Simpson's diversity index value of herb and shrub was higher in undisturbed forest (Table 2).

Table 2: Shannon's diversity index (H) and Simpson's diversity index (D) for herbs, shrubs and trees in disturbed and undisturbed forests during dry and rainy season.

Diversity Index	Rainy Season		Dry Season		Life Form
	UDF	DF	UDF	DF	
Shannon's diversity index (H)	0.621	0.1521	0.621	0.1521	Tree
	0.344	1.670	0.563	1.631	Shrub
	3.213	3.132	3.079	3.311	Herb
Simpson's diversity index (D)	0.776	0.959	0.776	0.959	Tree
	0.001	0.312	0.741	0.275	Shrub
	0.051	0.066	0.051	0.048	Herb

4.4 Forest Structure

The herb density was higher in disturbed forest while the tree and shrub density was higher in undisturbed forest during both (rainy and dry) season. The herb density of undisturbed forest was higher than tree and shrub density during rainy season. However, the tree density was higher than shrub and herb density in undisturbed forest during dry season. Total Number of plants present in disturbed and undisturbed forest (Figure 6).

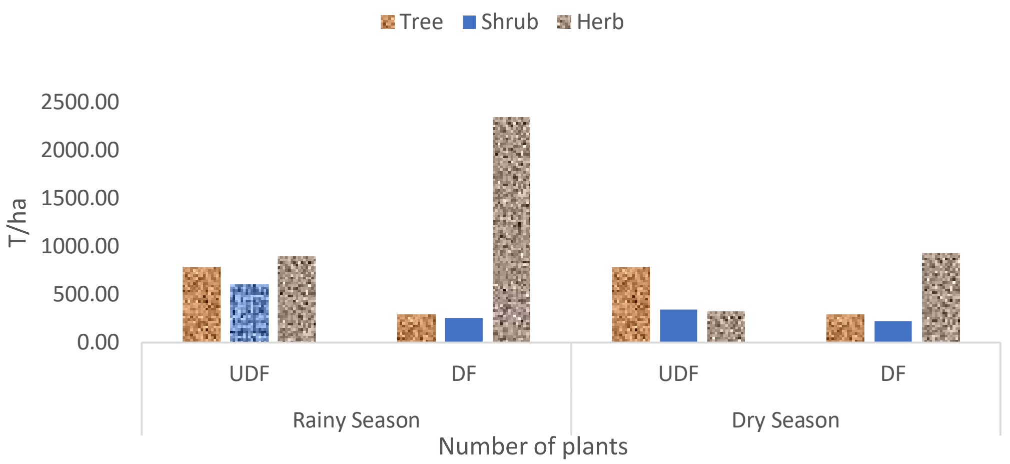

Figure 6: Total plant density present in disturbed and undisturbed forests

In undisturbed forest, the tree density was highest in 10-20 cm DBH class followed by 20-30 cm class (Figure 7).

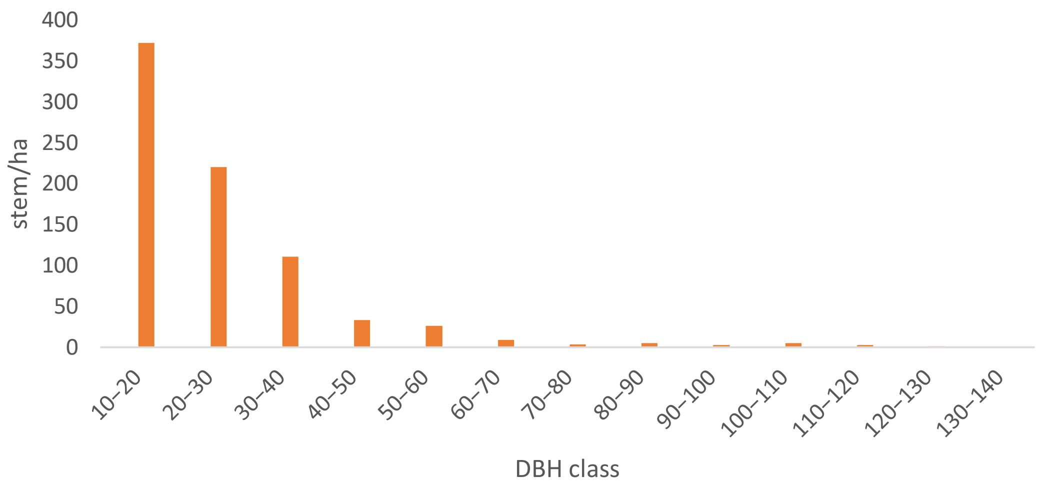

Figure 7: Density- Diameter relationship of trees (≥10cm) in undistrubed forest.

In disturbed forest the tree density was highest in 20-30 cm class followed by 30-40 cm (Figure 8).

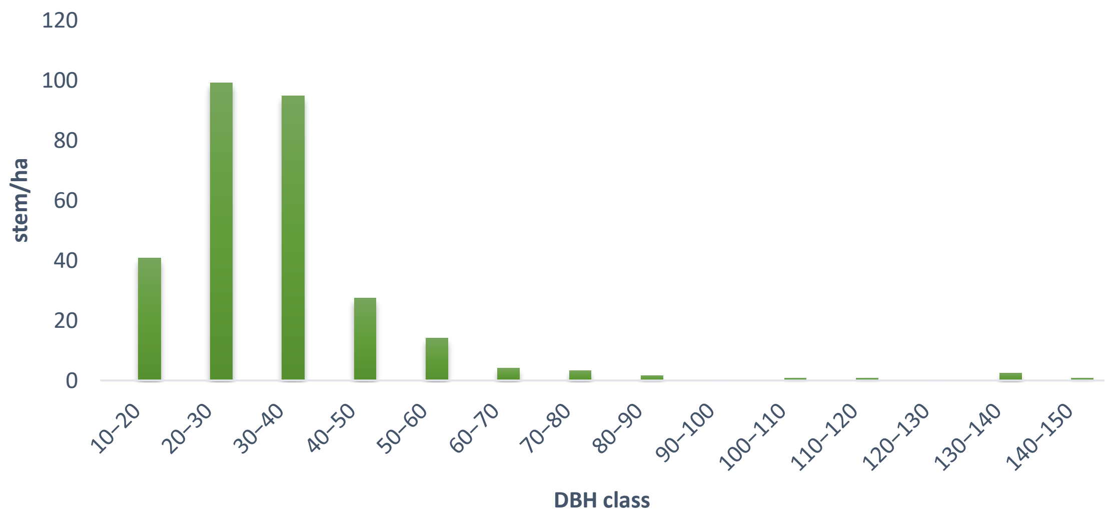

Figure 8: Density- Diameter relationship of trees (≥10cm) in distrubed forest.

The tree height class distribution showed that the highest tree density was found in 15-20 m class followed by 20-25m class and 10-15m class in undisturbed forest. Where as in disturbed forest, tree density was highest in 20-25m class followed by 15-20m class and 10-15m class. There was very low tree density in 30-35m class in both forest (Figure 9).

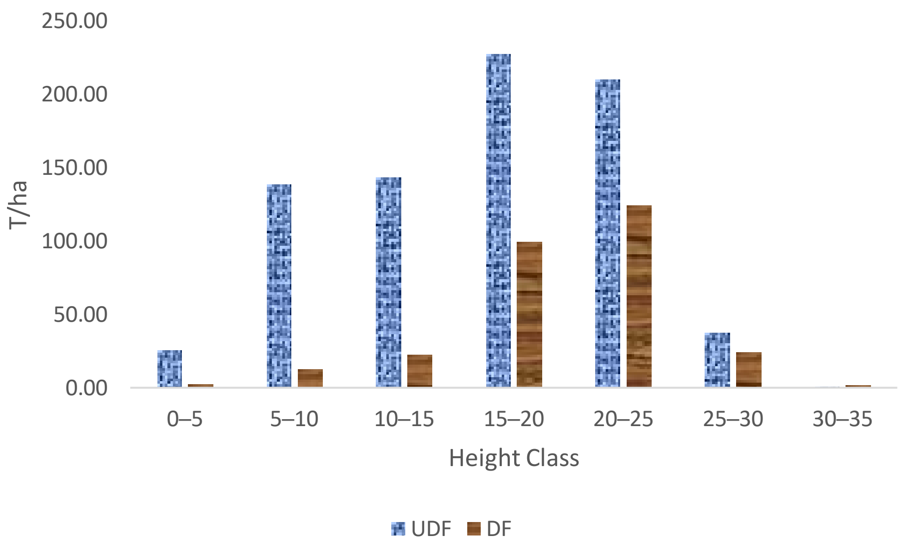

Figure 9: Height class distribution of trees (≥10cm) in disturbed and undisturbed forests.

4.5 Regeneration

In undisturbed forest the total density of seedlings was highest following sapling density and tree density. Whereas, in disturbed forest tree density was highest followed by sapling and seedling density. There was good regeneration in undisturbed forest as there was more seedlings followed by saplings and trees while in disturbed forest, the pattern was just opposite showing poor regeneration (Figure 10).

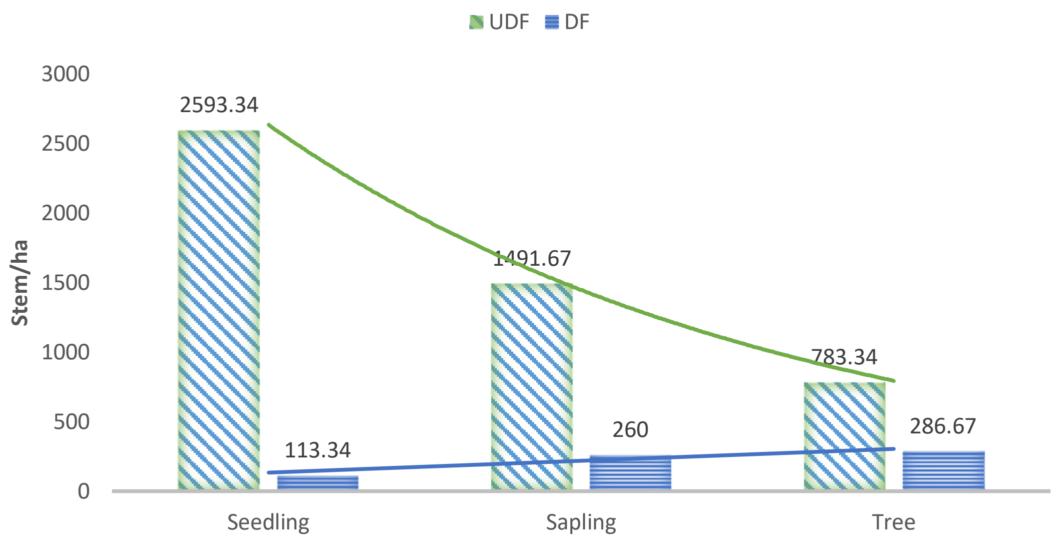

Figure 10: Life form diagram to show the regeneration status of all species in disturbed and undisturbed forests.

The total density of seedlings, saplings and trees of all species in undisturbed forest were 2593.34, 1491.67 and 783.34 individuals/hectare respectively whereas in disturbed forest seedlings, saplings, and trees were found to be 113.34, 260 and 286.67 individuals/hectare, respectively. The density of seedlings, saplings, and trees of *Shorea robusta, Leucaena leucocephala* and *Dalbergia sissoo*were higher in undisturbed forest while in disturbed forest only *Shorea robusta* and *Cassia fistula* had seedlings, saplings and trees density. The saplings density of *Mallotus philippensis* was higher than others in disturbed forest (Table 3).

Table 3: Species wise total regeneration status in Disturbed and Undisturbed forests.

S.N	Name of plants	UDF			DF		
		SD	SP	Trees	SD	SP	Trees
1	*Acacia catechu*	40	-	3	-	-	2
2	*Aegle marmelos*	-	-	-	-	-	1
3	*Albizia lebbeck*	120	12	13	-	-	-
4	*Bombax ceiba*	8	24	6	-	-	-
5	*Buchanania latifolia*	-	-	2	-	-	-
6	*Cassia fistula*	-	-	2	32	52	2
7	*Dalbergia sissoo*	244	244	44	-	-	-
8	*Largestroemia parviflora*	-	-	-	-	-	2
9	*Leucaena leucocephala*	624	72	3	-	-	-
10	*Madhuca longifolia*	-	-	3	4	-	4
11	*Magnifera indica*	-	-	3	-	-	-
12	*Mallotus philippensis*	269	332	7	-	140	-

13	*Phyllanthus emblica*	-	-	1	-	-	-
14	*Shorea robusta*	1568	956	828	100	112	326
15	*Syzygium cumini*	-	-	-	-	4	3
16	*Terminalia arjuna*	12	8	5	-	-	-
17	*Terminalia bellirica*	-	-	2	-	4	2
18	*Terminalia chebula*	-	-	1	-	-	-
19	*Terminalia tomentosa*	-	-	1	-	-	2
20	*Tectona grandis*	227	142	16	-	-	
	Total	3112	1790	940	136	312	344

(Where, SD-seedlings and SP-saplings.)

4.6 Tree Biomass

The total tree biomass was comparatively higher in undisturbed forest than disturbed forest. The distribution of tree biomass shows that plot 2 had maximum tree biomass in both forests while 7 had the lowest tree biomass. The trend of tree biomass went upward after plot 7 for undisturbed forest while plot 9 for disturbed forest. The above ground tree biomass was 1351.75 t/ha in plot 2 of undisturbed forest while it was 912.63 t/ha for disturbed forest (Figure 11).

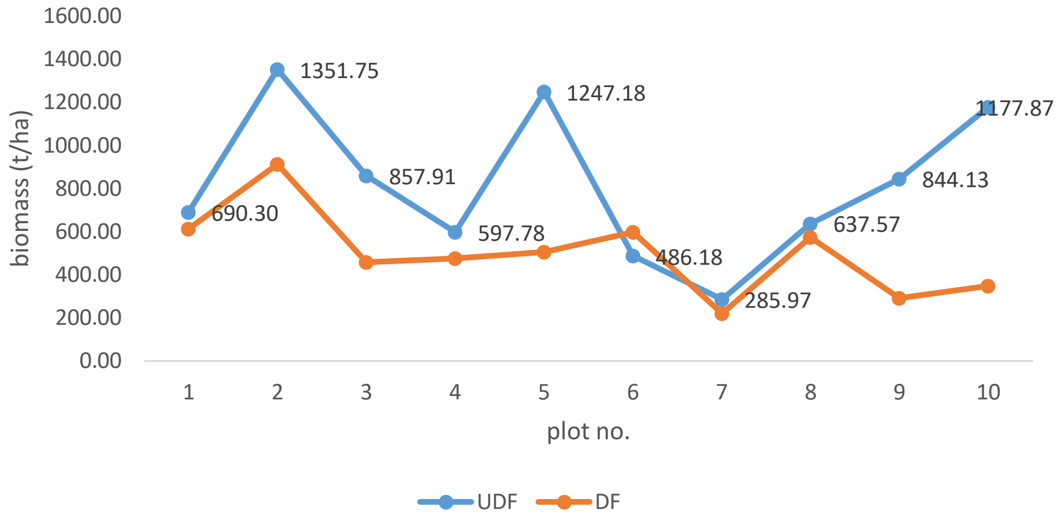

Figure 11 Plot wise distribution of tree biomass along disturbed and undisturbed forests

Both above ground biomass and below ground biomass of undisturbed forest were almost doubled to the AGB and BGB of disturbed forest. AGB for undisturbed forest was 682.26

t/ha for undisturbed forest while it was 416.66 t/ha for disturbed forest (figure 12).

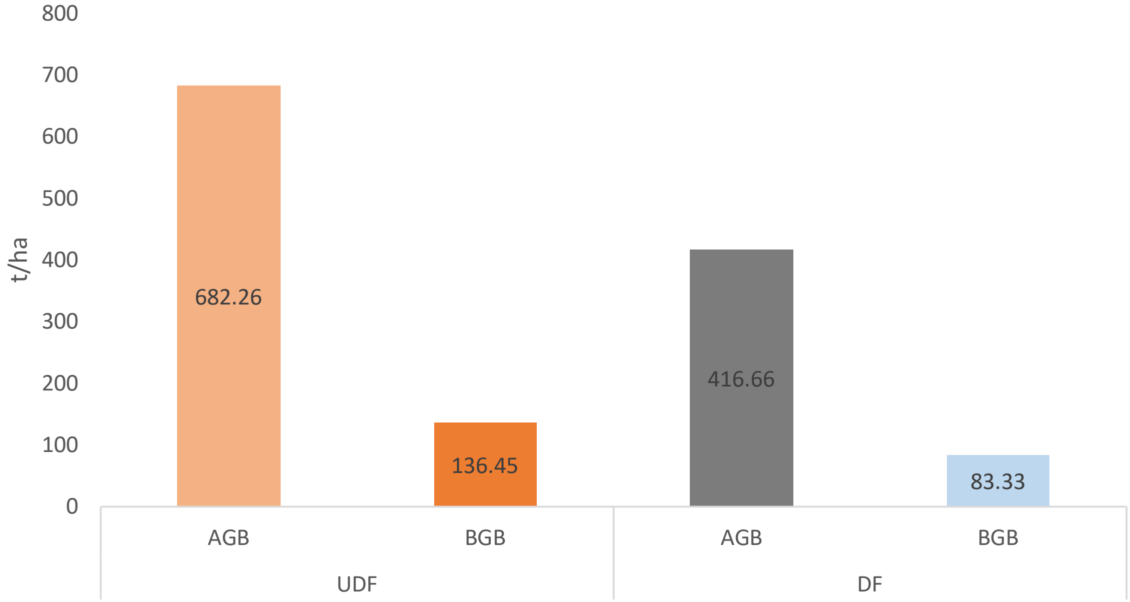

Figure 12: Above and below ground tree biomass in disturbed and undisturbed forest.

The tree species *Shorea robusta* had the highest tree biomass in both forest while *Terminalia bellirica* had the lowest tree biomass in undisturbed forest. Whereas, it was Aegle marmelos in disturbed forest (Table 4).

Table 4: Species wise total tree biomass in disturbed and undisturbed forest.

S.N	Name of Tree	Total Biomass (t/ha)	
		UDF	DF
1	*Acacia catechu*	2.552	3.606
2	*Aegle marmelos*		1.109
3	*Albizia lebbeck*	34.020	
4	*Bombax ceiba*	29.269	
5	*Buchanania latifolia*	21.641	
6	*Cassia fistula*	32.226	20.328
7	*Dalbergia sissoo*	44.671	
8	*Largestroemia perviflora*		7.221
9	*Leucaena leucocephala*	30.693	
1	*Madhuca longifolia*	36.906	57.251
11	*Mallotus philippensis*	0.457	
12	*Mangifera indica*	2.763	
13	*Phyllanthus emblica*	0.445	
14	*Shorea robusta*	595.190	477.390
15	*Syzizium cumini*		5.188
16	*Tectona grandis*	35.738	
17	*Terminalia arjuna*	10.240	
18	*Terminalia bellirica*	0.212	41.461
19	*Terminalia chebula*	0.736	
20	*Terminalia tomentosa*	29.421	14.967

4.7 Soil properties

Table 5: Soil parameters of disturbed and undisturbed forest.

Soil Parameters	UDF	DF
Sand%	72.257	76.076
Silt%	15.799	17.132
Clay%	11.229	6.616
pH value	6.075	6.195
Humus content	5.032	6.013
W.H.C	49.280	39.200
Soil Moisture	11.498	9.975
Bulk Density	1.314	1.415
Organic matter %	1.275	1.473
N%	0.294	0.290
P Kg/h	52.278	41.654
K Kg/h	450.779	379.008

In both forests, soil was sandy and slightly acidic. Soil physical parameters like water holding capacity and soil moisture content were higher in undisturbed forest while humus content and bulk density were higher in disturbed forest. Similarly, soil chemical properties like nitrogen, phosphorus and potassium content were higher in undisturbed whereas organic matter (1.473) was higher in disturbed forest (table 5).

4.8 Correlation between soil parameters and plant diversity

There was significant positive correlation between Potassium and Nitrogen, Potassium and organic matter, pH and organic matter, clay and species richness, biomass and species richness, and significant negative correlation among silt and species richness and clay and sand (APPENDIX VII). Similarly, there was significant positive correlation between Nitrogen and Sand, Phosphorus and potassium and significant negative correlation among species richness and water holding capacity, species richness and soil moisture, Nitrogen and pH value, Nitrogen and silt, Humus content and Water holding capacity, Sand and silt and sand and clay (APPENDIX VIII).

CHAPTER 5: DISCUSSION

Plant diversity

In this study, the total plant species diversity in disturbed forest was found to be higher than undisturbed forest. This might be due to opening of the forest area making availability of light and resources (Gautam and Mandal, 2018). According to Huston (1994), disturbances is a factor that can change plant species diversity either by removing disturbance-sensitive species, or by adding new species in the area through opening up growing space and resources for use by colonizing species. Thus disturbance helps to maintain species richness by slowing or preventing competitive exclusion, and alter spatial heterogeneity in plant community. Similarly, the intermediate disturbance hypothesis (IDH) (Connell, 1978; Huston, 1994) predicts that species diversity will be maximized at intermediate disturbance as it will provide space for the new species. Human disturbances, particularly from the overexploitation of biological resources, generally have negative impacts on species diversity (Goudie, 2000), Many researchers have tested the impact of anthropogenic disturbances on plant species diversity; most of them (Busssmann, 2004, Rahman et al., 2009, Shrestha et al., 2013) have agreed that there is positive role of medium level disturbance on maintaining the heterogeneity of plant species. However, in the present study the tree and shrub species diversity was higher in undisturbed forest whereas herb species diversity was higher in disturbed forest. The common anthropogenic disturbances like burning, grazing, browsing, timber harvesting, fodder and fuel extraction etc have widely been reported from forests of Nepal and India (Sagar et al., 2003), the lesser diversity of tree and shrub in disturbed forest might relate to the over exploitation of the forest resources by human for daily household use. Likely, the higher herb species diversity in disturbed forest might be due to the availability of light and space. The overall diversity of the forest was higher during rainy season than dry season which showed that there is correlation between physical attributes like rainfall and temperature of forest and its vegetation. Also there may be more species grazed by livestock during dry season or more species were flourished during rainy season. Similarly, during dry season the forest were under biotic pressure due to firewood, timber and fodder collection as well as the occurrence of fire (Bhuyan *et al.*, 2003).

The dominance of grass species of Poaceae was found in disturbed forest showed that the grass species are more tolerant to disturbance factors and it has great resilience (Linder et.

al, 2018). The presence of invasive species like *Ageratum houstonianm, A. conyzoids* and *Parthenium* sp. only in disturbed forest was due to human disturbance like livestock grazing, fodder and fire wood collection etc shows that anthropogenic disturbance favours weeds (Tilman & Lehman 2001). Unrestricted and open accessibility may cause enhanced utilization of the forest resource and this may eventually lead to a species poor state (Murali et al. 1996). The plant species diversity of tropical forest is very high (Richards 1952) and many factors affect their diversity (Connell 1971; Hubbell 1979). The presence of more unique species in disturbed forest or a decrease in the total number of tree species in disturbed forest may reflect high utilization pressure (Bhat et al., 2000). The recurrent human interventions for collection of fuel wood and minor forest products and the practices of grazing and trampling may change the habitat fitness for many species (Pandey and Shukla, 1999). The dominance of tree species like *Shorea robusta* in all the quadrates in disturbed forest suggests its tolerance to biotic pressure and a wide ecological amplitude. The higher IVI of shrub species *Clerodendrum infortunatum* may be due to its large and attractive inflorescence which helps in its higher seed dispersal.

The Forest Structure

Forest structure affects forest productivity, tree species diversity, and biological habitat that eventually determines the quality of forest ecosystem goods and services (Spies 1998). The high dominance of tree species like *Shorea robusta, Dalbergia sissoo* and *Cassia fistula* in emergent layer restrict the light availability to other species of main canopy and ground vegetation in undisturbed forest. Which visualized that why in this study the shrub and herb density was lower in undisturbed forest compared to disturbed one. Webb and Sah (2003) reported the abundance of shrubs and climbers increased with a decrease of regeneration density and by gap creation. However, in this study the number of shrubs was less in disturbed forest than undisturbed. It appears that, in disturbed forest, people cut more shrubs for fodder, fuel wood production, and collected more climbers to use as medicines than in undisturbed forest. The diameter - density relation showed that the tree density was high in 10-20 cm DBH. This showed that most of the stands were at the intermediate stage of growth and there is a rapid decrease in density with an increase in DBH of trees. In this study it was observed that the lower diameter classes contained higher stem density and higher diameter class contained lower stem density which was similar to result of Gogoi and Sahoo 2018. In disturbed forest the 20-25cm diameter class had higher tree density and there was lower tree density in 10-20cm DBH class which might be due to unrestricted lopping and felling of young trees by local people. The height class distribution of tree species showed that the tree density was high in 15-20m class in disturbed forest while it was for 20-25m class in disturbed forest which is similar to finding of Rahman et al., 2009.

Regeneration

In present study, during rainy season the total density of seedlings, saplings and trees of all species in undisturbed forest were 1865.83, 1096.67 and 784.17 individuals/hectare respectively whereas in disturbed forest seedlings, saplings, and trees were found to be 60, 176.667 and 286.667 individuals/hectare, respectively. Similarly, during dry season the total density of seedlings, saplings and trees of all species in undisturbed forest were 677.5, 395 and 784.17 individuals/hectare respectively whereas in disturbed forest seedlings, saplings, and trees were found to be 53.34, 83.34 and 286.667 individuals/hectare, respectively. It suggested that increased plant available nutrients could be the reason for an enhanced number of seedlings. The tree density of undisturbed and disturbed forest were 784.17 and 286.667 individuals/hectare in undisturbed and disturbed forest respectively. Koirala (2004) reported the density of Tamafok forest and Madimulkharka forests in Tinjure-Milke region Nepal to be 756 stems/ha and 346 stems/ha respectively. Likely, the lesser seedlings, saplings and tree density in disturbed forest can relate to unrestricted use of forest products and high occurrence of disturbance factors.

Seed germination mostly depends upon various environmental factors like temperature, moisture, and light and also on the viability of seeds. Also, plant seeds on the ground experience repeated desiccation and dehydration. So, there is importance of assessment to the ability of seeds to germinate after being subjected to varying levels of desiccation (Angelovici et al. 2010). On the other hand, establishment of seed is another important part of regeneration. It may be affected by environmental factors for the establishment and also the seedlings must compete with herbaceous flora for limited resources. In disturbed forest, lower or no regeneration may be attributed to the degree of disturbance and presence of the mature trees. The saplings of *Mallotus philippensis,* which were all cut found in disturbed forest and no seedlings and trees were recorded pointed to the preference to this particular species as animal fodder by local people. The regeneration pattern in undisturbed forest was comparatively good as the number of seedlings were higher followed by number of saplings and trees. The presence of sufficient numbers of seedlings, saplings and young trees in a given population indicates successful regeneration (Khan et al. 1987). Whereas, in disturbed forest there were more trees than seedlings and saplings. *Shorea robusta* had the higher regeneration power compared to other species in both forest, which may be the reason for its higher dominance or vice-versa. *Shorea robusta* has the high resilience power over disturbance.

Many studies showed that frequency of sprouting declines with increasing severity of disturbance. For example, in both wet and dry tropical forests, sprouts were less common after slash burning than after less intense disturbances (Uhl et al., 1981; Kauffman, 1991; Miller and Kauffman, 1998). While less intense disturbances such as canopy opening may stimulate many seeds to germinate (Vazquez-Yanes and Orozco-Segovia, 1993), more severe disturbances, such as intense fires, kill seeds buried in surface soils (Brinkmann and Vieira, 1971; Uhl et al., 1981).Therefore, it is often colonizing species that regenerate via widely dispersed seeds that dominate following disturbances of high intensity (Uhl et al., 1981; Schimmel and Granstrom, 1996).

Tree biomass

The total tree biomass of the undisturbed forest was much higher compared to disturbed forest. This may be due to the presence of more trees in undisturbed forest compared to disturbed forest. The lower tree biomass in disturbed may be the result of lower density of trees (286.67 stem/ha) in comparison to undisturbed one (783.34 stem/ha). Both above-ground and below-ground biomass is a significant quantitative characteristic of forest ecosystems. The tree biomass changes due to numerous factors in forest ecosystems such as stand age, species composition, size class of trees, forest type, site conditions, rainfall pattern, edaphic factors, and elevation (Peichl and Arain, 2006). Among tree species *Shorea robusta* had the highest above ground and below ground biomass in both forests this may be due to the dominance of *Shorea robusta*. The lower tree biomass of *T. bellirica* and *A. marmelos* may be due to their low tree density.

Soil properties

In this study, the soil texture was sandy in both forest. The soil of terai, siwaliks and dun valleys is more commonly sandy (Jackson, 1994). Soil texture plays important role in supply of air, water and nutrients which eventually help in vegetation development and nutrient cycling (Robertson and Vitousek, 1981). The result showed similarity with the result of Paudel and Shah, 2003 reported form mixed Sal forest of Udayapur Nepal. Values of water holding capacity and soil moisture content were higher in undisturbed forest. The higher value of WHC may be due to the presence of higher amount of clay which can absorb large quantity of water and other substances (Brady and Well, 2013). The higher soil moisture in UDF and high temperature of terai also favors the decomposition of litter and fine roots which results in higher soil nutrient enrichment causing higher water holding capacity (Reth et al., 2005).Higher bulk density in disturbed forest may be due to compaction of soil as a result of disturbances like trampling.

The acidic nature of soil in both forest might be due to formation of weak organic acid produced from carbon dioxide by the decomposition of soil organic matter by microorganisms. Similar results was found by Bhattrai and Mandal, 2016 in sal forest of eastern Nepal. The greater availability of soil nutrients like nitrogen, potassium and phosphorus in undisturbed forest may be due to greater litter production and higher decay rate in this site. While high organic matter in disturbed forest might be due to the presence of more ground vegetation.

In UDF, from the present finding clay concentration has significant positive correlation with species richness as well the biomass, whereas significant negative correlation observed with silt of soil. Proportion of clay and silt in soil determines the porosity and water holding capacity which directly affects the growth of plants in soil, consequently species richness. Similarly in disturbed forest, significant negative correlation was found among species richness and water holding capacity, species richness and soil moisture. Water holding capacity increases when there is more decomposed organic compound. Presence of higher number of species decreases the decomposition resulting negative correlation.

CHAPTER 6: CONCLUSION

From this study it can be concluded that there is various effects of disturbance on plant species diversity, forest structure, regeneration, soil properties and tree biomass. This study shows that, the total plant species diversity in disturbed forest was found to be higher than undisturbed forest. However, the tree density was higher in undisturbed forest. The dominance of grass species of Poaceae was found in disturbed forest showed that the grass species are more tolerant to disturbance factors and it has great resilience. The dominance of tree species like *S. robusta* shows its tolerance to biotic pressure and a wide ecological amplitude. The higher IVI of shrub species *C. infortunatum* may be due to its large and attractive inflorescence which helps in its higher seed dispersal.

The high dominance of tree species like *Shorea robusta, Dalbergia sissoo*and *Cassia fistula* in emergent layer restrict the light availability to other lower species resulting less shrubs and herbs density in undisturbed forest. The diameter - density relation showed that the tree density was high in 10-20 cm DBH. The unrestricted lopping and felling of young trees in disturbed forest resulted in more trees with intermediate growth stage. This study suggest that disturbance activities lowers the regeneration of forest, as there found lesser density of trees, saplings and seedlings in disturbed forest. *S. robusta* had the higher regeneration power compared to other species in both forest, which may be the reason for its higher dominance.

Higher density of trees results in more tree biomass while lower tree density results less tree biomass. The high tree biomass of *S. robusta* is due to its higher dominance. In both forests, soil was sandy and slightly acidic. Soil physical parameters like water holding capacity and soil moisture content were higher in undisturbed forest while humus content and bulk density were higher in disturbed forest. Similarly, soil chemical properties like nitrogen, phosphorus and potassium content were higher in UDF.

CHAPTER 7: RECOMMENDATION

From this study it is found that although overall plant species diversity is higher in disturbed forest, it's mostly due to ground vegetation. The shrubs and tree diversity is very low, the major reason for this is low regeneration. There should be replantation of certain tree and shrub species. It is recommended to carry out specific research to understand which species are more suitable for plantation program.

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APPENDICES

APPENDIX I

Data sheet used for sampling

Date: Locality: District:

Forest type: Latitude: Longitude:

Altitude: Slope: Aspect:

Plot no: Quadrate no. Quadrate size:

Fire: Flood: Grazing:

Trampling: Tree lopping & felling: Litter on floor (%):

Canopy cover (%): Overall Disturbance (0 - 4): Name of recorder:

S.N	Plant Species	Local Name	DBH(cm)	Height (m)	Remarks
1					
2					
3					

S.N	Plant Species	Local Name	Seedling	Sapling	Remarks
1					
2					
3					

S.N	Plant Species	Local Name	No. of Plants	Coverage (%)	Remarks
1					
2					
3					

APPENDIX II

Plant species along disturbed and undisturbed forest.

S.N	Scientific Name	Local name	Family	UDF	DF
1	*Acacia catechu (L.f) Willd.*	Khayer	Fabaceae	√	√
2	*Achnatherum* sp.		Poaceae		√
3	*Achyranthes aspera* L.	Datiwan	Amaranthaceae		√
4	*Acmella paniculata Wall ex DC.*	*Banmarauti*	*Asteraceae*	*√*	*√*
5	*Adiantum* sp.	Kalisinki	Pteridaceae	√	√
6	*Aegle marmelos* Linn.	Bel	Rutaceae		√
7	*Ageratum conyzoides* L.	Seto gandhe	Asteraceae		√
8	*Ageratum houstonianum* Mill.	Nilo ghandhe	Asteraceae		√
9	*Agrostis stolonifera* L.		Poaceae		√
10	*Albizia lebbeck* (L.) Benth.	Sirish	Fabaceae	√	
11	*Anagallis arvensis* L.		Primulaceae	√	
12	*Anaphalis* sp.	Buki jhar	Asteraceae	√	√
13	*Annona squamosa* L.	Salipha	Annonaceae	√	√
14	*Artimesia vulgaris* L.	Titepati	Asteraceae	√	√
15	*Asplenium* sp.		Aspleniaceae	√	
16	*Bauhinia* sp.	Maluka	Fabaceae	√	
17	*Berberis aristata* DC	Chutro	Berberidaceae	√	√
18	*Bidens pilosa* Linn.	Kuro	Asteraceae		√
19	*Bombax ceiba* Linn.	Simal	Malvaceae	√	
20	Buchanania latifolia Roxb.	Piyari/pyar	Anacardiaceae	√	
21	*Carissa spinarum* L.		Apocynaceae		√
22	*Cassia fistula* L.	Rajbriksha	Fabaceae	√	√
23	*Centella asiatica* L.	Ghodtapre	Apiaceae	√	√
24	*Clerodendrum infortunatum* L.	Tite	Lamiaceae	√	√
25	*Colebrookea oppositifolia* Smith	Durseto	Lamiaceae	√	√
26	*Conyza* sp.		Asteraceae		√
27	*Cyanotis cristata* (L.) D.Don		Commelianaceae	√	
28	*Cyanthillium cinereum* (L.) H.Rob	Marcha jhar	Asteraceae	√	√
29	*Cycas pectinata* Griff.	Thakal	Cycadaceae	√	√
30	*Cynodon dactylon* (L.) Pers.	Dubo	Poaceae	√	√
31	*Cyperus iria* L.		Cyperaceae	√	√
32	*Cyperus rotundus* L.	Mothe	Cyperaceae	√	√
33	*Dalbergia sissoo* Roxb.ex DC	Sissoo	Fabaceae	√	
34	*Desmodium gangeticum* (Linn.) Candolle		Fabaceae		√
35	*Desmodium triflorum* (L.) DC		Fabaceae	√	√
36	*Desmostachya bipinnata* (Linn.) Stapf.	Kush	Poaceae	√	√
37	*Digitaria sanguinalis* (L.) Scop.		Poaceae		√
38	*Dioscorea alata* L.	Githo	Dioscoreaceae	√	√
39	*Dioscorea deltoidea* Wall. ex Griseb.	Tarul	Dioscoreaceae	√	
40	*Drymaria cordata* (L.) Walld. ex Roem. & Schult.	Abijalo	Caryophyllaceae	√	
41	*Eclipta prostrata (L.) L.*	Bhringraj	Asteraceae	√	

42	*Erigeron canadensis* L.		Asteraceae		√
43	*Eleusine indica* (L.) Gaertn.	Kode	Poaceae	√	√
44	*Eragrostis* sp.	Eragrostis	Poaceae	√	√
45	*Eulaliopsis binata* (Retz.) C.E. Hubb.		Poaceae		√
46	*Euphorbia hirta* L.		Euphorbiaceae	√	√
47	*Evolvulus nummularius* (L.) L.		Convolvulaceae	√	√
48	*Fraxinus* sp.	Padky	Oleaceae		√
49	*Flemingia* sp.		Fabaceae		√
50	*Galinsoga* sp.		Asteraceae		√
51	*Gallium* sp.		Rubiaceae	√	√
52	*Hemidesmus indicus* (L.) R.Br.	Lahara	Apocynaceae	√	
53	*Hyparrhenia hirta* L.		Poaceae	√	√
54	*Hyperthelia sp.*	Kuro ghas	Poaceae		√
55	*Mesosphaerum suaveolens* (L.) Poit.		Poaceae		
56	*Imperata cylindrica* (L.) P. Beauv.	Siru	Poaceae	√	√
57	*Jatropha curcas* L.	Sajiwan	Euphorbiaceae		√
58	*Jasminum* sp.	Jasmin	Oleaceae		√
59	*Kylinga* sp.		Cyperaceae		√
60	*Clinopodium* sp.		Lamiaceae		√
61	*Largestroemia parviflora* Roxb.	Botdhairo	Lythraceae		√
62	*Leucaena leucocephala* (Lam.) de Witt	Ipil	Fabaceae	√	
63	*Leucas cephalotes* (Roth.) Spreng.	Kade	Lamiaceae	√	√
64	*Lillium* sp.	Ribbon plant	Liliaceae	√	√
65	*Lygodium* sp.		Schizaeaceae	√	√
66	*Madhuca longifolia* (J.Konig ex L.)	Mahuwa	Sapotaceae	√	√
67	*Mallotus philippensis* (Lam.) Mull. Arg.	Rohini	Euphorbiaceae	√	
68	*Mangifera indica* L.	Mango	Anacardiaceae	√	
69	*Medicago sp.*	Bhatte ghas	Fabaceae	√	√
70	*Mimosa pudica* L.		Fabaceae	√	√
71	*Ocimum basilicum* L.	Babari	Lamiaceae	√	
72	*Oxalis sp.*	Choriamilo	Oxalidaceae		√
73	*Parthenium sp.*	Paty jhar	Asteraceae		√
74	*Parthenocissus sp.*		Vitaceae	√	
75	*Paspalum sp.*	Paspalum	Poaceae	√	√
76	*Phalaris arundinaceae* L.		Poaceae		√
77	*Phyllanthus emblica* Linn.	Amala	Euphorbiaceae	√	
78	*Piper longum* L.	Pipala	Piperaceae		√
79	*Poa annua* L.		Poaceae		√
80	*Persicaria* (L.) Mill.	Khursani jhar	Polygoniaceae	√	√
81	*Polygonum plebeium* R.Br	Sano khursani jhar	Polygoniaceae	√	√
82	*Ranunculus sp.*		Ranunculaceae	√	√
83	*Rubia cordifolia* L.		Rubiaceae	√	
84	*Saccharum spontaneum* Linn.	Narkat	Poaceae		√
85	*Senna occidentalis* L.		Fabaceae		√

86	*Setaria viridis* (L.) P.Beauv.		Poaceae		√
87	*Shorea robusta* Roth.	Sal	Dipterocapaceae	√	√
88	*Sida* sp.	Sida	Convolvulaceae	√	√
89	*Smilax* sp.		Smilacaceae	√	
90	*Solanum incanum* L.		Solanaceae		√
91	*Solanum nigrum* L.		Solanaceae		√
92	*Sonchus* sp.	Dudhe	Asteraceae	√	√
93	*Syzygium cumini* (L.) Skeels	Jamun	Myrtaceae		√
94	*Tectona grandis* L.	Khaltu/Teak	Lamiaceae	√	
95	*Terminalia arjuna* (Roxb.) Wight & Arn.	Siddha	Combretaceae	√	
96	*Terminalia bellirica* (Gaertn.) Roxb.	Barro	Combretaceae	√	√
97	*Terminalia chebula* Retz.	Harro	Combretaceae	√	
98	*Terminalia Tomentosa* Roxb.	Saj	Combretaceae	√	√
99	*Themeda arundinacea* (Roxb.) A. Camus		Poaceae		√
100	*Themeda villosa* (Lam.) A. Camus		Poaceae		√
101	*Tinospora cordiflora* (Willd.) Miers.	Gurjo	Menispermaceae	√	
102	*Tribulus* sp.	Lawase	Zygophyllaceae	√	√
103	*Trifolium repens* L.	Trifolium	Fabaceae	√	√
104	*Urena lobata* L.		Malvaceae		√
105	*Veronica* sp.		Plantaginaceae	√	√
106	*Zizyphus jujuba* Mill.	Bayar	Rhamnaceae	√	√

APPENDIX III

IVI of herbs species in disturbed and undisturbed forest during rainy and dry season.

		IVI			
		Rainy Season		**Dry Season**	
SN.	**Scientific Name**	**UDF**	**DF**	**UDF**	**DF**
1	*Achnatherum sp.*		6.88782		
2	*Achyranthes aspera*		0.9706		
3	*Acmella Paniculata*	2.83557	3.06148	1.4018	3.80577
4	*Adiantum* sp.	12.9359	3.55169		0.73084
5	*Ageratum conyzoids*		5.15127		1.68514
6	*Ageratum haustoniaum*		1.81558		1.50962
7	*Agrostis stolonifera*		7.08235		
8	*Anagallis arvensis*			6.83696	
9	*Anaphilis* sp.	4.98892		13.5501	2.11804
10	*Artemisia vulgaris*	1.59204			3.70214
11	*Asplenium* sp.	2.03496			
12	*Bidens pilosa*		2.35471		3.43077
13	*centella asiatica*	1.57834	2.09206	7.50725	5.01744

14	*Conyza* sp.				5.81022
15	*Cyanotis cristata*			3.76653	
16	*Cyanthillium cinereum*	1.39263	2.37153	6.12642	5.57276
17	*Cynodon dactylon*	16.4708	33.1734	18.535	17.361
18	*Cyperus iris*	6.9365			10.6068
19	*Cyperus rotundus*	7.32346	18.4356	20.5735	20.017
20	*Desmodium gangeticum*		1.62499		
21	*Desmodium triflorum*	11.1916	5.40086		11.4376
22	*Desmostachya bipinnata*	16.7319	4.83321	7.52339	
23	*Digitaria sanguinalis*		5.24058		1.55128
24	*Dioscorea alata*	24.1808	4.08009		
25	*Dioscorea deltoidea*	4.87846			
26	*Drymaria cordata*	4.92071			
27	*Eclipta prostata*	2.70625		4.21829	
28	*Eleusine indica*	3.01394	6.85524		10.2709
29	*Eragrostis* sp.	16.2692	24.6348	12.5181	7.56101
30	*Erigeron canadensis*		2.81123		
31	*Eulaliopsis binata*				3.80687
32	*Euphorbia hirta*	2.04259	6.93387	8.91389	1.31014
33	*Evolvulus nummularius*	5.6057	3.05426		10.088
34	*Flemingia* sp.				1.84295
35	*Galinsoga* sp.				2.80463
36	*Gallium* sp.	4.16463	3.17691		
37	*Hemidesmus indicus*	29.5512		3.24569	
38	*Hyparrhenia hirta*	1.13542	1.6408		5.27775
39	*Hyperthelia* sp.		23.1128		2.58892
40	*Mesosphaerum suaveolens*				3.53178
41	*Imperata cylindrica*	8.5709	12.8807	18.4692	18.6807
42	*Kylinga* sp.		6.56254		2.6494
43	*Clinopodium* sp.		1.91185		
44	*Leucas cephalotes*	5.29211	1.45533	9.60358	11.2344
45	*Lillium* sp.	16.4321	3.95035	23.1827	5.02775
46	*Lygodium* sp	10.5386	1.23754	17.8649	4.65385
47	*Medicago denticulata*	11.424	2.67636	12.0792	5.62732
48	*Mimosa pudica*		1.76529	6.86597	3.90533
49	*Ocimum basilicum*	1.68489			
50	*Oxalis* sp.		7.84524		20.1665
51	*Parthenium*		2.71197		3.35515
52	*Parthenocissus* sp.	2.62884		1.4018	
53	*Paspalum* sp.	12.8049	20.9807	17.344	18.6387
54	*Phalaris arundinaceae*		3.2971		
55	*Poa annua*		2.6114		4.58196
56	*Polygonum barbatum*		2.49716	1.83906	3.49011
57	*Polygonum plebeium*			9.54731	
58	*Ranunculus* sp.	6.93445		16.7379	3.92191
59	*Rubia cordifolia*	2.8066		6.47531	

60	*Saccharum spontaneum*		2.74741		2.83634
61	*Setaria viridis*		9.0625		6.05508
62	*Sida* sp.	22.9671	12.8895	24.2469	19.5056
63	*Smilax* sp.	2.02919		3.76653	
64	*Solanum incanum*		1.55376		
65	*Solanum nigrum*		0.61877	1.4018	
66	*Sonchus* sp.	3.44893	1.6334	8.66961	3.95841
67	*Themeda arundinacea*		4.63964		
68	*Themeda villosa*		1.21148		
69	*Tribulus Terestis*	1.77774	1.76529	5.78725	
70	*Trifolium repens*	2.99231	9.51981		16.7147
71	*Veronica* sp.	3.18594	1.62713		1.55756

APPENDIX IV

IVI of tree species in disturbed and undisturbed forest.

		IVI	
S.N	**Name of Species**	**UDF**	**DF**
1	*Acacia catechu*	1.8424	3.385
2	*Aegle marmelos*		2.8036
3	*Albizia lebbeck*	8.7871	
4	*Bombax ceiba*	7.2993	
5	*Buchanania latifolia*	2.8347	
6	*Cassia fistula*	1.6299	5.6072
7	*Dalbergia sissoo*	25.0144	
8	*Largestroemia parviflora*		5.6072
9	*Leucaena leucocephala*	3.0473	
10	*Madhuca longifolia*	3.0473	8.9922
11	*Magnifera indica*	3.0473	
12	*Mallotus philippensis*	3.8974	
13	*Phyllanthus emblica*	2.8347	
14	*Shorea robusta*	212.1276	256.2016
15	*Syzygium cumini*		8.4109
16	*Terminalia arjuna*	5.882	
17	*Terminalia bellirica*	1.4174	5.6072
18	*Terminalia chebula*	2.8347	
19	*Terminalia tomentosa*	1.4174	
20	*Tectona grandis*	13.0392	

APPENDIX III

Frequency, density and coverage and their relative value for herbs, shrubs and trees in disturbed and undisturbed forest during dry and rainy season.

Herbs:

During dry season, in disturbed forest

SN.	Name of herbs	Total no. of plants	F	RF (%)	D	RD (%)	C	RC (%)	IVI
1	*Acmella uliginosa*	17	6.667	0.866	0.567	1.523	1.133	1.417	3.806
2	*Adiantum sp.*	1	3.333	0.433	0.033	0.090	0.167	0.208	0.731
3	*Ageratum conyzoides*	7	3.333	0.433	0.233	0.627	0.500	0.625	1.685
4	*Ageratum houstonianum*	3	6.667	0.866	0.100	0.269	0.300	0.375	1.510
5	*Anaphalis sp.*	7	6.667	0.866	0.233	0.627	0.500	0.625	2.118
6	*Artimesia vulgaris*	6	16.667	2.165	0.200	0.538	0.800	1.000	3.702
7	*Bidens pilosa*	17	6.667	0.866	0.567	1.523	0.833	1.042	3.431
8	*Centella asiatica*	19	13.333	1.732	0.633	1.703	1.267	1.583	5.017
9	*Conyza sp.*	14	20.000	2.597	0.467	1.254	1.567	1.958	5.810
10	*Cyanthillium cinereum*	16	20.000	2.597	0.533	1.434	1.233	1.542	5.573
11	*Cynodon dactylon*	73	40.000	5.195	2.433	6.541	4.500	5.625	17.361
12	*Cyperus iris*	31	33.333	4.329	1.033	2.778	2.800	3.500	10.607
13	*Cyperus rotundus*	82	43.333	5.628	2.733	7.348	5.633	7.042	20.017
14	*Desmodium triflorum*	62	10.000	1.299	2.067	5.556	3.667	4.583	11.438
15	*Digitaria sanguinalis*	3	6.667	0.866	0.100	0.269	0.333	0.417	1.551
16	*Eleusine indica*	28	36.667	4.762	0.933	2.509	2.400	3.000	10.271
17	*Eragrostis sp.*	30	16.667	2.165	1.000	2.688	2.167	2.708	7.561
18	*Eulaliopsis binata*	12	13.333	1.732	0.400	1.075	0.800	1.000	3.807
19	*Euphorbia hirta*	7	3.333	0.433	0.233	0.627	0.200	0.250	1.310
20	*Evolvulus nummularius*	45	20.000	2.597	1.500	4.032	2.767	3.458	10.088
21	*Flemingia sp.*	3	6.667	0.866	0.100	0.269	0.567	0.708	1.843
22	*Galinsoga sp.*	5	13.333	1.732	0.167	0.448	0.500	0.625	2.805
23	*Hyparrhenia hirta*	14	13.333	1.732	0.467	1.254	1.833	2.292	5.278
24	*Hyperthelia dissoluta*	9	6.667	0.866	0.300	0.806	0.733	0.917	2.589
25	*Mesosphaerum suaveolens*	8	13.333	1.732	0.267	0.717	0.867	1.083	3.532
26	*Imperata cylindrica*	76	33.333	4.329	2.533	6.810	6.033	7.542	18.681
27	*Kylinga sp.*	12	6.667	0.866	0.400	1.075	0.567	0.708	2.649
28	*Leucas cephalotes*	34	30.000	3.896	1.133	3.047	3.433	4.292	11.234
29	*Lillium sp.*	14	13.333	1.732	0.467	1.254	1.633	2.042	5.028
30	*Lygodium sp.*	9	20.000	2.597	0.300	0.806	1.000	1.250	4.654
31	*Medicago denticulata*	14	16.667	2.165	0.467	1.254	1.767	2.208	5.627
32	*Mimosa pudica*	17	10.000	1.299	0.567	1.523	0.867	1.083	3.905
33	*Oxalis sp.*	111	36.667	4.762	3.700	9.946	4.367	5.458	20.166
34	*Partheniumsp.*	9	10.000	1.299	0.300	0.806	1.000	1.250	3.355
35	*Paspalum sp.*	80	36.667	4.762	2.667	7.168	5.367	6.708	18.639
36	*Poa annua*	16	13.333	1.732	0.533	1.434	1.133	1.417	4.582
37	*Polygonum capitatum*	8	13.333	1.732	0.267	0.717	0.833	1.042	3.490
38	*Ranunculus sp.*	13	10.000	1.299	0.433	1.165	1.167	1.458	3.922

39	*Saccharum spontaneum*	6	10.000	1.299	0.200	0.538	0.800	1.000	2.836
40	*Setaria viridis*	25	13.333	1.732	0.833	2.240	1.667	2.083	6.055
41	*Sida acuta*	58	63.333	8.225	1.933	5.197	4.867	6.083	19.506
42	*Sonchus sp.*	7	16.667	2.165	0.233	0.627	0.933	1.167	3.958
43	*Trifolium sp.*	84	30.000	3.896	2.800	7.527	4.233	5.292	16.715
44	*Vernonia cinera*	4	6.667	0.866	0.133	0.358	0.267	0.333	1.558

During rainy season, in disturbed forest

SN.	Name of plants	Total no. of plants	F	RF(%)	D	RD(%)	C	RC(%)	IVI
1	*Achnatherum sp.*	65	13.333	1.914	2.167	2.315	4.233	2.659	6.888
2	Achyranthes aspera	5	3.333	0.478	0.167	0.178	0.500	0.314	0.971
3	*Acmella ciliata*	15	6.667	0.957	0.500	0.534	2.500	1.570	3.061
4	*Adiantum sp.*	26	13.333	1.914	0.867	0.926	1.133	0.712	3.552
5	*Ageratum conyzoids*	17	20.000	2.871	0.567	0.605	2.667	1.675	5.151
6	*Ageratum haustoniaum*	10	6.667	0.957	0.333	0.356	0.800	0.503	1.816
7	*Agrostis stolonifera*	54	13.333	1.914	1.800	1.923	5.167	3.245	7.082
8	*Bidens pilosa*	7	10.000	1.435	0.233	0.249	1.067	0.670	2.355
9	*centella asiatica*	16	6.667	0.957	0.533	0.570	0.900	0.565	2.092
10	*Cyanthillium cinereum*	11	10.000	1.435	0.367	0.392	0.867	0.544	2.372
11	*Cynodon dactylon*	392	53.333	7.656	13.067	13.960	18.400	11.558	33.173
12	*Cyperus rotundus*	193	40.000	5.742	6.433	6.873	9.267	5.821	18.436
13	*Desmodium gangeticum*	7	6.667	0.957	0.233	0.249	0.667	0.419	1.625
14	Desmodium triflorum	45	13.333	1.914	1.500	1.603	3.000	1.884	5.401
15	*Desmostachya bipinnata*	32	13.333	1.914	1.067	1.140	2.833	1.780	4.833
16	*Digitaria sanguinalis*	41	10.000	1.435	1.367	1.460	3.733	2.345	5.241
17	*Dioscorea alata*	8	16.667	2.392	0.267	0.285	2.233	1.403	4.080
18	*Eleusine indica*	52	23.333	3.349	1.733	1.852	2.633	1.654	6.855
19	*Eragrostis sp.*	337	36.667	5.263	11.233	12.001	11.733	7.370	24.635
20	*Erigeron canadensis*	11	10.000	1.435	0.367	0.392	1.567	0.984	2.811
21	*Euphorbia hirta*	125	10.000	1.435	4.167	4.452	1.667	1.047	6.934
22	Evolvulus nummularius	19	10.000	1.435	0.633	0.677	1.500	0.942	3.054
23	Gallium sp.	30	6.667	0.957	1.000	1.068	1.833	1.152	3.177
24	*Hyparrhenia hirta*	15	3.333	0.478	0.500	0.534	1.000	0.628	1.641
25	*Hyperthelia sp.*	293	33.333	4.785	9.767	10.434	12.567	7.894	23.113

26	*Imperata cylindrica*	143	23.333	3.349	4.767	5.093	7.067	4.439	12.881
27	*Kylinga sp.*	84	10.000	1.435	2.800	2.991	3.400	2.136	6.563
28	Clinopodium sp.	8	6.667	0.957	0.267	0.285	1.067	0.670	1.912
29	Leucas cephalotes	4	6.667	0.957	0.133	0.142	0.567	0.356	1.455
30	*Lillium sp.*	12	16.667	2.392	0.400	0.427	1.800	1.131	3.950
31	*Lygodium sp.*	2	6.667	0.957	0.067	0.071	0.333	0.209	1.238
32	*Medicago denticulata*	23	6.667	0.957	0.767	0.819	1.433	0.900	2.676
33	*Mimosa pudica*	8	6.667	0.957	0.267	0.285	0.833	0.523	1.765
34	*Oxalis sp.*	96	13.333	1.914	3.200	3.419	4.000	2.513	7.845
35	Parthenium	24	6.667	0.957	0.800	0.855	1.433	0.900	2.712
36	*Paspalum sp.*	194	43.333	6.220	6.467	6.909	12.500	7.852	20.981
37	*Phalaris arundinaceae*	17	10.000	1.435	0.567	0.605	2.000	1.256	3.297
38	*Poa annua*	20	6.667	0.957	0.667	0.712	1.500	0.942	2.611
39	*Polygonum persicaria*	11	10.000	1.435	0.367	0.392	1.067	0.670	2.497
40	*Saccharum spontaneum*	15	6.667	0.957	0.500	0.534	2.000	1.256	2.747
41	*Setaria viridis*	74	23.333	3.349	2.467	2.635	4.900	3.078	9.062
42	*Sida acuta*	34	50.000	7.177	1.133	1.211	7.167	4.502	12.890
43	*Solanum incanum*	5	6.667	0.957	0.167	0.178	0.667	0.419	1.554
44	*Solanum nigrum*	1	3.333	0.478	0.033	0.036	0.167	0.105	0.619
45	*Sonchus sp.*	9	6.667	0.957	0.300	0.321	0.567	0.356	1.633
46	*Themeda arundinacea*	40	10.000	1.435	1.333	1.425	2.833	1.780	4.640
47	*Themeda villosa*	10	3.333	0.478	0.333	0.356	0.600	0.377	1.211
48	*Tribulus Terestis*	8	6.667	0.957	0.267	0.285	0.833	0.523	1.765
49	*Trifolium sp*	130	10.000	1.435	4.333	4.630	5.500	3.455	9.520
50	*Veronica sp.*	10	6.667	0.957	0.333	0.356	0.500	0.314	1.627

During dry season in undisturbed forest

SN.	Name of plants	Total no. of plants	F	RF(%)	D	RD(%)	C	RC(%)	IVI
1	*Acmella paniculata*	1	3.333	0.699	0.033	0.260	0.167	0.442	1.402
2	*Anagallis arvensis*	9	6.667	1.399	0.300	2.344	1.167	3.095	6.837
3	*Anaphilis sp.*	22	20.000	4.196	0.733	5.729	1.367	3.625	13.550
4	*Centela asiatica*	15	10.000	2.098	0.500	3.906	0.567	1.503	7.507
5	*Cyanotis cristata*	4	6.667	1.399	0.133	1.042	0.500	1.326	3.767
6	*Cyanthillium cinereum*	8	10.000	2.098	0.267	2.083	0.733	1.945	6.126
7	*Cynodon dactylon*	35	16.667	3.497	1.167	9.115	2.233	5.924	18.535
8	*Cyperus rotundus*	29	26.667	5.594	0.967	7.552	2.800	7.427	20.574

9	*Desmostachya bipinnata*	10	13.333	2.797	0.333	2.604	0.800	2.122	7.523
10	*Eclipta prostata*	2	6.667	1.399	0.067	0.521	0.867	2.299	4.218
11	*Eragrostis sp.*	16	20.000	4.196	0.533	4.167	1.567	4.156	12.518
12	*Euphorbia hirta*	15	13.333	2.797	0.500	3.906	0.833	2.210	8.914
13	*Hemidesmus indicus*	2	6.667	1.399	0.067	0.521	0.500	1.326	3.246
14	*Imperata cylindrica*	27	23.333	4.895	0.900	7.031	2.467	6.543	18.469
15	*Leucas cephalotes*	12	26.667	5.594	0.400	3.125	0.333	0.884	9.604
16	*Lillium sp.*	28	46.667	9.790	0.933	7.292	2.300	6.101	23.183
17	*Lygodium sp*	19	33.333	6.993	0.633	4.948	2.233	5.924	17.865
18	*Medicago denticulata*	17	16.667	3.497	0.567	4.427	1.567	4.156	12.079
19	*Mimosa pudica*	3	6.667	1.399	0.100	0.781	1.767	4.686	6.866
20	*Parthenocissus sp.*	1	3.333	0.699	0.033	0.260	0.167	0.442	1.402
21	*Paspalum sp.*	22	23.333	4.895	0.733	5.729	2.533	6.720	17.344
22	*Polygonum barbatum*	2	3.333	0.699	0.067	0.521	0.233	0.619	1.839
23	*Polygonum plebeium (sano khursani jhar)*	12	13.333	2.797	0.400	3.125	1.367	3.625	9.547
24	*Ranunculus sp.*	21	20.000	4.196	0.700	5.469	2.667	7.073	16.738
25	*Rubia cordifolia*	4	20.000	4.196	0.133	1.042	0.467	1.238	6.475
26	*Sida sp*	29	43.333	9.091	0.967	7.552	2.867	7.604	24.247
27	*Smilax sp.*	4	6.667	1.399	0.133	1.042	0.500	1.326	3.767
28	*Solanum nigrum*	1	3.333	0.699	0.033	0.260	0.167	0.442	1.402
29	*Sonchus sp*	9	16.667	3.497	0.300	2.344	1.067	2.829	8.670
30	*Tribulus Terestis*	5	10.000	2.098	0.167	1.302	0.900	2.387	5.787

During rainy season, in undisturbed forest.

SN.	Name of plants	Total no. of plants	F	RF(%)	D	RD(%)	C	RC(%)	IVI
1	*Acmella paniculata*	15	3.333	0.457	0.500	1.393	1.000	0.986	2.836
2	*Adiantum sp*	75	10.000	1.370	2.500	6.964	4.667	4.602	12.936
3	*Anaphilis sp.*	9	20.000	2.740	0.300	0.836	1.433	1.414	4.989
4	*Artemisia vulgaris*	2	6.667	0.913	0.067	0.186	0.500	0.493	1.592
5	*Asplenium sp.*	5	6.667	0.913	0.167	0.464	0.667	0.657	2.035
6	*Centella asiatica*	5	3.333	0.457	0.167	0.464	0.667	0.657	1.578
7	*Cyanthillium cinereum*	3	3.333	0.457	0.100	0.279	0.667	0.657	1.393
8	*Cynodon dactylon*	79	33.333	4.566	2.633	7.335	4.633	4.569	16.471
9	*Cyperus iris*	19	20.000	2.740	0.633	1.764	2.467	2.433	6.936
10	*Cyperus rotundus*	26	20.000	2.740	0.867	2.414	2.200	2.170	7.323
11	*Desmodium triflorum*	57	16.667	2.283	1.900	5.292	3.667	3.616	11.192
12	*Desmostachya bipinnata*	73	36.667	5.023	2.433	6.778	5.000	4.931	16.732
13	*Dioscora alata*	76	63.333	8.676	2.533	7.057	8.567	8.448	24.181

14	*Dioscorea deltoidea*	18	13.333	1.826	0.600	1.671	1.400	1.381	4.878
15	*Drymaria cordata*	17	10.000	1.370	0.567	1.578	2.000	1.972	4.921
16	*Eclipta prostata*	14	6.667	0.913	0.467	1.300	0.500	0.493	2.706
17	*Eleusine indica*	5	13.333	1.826	0.167	0.464	0.733	0.723	3.014
18	*Eragrostis sp.*	81	26.667	3.653	2.700	7.521	5.167	5.095	16.269
19	*Euphorbia hirta*	10	3.333	0.457	0.333	0.929	0.667	0.657	2.043
20	*Evolvulus nummularius*	23	13.333	1.826	0.767	2.136	1.667	1.644	5.606
21	*Gallium sp.*	17	10.000	1.370	0.567	1.578	1.233	1.216	4.165
22	*Hemidesmus indicus*	117	76.667	10.502	3.900	10.864	8.300	8.185	29.551
23	*Hyparrhenia hirta*	2	3.333	0.457	0.067	0.186	0.500	0.493	1.135
24	*Imperata cylindrica*	32	20.000	2.740	1.067	2.971	2.900	2.860	8.571
25	*Leucas cephalotes*	21	10.000	1.370	0.700	1.950	2.000	1.972	5.292
26	*Lillium sp.*	37	50.000	6.849	1.233	3.435	6.233	6.147	16.432
27	*Lygodium sp*	24	36.667	5.023	0.800	2.228	3.333	3.287	10.539
28	*Medicago denticulata*	25	33.333	4.566	0.833	2.321	4.600	4.536	11.424
29	*Ocimum basilicum*	3	6.667	0.913	0.100	0.279	0.500	0.493	1.685
30	*Parthenocissus sp.*	4	10.000	1.370	0.133	0.371	0.900	0.888	2.629
31	*Paspalum sp.*	49	26.667	3.653	1.633	4.550	4.667	4.602	12.805
32	*Ranunculus sp.*	32	13.333	1.826	1.067	2.971	2.167	2.137	6.934
33	*Rubia cordifolia*	8	6.667	0.913	0.267	0.743	1.167	1.151	2.807
34	*Sida sp.*	54	56.667	7.763	1.800	5.014	10.333	10.191	22.967
35	*Smilax sp.*	6	6.667	0.913	0.200	0.557	0.567	0.559	2.029
36	*Sonchus sp.*	10	10.000	1.370	0.333	0.929	1.167	1.151	3.449
37	*Tribulus Terestis*	4	6.667	0.913	0.133	0.371	0.500	0.493	1.778
38	*Trifolim repens*	10	6.667	0.913	0.333	0.929	1.167	1.151	2.992
39	*Veronica cinera*	10	10.000	1.370	0.333	0.929	0.900	0.888	3.186

Shrubs

During dry season in disturbed forest.

SN.	Name of plants	Total no. of plants	F	RF(%)	D	RD(%)	C	RC(%)	IVI
1	*Annona squamosa*	5	13.333	5.634	4.167	1.873	1.833	5.729	13.236
2	*Berberis aristata*	35	40.000	16.901	29.167	13.109	6.533	20.417	50.427
3	*Clerodendrum infortunatum*	125	36.667	15.493	104.167	46.816	5.067	15.833	78.143
4	*Colebrookea oppositifolia*	46	56.667	23.944	38.333	17.228	8.433	26.354	67.526
5	*Cycas pectinata*	17	30.000	12.676	14.167	6.367	2.867	8.958	28.001
6	*Fraxinus sp.*	19	23.333	9.859	15.833	7.116	3.700	11.563	28.538
7	*Senna*	5	10.000	4.225	4.167	1.873	0.900	2.813	8.911

8	*Urena lobata*	4	10.000	4.225	3.333	1.498	0.500	1.563	7.286
9	*Zizyphus jujuba*	11	16.667	7.042	9.167	4.120	2.167	6.771	17.933

During rainy season in disturbed forest.

SN.	Name of plants	Total no. of plants	F	RF(%)	Density	RD%	C	RC(%)	IVI
1	*Annona squamosa*	12	16.667	6.757	10.000	3.960	2.500	5.774	16.491
2	*Berberis aristata*	28	43.333	17.568	23.333	9.241	7.167	16.551	43.360
3	*Carissa spinarum*	6	10.000	4.054	5.000	1.980	1.767	4.080	10.114
4	*Clerodendrum infortunatum*	158	26.667	10.811	131.667	52.145	9.000	20.785	83.741
5	*Colebrookea oppositifolia*	51	53.333	21.622	42.500	16.832	11.000	25.404	63.857
6	*Cycas pectinata*	10	20.000	8.108	8.333	3.300	1.600	3.695	15.104
7	*Fraxinus sp.*	4	10.000	4.054	3.333	1.320	1.133	2.617	7.992
8	*Jatropa curcus*	3	6.667	2.703	2.500	0.990	0.700	1.617	5.309
9	*Jasminumsp*	3	6.667	2.703	2.500	0.990	0.467	1.078	4.771
10	*Piper longum*	6	13.333	5.405	5.000	1.980	1.733	4.003	11.389
11	*Senna accidentalis*	5	13.333	5.405	4.167	1.650	1.400	3.233	10.289
12	*Urena lobata*	6	13.333	5.405	5.000	1.980	1.667	3.849	11.235
13	*Zizyphus jujuba*	11	13.333	5.405	9.167	3.630	3.167	7.313	16.349

During dry season, in undisturbed forest.

S.N	Name of plants	Total no. of plants	F	RF(%)	D	RD(%)	C	RC(%)	IVI
1	*Annona squamosa*	7	2.500	5.660	5.833	1.716	1.333	4.551	11.927
2	*Berberis aristata*	3	1.667	3.774	2.500	0.735	0.567	1.934	6.443
3	*Clerodendrum infortunatum*	349	23.333	52.830	290.833	85.539	19.267	65.757	204.126
4	*Colebrookea oppositifolia*	9	3.333	7.547	7.500	2.206	2.000	6.826	16.579
5	*Cycas pectinata*	39	12.500	28.302	32.500	9.559	5.633	19.226	57.087

6	*Tinospora cordiflora*	1	0.833	1.887	0.833	0.245	0.500	1.706	3.838

During rainy season, in undisturbed forest.

SN.	Name of plants	Total no. of spp.	F	RF(%)	D	RD(%)	C	RC(%)	IVI
1	Clerodendrum infortunatum	661	96.667	61.702	550.833	91.678	36.133	75.487	228.868
2	*Cycas pectinata*	50	40.000	25.532	41.667	6.935	9.667	20.195	52.662
3	*Bauhinia sp.*	3	6.667	4.255	2.500	0.416	0.667	1.393	6.064
4	*Annona squamosa*	1	3.333	2.128	0.833	0.139	0.333	0.696	2.963
5	*Colebrookea oppositifolia*	4	3.333	2.128	3.333	0.555	0.667	1.393	4.075
6	*Zizyphus jujuba*	1	3.333	2.128	0.833	0.139	0.167	0.348	2.615
7	*Berberis aristata*	1	3.333	2.128	0.833	0.139	0.233	0.487	2.754

Trees

In disturbed forest.

SN.	Name of plants	Total no of plants	F	RF(%)	D	RD(%)	C	RC(%)	IVI
1	*Shorea robusta*	30	100.00	66.667	4346.67	94.767	10.87	94.77	256.20
2	*Madhuca indica*	3	10.00	6.667	53.33	1.163	0.13	1.16	8.99
3	*Largestroemia parviflora*	2	6.67	4.444	26.67	0.581	0.07	0.58	5.61
4	*Syzygium cumini*	3	10.00	6.667	40.00	0.872	0.10	0.87	8.41
5	*Aegle marmelos*	1	3.33	2.222	13.33	0.291	0.03	0.29	2.80
6	*Terminalia tomentosa*	1	3.33	2.222	26.67	0.581	0.07	0.58	3.39

7	*Terminalia bellirica*	2	6.67	4.444	26.67	0.581	0.07	0.58	5.61
8	*Cassia fistula*	2	6.67	4.444	26.67	0.581	0.07	0.58	5.61
9	Acacia catechu	1	3.33	2.222	26.67	0.581	0.07	0.58	3.39

In undisturbed forest.

SN.	Name of plants	Total no. of plants	D	RD%	F	RF(%)	C	RC(%)	IVI
1	*Acacia catechu*	3	40.00	0.32	3.33	1.20	0.10	0.32	1.84
2	*Albizia lebbeck*	13	173.33	1.38	16.67	6.02	0.43	1.38	8.79
3	*Bombax ceiba*	6	80.00	0.64	16.67	6.02	0.20	0.64	7.30
4	*Buchanania latifolia*	2	26.67	0.21	6.67	2.41	0.07	0.21	2.83
5	*Cassia fistula*	2	26.67	0.21	3.33	1.20	0.07	0.21	1.63
6	*Dalbergia sissoo*	44	586.67	4.68	43.33	15.66	1.47	4.68	25.01
7	*Leucaena leucocephala*	3	40.00	0.32	6.67	2.41	0.10	0.32	3.05
8	*Madhuca longifolia*	3	40.00	0.32	6.67	2.41	0.10	0.32	3.05
9	*Mangifera indica*	3	40.00	0.32	6.67	2.41	0.10	0.32	3.05
10	*Mallotus philippensis*	7	93.33	0.74	6.67	2.41	0.23	0.74	3.90
11	*Phyllanthus emblica*	2	26.67	0.21	6.67	2.41	0.07	0.21	2.83
12	*Shorea robusta*	828	11040.00	87.99	100.00	36.14	27.60	87.99	212.13
13	*Terminalia arjuna*	5	66.67	0.53	13.33	4.82	0.17	0.53	5.88
14	*Terminalia bellirica*	1	13.33	0.11	3.33	1.20	0.03	0.11	1.42
15	*Terminalia chebula*	2	26.67	0.21	6.67	2.41	0.07	0.21	2.83
16	*Terminalia elliptica*	1	13.33	0.11	3.33	1.20	0.03	0.11	1.42
17	*Tectona grandis*	16	213.33	1.70	26.67	9.64	0.53	1.70	13.04

Note: where, F- Frequency, D- Density, C- Coverage, RF- Relative frequency, RD- Relative density, RC- Relative coverage and IVI- Important value index.

APPENDIX IVI

Wood density of tree species used to estimate tree biomass by following Reyes et al (1992).

S.N	Name of species	Wood density (g/cm³)
1	*Aegle marmelos*	0.75

2	*Acacia catechu*	0.88
3	*Lagesteroemia parvifolia*	0.85
4	*Terminalia bellirica*	0.72
5	*Terminalia tomentosa*	0.76
6	*Bombax ceiba*	0.36
7	*Buchanania latifolia*	0.45
8	*Shorea robusta*	0.88
9	*Syzygium cumini*	0.77
10	*Madhuca longifolia*	0.74
11	*Terminalia chebula*	0.96
12	*Dalbergia sissoo*	0.78
13	*Mangifera indica*	0.59
14	*Phyllanthus emblica*	0.67
15	*Mallotus philippenis*	0.64
16	*Leucaena leucocephala*	0.64
17	*Terminalia arjuna*	0.68
18	*Tectona grandis*	0.55
19	*Albizia lebback*	0.55
20	*Cassia fistula*	0.71

Source: Sharma and Pukkala (1990); MPFS (1989)

APPENDIX VI

Correlation between soil parameters and plant diversity of undisturbed forest.

	Sp_ri	N	P	K	pH	Hum	WHC	OM	SM	BD	Sand	Silt	Clay	Bio
Sp_ri	1.000													
N	0.474	1.000												
P	0.081	0.410	1.000											
K	0.246	.745*	0.531	1.000										
pH	0.251	0.554	0.512	0.236	1.000									
Humus	-0.202	0.412	0.178	0.227	0.516	1.000								
WHC	-0.228	-0.110	-0.176	-0.275	-0.340	-0.096	1.000							
OM	-0.031	0.384	.785**	0.326	.760*	0.513	-0.004	1.000						
SM	-0.203	-0.369	-0.353	-0.476	-0.429	-0.300	0.484	-0.485	1.000					
BD	0.446	0.152	-0.161	0.226	-0.185	-0.208	-0.076	-0.155	-0.427	1.000				
Sand	-0.357	-0.321	-0.542	-0.451	-0.330	0.122	0.168	-0.368	0.048	-0.350	1.000			
Silt	-.728*	-0.386	0.053	-0.112	-0.552	-0.142	0.346	-0.120	0.193	0.027	0.085	1.000		
Clay	.708*	0.426	0.239	0.254	0.310	-0.100	-0.073	0.093	0.231	0.236	-.774**	-0.484	1.000	
Bio	.658*	0.335	0.015	0.462	-0.132	-0.241	-0.593	-0.400	-0.198	0.301	-0.138	-0.395	0.352	1.000

* Correlation is significant at the 0.05 level (2-tailed).

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

(Note: Where, Sp_ri- species richness, N-nitrogen, P-phosphorus, K- potassium, pH-pH value, Hum-humus content,WHC-Water holding capacity, OM-organic matter, SM-soil moisture, BD-bulk density and Bio-tree biomass)

APPENDIX VII

Correlation between soil parameters and plant diversity of disturbed forest.

	Sp_ri	N	P	K	pH	Hum	WHC	OM	SM	BD	Sand	Silt	Clay	Bio
Sp_ri	1.000													
N	-0.130	1.000												
P	-0.369	0.104	1.000											
K	-0.159	-0.069	.832**	1.000										
pH	-0.115	-.806**	0.027	-0.066	1.000									
Hum	0.365	0.181	-0.180	-0.017	-0.612	1.000								
WHC	-.689*	-0.159	0.373	0.052	0.546	-.781**	1.000							
OM	-0.302	-0.015	-0.106	-0.346	0.454	-0.609	0.454	1.000						
SM	-.634*	-0.049	0.328	0.285	0.261	-0.601	0.451	0.456	1.000					
BD	-0.194	0.161	0.016	-0.463	0.288	-0.240	0.465	0.340	-0.250	1.000				
Sand	-0.245	.696*	-0.047	-0.239	-0.620	0.138	-0.013	-0.161	0.043	0.076	1.000			
Silt	0.254	-.699*	0.029	0.324	0.538	-0.064	-0.128	-0.079	0.019	-0.225	-.924**	1.000		
Clay	0.127	-0.444	0.063	0.100	0.537	-0.256	0.196	0.499	-0.042	0.107	-.858**	0.609	1.000	
Bio	0.462	-0.032	-0.368	-0.025	-0.124	0.037	-0.284	-0.242	-0.399	-0.188	-0.421	0.465	0.324	1.000

* Correlation is significant at the 0.05 level (2-tailed).

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

(Note: Where, Sp_ri- species richness, N-nitrogen, P-phosphorus, K- potassium, pH-pH value, Hum-humus content,WHC-Water holding capacity, OM-organic matter, SM-soil moisture, BD-bulk density and Bio-tree biomass)

PHOTO GRIDS

a. Disturbance on disturbed forest.

b. Disturbed forest.

c. Measuring DBH of a tree in undisturbed forest.

d. Taking soil sample.