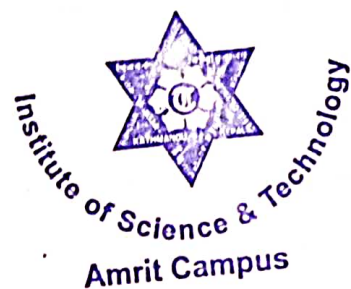


**PLANT DIVERSITY AND TREE CARBON STOCK IN SWAYAMBHU  
AND DAKSHINKALI SACRED GROVES OF KATHIMANDU DISTRICT  
CENTRAL NEPAL**



**A DISSERTATION SUBMITTED FOR THE PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE MASTER'S DEGREE IN BOTANY**

**By**

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**June, 2022**

## DECLARATION

I, Samrita Budhathoki, hereby declare that the dissertation work entitled “**Plant Diversity and Tree Carbon Stock in Swayambhu and Dakshinkali Sacred Groves of Kathmandu District, Central Nepal**” which is being submitted to Department of Botany, Amrit Campus, Tribhuvan University, for the award of Master's degree in Botany is a genuine research work done by me under the supervision of Dr. Laxmi Joshi Shrestha, Lecturer/ M. Sc Coordinator, Department of Botany, Amrit Campus. The research is original and has not been submitted or published earlier elsewhere, in whole or in part for the award of any degree. All the information cited in this piece of work are specifically acknowledged and credited to the respective authors or institutions as references.

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### RECOMMENDATION

This is to certify that the dissertation work entitled “**Plant Diversity and Tree Carbon Stock in Swayambhu and Dakshinkali Sacred Groves of Kathmandu District, Central Nepal**” carried out by Ms. Samrita Budhathoki under my supervision. The dissertation is primarily based on the data collected by the student herself and the results of this work have not been submitted for any other academic degree in any institutions. I, therefore, recommend this dissertation to be accepted for partial fulfillment of Master’s Degree in Botany from Amrit Campus, Tribhuvan University.

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### LETTER OF APPROVAL

This dissertation work entitled “Plant Diversity and Tree Carbon Stock in Swayambhu and Dakshinkali Sacred Groves of Kathmandu District, Central Nepal” submitted by Ms. Samrita Budhathoki to the Department of Botany, Amrit Campus, Tribhuvan University has been accepted for the partial fulfillment of the requirement for Master’s Degree in Botany (Ecology).

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*Samrita..*  
.....

Samrita Budhathoki

6<sup>th</sup> June, 2022

## ABBREVIATIONS AND ACRONYMS

GHGs	Green House Gases
IPCC	Intergovernmental Panel on Climate Change
CO <sub>2</sub>	Carbondioxide
%	Percentage
C	Carbon
FAO	Food and Agriculture Organization
UNFCCC	United Nations Framework Convention on Climate Change
REDD	Reducing emission from deforestation and forest degradation
AWGLCA	Ad hoc Working Group on Long Term Cooperative Action
MFSC	Ministry of Forests and Soil Conservation
cm	centimeter
ha	Hectare
DBH	Diameter at breast height
FRA	Forest Resource Assessment
DFRS	Department of Forest Research and Survey
t/ha	Tonne per hectare
IVI	Importance Value Index
SOC	Soil Organic Carbon
°C	degree celsius
km <sup>2</sup>	square kilometre
SSG	Swayambhu Sacred Grove
DSG	Dakshinkali Sacred Grove

UNESCO	United Nations Educational, Scientific and Cultural Organization
FSCM	Federation of Swayambhu Management and Conservation
GPS	Global Positioning System
g	gram
KATH	National Herbarium and Plant Laboratories
$K_2Cr_2O_7$	Potassium dichromate
$H_2SO_4$	Sulphuric acid
$Ag_2SO_4$	Silver sulphate
AGTB	Above Ground Tree Biomass
BGTB	Below Ground Tree Biomass
SPSS	Statistical Package for Social Sciences
sp.	Species
D-D	Density diameter

## ABSTRACT

Species diversity is the combination of species evenness and species richness. Sacred groves play significant role in conservation of rare and endemic species due to taboos and prohibitions. Nepal has centuries old traditions of establishing sacred groves of various size devoted to a particular deity. The relationship of tree diversity and carbon stock, an important concern of climate change mitigation and biodiversity conservation has been less studied in sacred groves of Nepal. This study aimed to assess the plant diversity and carbon stock in Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG) of Kathmandu district. To study diversity, IVI, regeneration, tree and soil carbon stock, altogether 77 plots were sampled in 9 parallel transects in SSG (30 plots) and 10 parallel transects in DSG (47 plots) by using systematic random sampling method. Circular plot of 10 m radius was laid for trees and within it, one concentric plot of 5 m radii for shrubs and 3 subplots of 1 m radius for herbs was laid. Soil samples were collected from surface upto 15 cm depth using core sampler (volume 356.5179 cm<sup>3</sup>) from the plot centre for estimation of bulk density and composite soil sample (one in the plot centre while other four in N, E, W and S directions) for estimation of soil organic carbon. Regeneration was assessed by using Density-Diameter (D-D) curve and calculating density of each tree species in seedling, sapling and tree phases. Tree biomass was calculated using allometric equation developed for moist forest and later converted into carbon stock using default factor. Altogether 115 species belonging to 57 families and 104 genera were recorded in the SSG and in DSG total 184 species belonging to 77 families and 159 genera were recorded. Shannon-Weiner diversity index (H) of plant species was found to be higher in DSG (H = 3.975) than in SSG (H = 3.213). The D-D curve showed reverse J-shaped size class distribution in DSG. Density of seedling, sapling and tree was higher in DSG than that of SSG. Tree carbon stock (113.76 t/ha) and soil carbon stock (18.31 t/ha) of SSG (113.76 t/ha) was found higher than tree carbon stock (79.87 t/ha) and soil carbon stock (17.93 t/ha) of DSG. Tree carbon stock showed non-significant weak positive correlation with species richness ( $r = 0.290$ ,  $p = 0.120$ ) and diversity index ( $r = 0.219$ ,  $p = 0.246$ ) in SSG but it showed non-significant weak negative correlation with species richness ( $r = - 0.077$ ,  $p = 0.607$ ) and diversity index ( $r = - 0.201$ ,  $p = 0.177$ ) in DSG. The findings of this study will be helpful to direct implication for the management and policies related to sacred groves for climate change mitigation and biodiversity conservation.

**Keywords:** Climate change, Regeneration, Species richness, Tree biomass

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# CHAPTER 1: INTRODUCTION

## 1.1 Background

Species diversity is an elemental multifaceted conception that incorporates species richness, abundance and evenness (Fisher *et al.*, 1943; Simpson, 1949 as cited by Purvis and Hector, 2000). Estimation of species diversity is used as vital component for characterization of community. The quantitative measure of the number of species present in a sample or community and their relative abundance is known as diversity index. Various indices are being used to determine the diversity of communities such as McIntosh (McIntosh, 1967), Margalef's index (Margalef, 1958), Simpson's index (Simpson, 1949), Shannon-wiener index (Shannon and Wiener, 1963 as cited by Thukral, 2010), etc. Among these, Simpson's index and Shannon-wiener index are most commonly used indices. Simpson's index is considered as dominance index as it gives more weight to common or dominant species whereas Shannon-wiener index is an information statistic index as it presumes all species are represented in a sample and they are randomly sampled (Gairhe, 2015). Diverse forest possesses high values of diversity indices while forest dominated by single species had lower values of diversity indices.

Global warming, one of the major problems the world is facing today has emerged due to the impact of Green House Gases (GHGs) released through anthropogenic activities such as fossil fuel combustion, land use change, industrialization, deforestation, etc (Le-Quere *et al.*, 2015). Of the GHGs, Carbon-dioxide (CO<sub>2</sub>) is the most important one computing of 76% of the total anthropogenic GHGs emissions (IPCC, 2014). Forests play a crucial role in global carbon (C) cycle as they store large quantities of C in vegetation and soil, exchange C with the atmosphere through photosynthesis and respiration particularly primary forest (McMohan, 2010). Forest ecosystem absorb CO<sub>2</sub> from atmosphere and store carbon in wood, leaves, litter, roots and soil by acting as “carbon sinks”. Overall, the world's forest ecosystems are estimated to store more carbon than the entire atmosphere (FAO, 2006). Unfortunately, the forest have been degraded and destroyed by human intervention like deforestation and degradation which has resulted in the emission of carbon into the atmosphere. The rapid changes in the dynamics of forests due to climate change have been acknowledged as crucial to sustaining the various ecosystem services that humanity depends on (Vayreda *et al.*, 2012). Thus, forest biomass estimation, its spatial distribution and changes over time, strategies for increase and conservation of forests have been subject of intensive research (Brown and Lugo, 1989).

Sacred groves has been defined as “A tract of virgin forest harboring rich biodiversity, protected by the local people based on the ground of indigenous cultural and religious beliefs and taboos” (Khumbongmayumi *et al.*, 2006). Human activities such as cutting wood for construction or firewood, hunting animals or other forms of resource extraction are strictly restricted in sacred groves due to taboos and prohibitions as a result they possess old growth vegetation, integrated nutrient cycling often with high soil fertility and many rare, endemic plant species of ecological and social values (Ramakrishnan, 1996).

Nepal has centuries old traditions of establishing sacred groves of various size devoted to a particular deity because of strong beliefs and traditions (Shrestha *et al.*, 2015). Current forest management regimes in Nepal included eleven different types, and the sacred grove is one of them. They are private forest, the government managed forest, protected forest, buffer zone forest, buffer zone community forest, conservation area, community forest, a sacred forest, collaborative forest, leasehold forest, and public land forest (FRA/DFRS, 2014). Nepal’s Forest Act 1992 has defined a sacred forest as a "Forest area that has been legally handed over to a legally registered religious group, communities, or organizations to carry out and continue traditional religious activities by sustainably utilizing its resources as described in its management plan." The influence of religious beliefs and rituals on forest conservation in Nepal is significant because they give rise to appropriate institutions and organizations for cooperative resource management and provide symbols of forest conservation in Nepalese society (Devkota, 2013). Out of 36 legally registered sacred groves covering an area of 2056 ha in Nepal, 12 sacred groves covering an area of 226.18 ha are present in the Kathmandu valley. The significant role of sacred groves in biodiversity conservation has been recognized long time back (Gadgil and Vartak, 1976; Haridasan and Rao, 1985; Khan *et al.*, 1997 as cited by Shrestha *et al.*, 2015). One of the prime objectives of ecology is to interpret the structure of such forest communities by relating their diversity with biomass and evaluating relationships between them (Hooper *et al.*, 2005; Keddy, 2005; Caspersen and Pacala, 2001).

Biodiversity and its relationship with the carbon cycle has become an important consideration in international efforts to minimize the problem of climate change, through reducing the conversion of natural ecosystems (Midgley *et al.*, 2010). The mechanism for reducing emissions from deforestation and forest degradation (REDD) has been primarily developed as a climate change mitigation option (UNFCCC, 2008). It has been expanded to include the roles of conserving and enhancing forest carbon stocks, and safeguarding biodiversity and local community life (Kohl *et al.*, 2009).The need for REDD to address biodiversity

conservation was recognized during negotiations in the Ad hoc Working Group on Long Term Cooperative Action (AWGLCA), when the scope of REDD schemes was broadened to include incentives for a wide array of forest management practices including conservation (Blom *et al.*, 2010). Increase in carbon stock with increasing biodiversity is beneficial through the view point of getting diverse forms of forest ecosystem services and tapping carbon trade money through REDD+ strategy. It is also a win-win scenario. Species richness is thought to enhance productivity through: a) Niche complementarity, where species have access to more available resources and enhance overall productivity (Tilman *et al.*, 2001); b) The selection effect, where a highly productive species is included in the community that store a lot of biomass (Loreau and Hector, 2001); c) The insurance effect, as one species contributes to the ecosystem productivity in one year and another species in another year (Yachi and Loreau, 1999). Hence, biodiversity conservation can be one of the effective strategies to mitigate the effects of global climate change.

## **1.2 Rationale**

Sacred groves contribute in providing habitat to local species that may otherwise become locally extinct in a changing landscape throughout Nepal (Devkota, 2013). There are inadequate conservation plans and policies of Government of Nepal for conservation of plant diversity of these sacred groves in National Biodiversity Strategy and Action Plan 2014-2020 (MFSC, 2014). There is paucity of data on the detail account of plant diversity in sacred groves of Kathmandu district to understand their potential role in biodiversity conservation (Shrestha *et al.*, 2015). In addition, carbon stock and biodiversity relationship which is an important issue for combating climate change through REDD+ mechanism has not been studied in sacred groves of Nepal (Shrestha *et al.*, 2020). Through REDD+ strategy, forests may be promoted to increase the high carbon stock bearing plants where the tree diversity may be less prioritized. While relating biodiversity with carbon stock, will it be possible to increase tree carbon stock along with tree diversity and to get benefitted from both the carbon stock and diversity. The Swayambhu is the most sacred among Buddhist pilgrimage site and Dakshinkali Temple is one of the major sacred temples for Hindus dedicated to goddess kali with long history of plant conservation due to taboos. In spite of their great religious importance and proximity from Kathmandu city, no such study has been carried in these sacred groves using this method. So, these sacred forests are selected for the present study. This study will establish baseline information for the carbon stock and tree diversity status of Swayambhu and Dakshinkali sacred groves of Kathmandu district. The study will also be helpful to direct implication for the management and policies related to sacred groves for climate change mitigation and biodiversity conservation.

## **1.3 Research Questions**

- What is the current status of plant diversity and regeneration of trees in Swayambhu and Dakshinkali sacred groves of Kathmandu district?
- Is there any significant difference in the tree carbon stock between two sacred groves?
- Is there any variation in soil carbon stock between two sacred groves?
- Is there any significant relationship of carbon stock with species richness and diversity of trees in two sacred groves?

## **1.4 Objectives**

The main objective of this study was to assess the plant diversity and carbon stock in Swayambhu and Dakshinkali sacred groves of Kathmandu district, Central Nepal. To achieve the goal of main objective following objectives were determined:

- 1) Comparative study of plant diversity and regeneration of trees in Swayambhu and Dakshinkali sacred groves of Kathmandu district.
- 2) To compare the tree carbon stock of two sacred groves.
- 3) To compare the soil carbon stock of two sacred groves.
- 4) Explore the relationship of carbon stock with species richness and the diversity of trees in two sacred groves.

## **1.5 Limitations**

Although the research was carefully designed and followed accordingly to get the reliable data for best results, however, some limitations are encountered and observed while performing the task. The major limitations of the study are as follows:

- Non-vascular plants were not included in the study.
- Diversity of epiphytic ferns was not included in the study.
- The study represents the carbon stock of tree biomass only. Biomass of shrubs, herbs and litter were not included.
- Soil carbon was calculated from single layer of 15 cm depth due to limitation of time and expenditure.

## CHAPTER 2: LITERATURE REVIEW

### 2.1 Plant Diversity and Other Community Attributes

Although Nepal occupies less than 0.1% of the Earth's land area, it is superfluously a species rich country. Current estimates of vascular plant's species richness denote that there are 550 species of pteridophytes (Fraser-Jenkins *et al.*, 2015), 41 species of gymnosperms (Shrestha *et al.*, 2018) and 5,309 species of angiosperms under 1,515 genera and 193 families (Rajbhandari *et al.*, 2017). In the middle mountain forest of Nepal, altogether 326 species of trees, 244 species of shrubs, 547 species of herbs (including flowering plants and pteridophytes), 109 species of climbers and 90 epiphyte species were recorded and also reported that about 94% of the sample plots were affected by the disturbances such as grazing, lathra cutting, tree cutting and lopping (DFRS, 2015).

Various researchers had estimated different number of species from forest of Kathmandu valley occupying different area. From Bajrabarahi forest having area 18 ha, 98 species of flowering plants including 44 tree species were recorded (Karmacharya *et al.*, 2003). Ranjitkar and Chaulagain (2004) enumerated altogether 104 plant species (98 angiosperms and 6 gymnosperms) which included species planted under afforestation program also from North-western slope of Swayambhu hillock. This study also revealed that the principle vegetation of hillock was made up of *Schima wallichii*, *Pinus roxburghii*, *Pyrus pashia* but the most predominant was exotic, cultivated species *Pinus roxburghii* with dominant ground layers of *Eupatorium adenophorum*, *Lantana camara*, *Justicia adhatoda*, etc.

Altogether 61 species including 17 tree species were reported by Ghimire *et al.* (2005) in Bhandarkhal forest with an area 6.75 ha. The study carried out to analyze the structural and community structure of the Ranibari forest enumerated 108 species of vascular plants belonging to 58 families and 92 genera (Maharjan *et al.*, 2006) and also revealed that the demand for recreational activities had increased the recreational pressure on the forests due to the increasing urban population.

The natural and anthropogenic disturbances can also affect the plant species diversity and growth. The composition of a forest depends on its size, past history, and natural disturbances (Levenson, 1981). Human activities such as trampling and soil compaction have a significant impact on the patterns of plant species diversity in forests. Trampling can exert enough pressure on soil to bring changes in plant species composition through compaction especially when such urban forests are lots near settlements (Bhujju and Ohsawa, 2001).

A study in understory plant diversity of urban forests in Central China revealed that species diversity was higher in suburban area than in urban areas. The species diversity of shrub and herb layers in urban forests was significantly affected by a gradient caused by visitor flow rate, shrub coverage, aspect, and neighboring land types (PenG-CHenG *et al.*, 2012). The principal driver of high understory species diversity in mature forests has been thought to be disturbance-mediated resource variability (Bartels and Chen, 2010).

Importance Value Index gives the overall importance of each species in the community. Species having high IVI values are considered as the dominant species which possess ecological success, good regeneration and greater ecological amplitude (Shameem and Kangaroo, 2011).

Poudyal *et al.* (2019) compared the composition and richness of tree species among regularly harvested community forests, irregularly harvested community forests, protected areas, national forests and demonstrated that regularly harvested community forests could be effective in supporting tree species richness and composition. The findings backed up the idea that both high and low forest disturbance do not promote tree species diversity and composition. Furthermore, according to this study community forests that are well-managed conserve ecologically important and fragile tree species. Anthropogenic disturbances affect urban forest ecosystems, including their structure and functioning. Such disturbances may result in the extinction of native and sensitive species in certain woodlands. Invasion success in urban forests was governed by forest structural characteristics and anthropogenic disturbances (Aryal *et al.*, 2021).

## **2.2 Forest Regeneration**

The phenomenon of growth of trees from fall-off seeds and germinate in-situ is known as regeneration (Harmer, 2001). The structure and composition of forest is ascertained by patterns of regeneration and its decisive factors. Regeneration is measured to determine whether it meets the objective of sustainable forest management and in particular, whether the productive capacity and biological diversity of forest are maintained (Lutze *et al.*, 2004 as cited by Awasthi *et al.*, 2015). The sustainable forest must have good regeneration, proper age class (age-gradation), normal increment and normal growing stock (Subedi, 2011).

The regenerating and productive character of forest is determined and characterized by the presence of sufficient population of seedlings, saplings and young trees of different age groups from young to old (Chauhan *et al.*, 2008). A population with sufficient number of

seedlings and saplings depicts satisfactory regeneration behavior, while inadequate number of seedlings and saplings of the species in a forest indicates poor regeneration (Tripathi and Khan, 2007). In context of Nepal, regeneration status of forest is considered to be good if it has seedling > 5000 and sapling > 2000 per hectare (MFSC, 2002). Density-Diameter (D-D) curve is another widely used parameter for study of regeneration. If the distribution of diameter class is such that maximum number of individuals is present at seedling stage and then decreases subsequently at the next level, the model is named as reverse J shaped curve. This signifies the good regeneration potential of the forest site (Chauhan *et al.*, 2008).

In the study of vegetation composition, biomass production and regeneration of *Shorea robusta* forest in Bardiya National park, the lower basal area, biomass and higher density showed that the forest were younger and in state of regeneration (Giri *et al.*, 1999).

The dynamic nature of forest canopies provides divergent regeneration niches to which different species have become specialist. Regeneration rely on various variables among which light environment is one important factor which affects natural regeneration and the germination of seeds (Denslow, 1987 as cited by Chikanbanjar *et al.*, 2020). Regeneration of light demanding species (herbs, shrubs and trees) are favored by open canopy which allows sufficient light to reach the forest understory providing suitable light environment for growth of seedling and sapling (Sapkota *et al.*, 2009).

The study of tree regeneration in Pashupati and Bajrbarahi sacred groves of Kathmandu valley reported higher number of seedling, sapling and adults in least disturbed areas showing good regeneration status of tree species. Tree species having good and fair regeneration status were *Pyrus pashia*, *Myrsine capitellata*, *Castanopsis indica*, *Neolitsea cuipala* (Shrestha *et al.*, 2015).

### **2.3 Tree Carbon Stock**

The majority of carbon stored in terrestrial ecosystems (about 60%) is stored in forest ecosystems. Forests are critical players in the global carbon cycle. Depending on the management regime and activities, they can be both sources and sinks of carbon (IPCC, 2000).

The carbon stock in forest vegetation differs according to geographical location, life zone, forest type, forest structure, plant species, age of the stand and degree of disturbances (Brown *et al.*, 1989; Dixon *et al.*, 1994). For young or degraded forests, forest management plays a

critical role in maximizing carbon storage (Zhang *et al.*, 2007). The biomass and carbon stock of forest increases with increasing forest age (Sedjo, 2001; Luyssaert *et al.*, 2008), tree density and area (Sedjo, 2001). Carbon sequestration is much faster in young, regenerating forests, whereas carbon stock is much higher in older, mature forests and it will be helpful to minimize the negative impacts of climate change (Luyssaert *et al.*, 2008).

The total air dried biomass of living trees (DBH  $\geq$  5 cm) in the middle mountains of Nepal is estimated to be 387.96 million tones. Out of it, forest contains 340.05 million tonnes (150.88 t/ha) (DFRS, 2015). Total carbon stock of *Schima-Castanopsis* forest in midhills of western Nepal, Palpa District was 178.52 t/ha (Shrestha, 2009) and total carbon stock in Chapako Community Forest of Kathmandu district was estimated 152.04 t/ha (Mishra, 2010). Urban forest carbon stock is an important aspect of the environment to attain carbon sequestration rate and also to conserve biodiversity. The study of carbon stock in Gokarna protected forest estimated the total biomass of standing trees 548.92 t/ha (Dhakal *et al.*, 2017). A study of carbon stock variance among trees in a planted forest in Kathmandu's Coronation Garden assessed a carbon stock of 196.4 Mg/h with 40.4 Mg/h below ground and 156 Mg/h aboveground (Bhatta *et al.*, 2018). Aryal *et al.* (2018) determined the total carbon stock (including soil carbon) 162.95 t/ha in the community forest of Kathmandu district. The diversity and density of trees were adversely associated to total carbon and biomass carbon in that forest.

The biggest share of aboveground biomass was contributed by trees with a diameter of (30–40) cm in the largest sacred grove of Manipur, Northeast India (Waikhom *et al.*, 2018). Tree carbon in the sacred groves of Central India ranged from 17.5 to 204.9 Mg/h with an average value of 97.0 Mg (Dar *et al.*, 2019). This study also found positive correlation of tree carbon stock with basal area of trees. The wildlife Sanctuary had a higher biomass and carbon content than the sacred forest of Western Odisha, India (Pradhan *et al.*, 2019).

Total basal area, large tree density, maximum diameter, species richness, and species diversity were found to be the most important variables affecting biomass carbon stock in the major forest types of Central Himalaya, India (Kaushal and Baishya, 2021). This study also discovered that huge trees make up to 65 percent of the growing stock. The increasing stock was significantly influenced by species dominance ( $R^2 = 0.707$ ,  $p = 0.001$ ).

## 2.4 Relationship of Tree Carbon Stock with Species Richness and Diversity

The study of carbon stock in three collaborative forest of Terai region showed very weak positive relationship between carbon stock and species richness whereas weak and negative relation between carbon stock and evenness (Mandal *et al.*, 2013). Day *et al.* (2014) showed a weak significant correlation between tree biomass and tree species diversity ( $r = 0.21$ ,  $p = 0.03$ ) in a study done in Central African Rainforests. The stem density and species richness of pioneer species were negatively correlated with increasing biomass in a study in Borneo forest of Indonesia (Imai *et al.*, 2014). Aryal *et al.* (2018) reported that the total carbon and biomass carbon were negatively related to the diversity and the density of trees.

Cardinale *et al.* (2011) also found positive relationship between species richness, productivity and biomass from meta-analysis. Chisholm *et al.* (2013) found a positive correlation between the species richness and productivity in a study of tropical and temperate forests at small spatial scales (20 m  $\times$  20 m). Significant affect of tree species richness ( $t = 1.98$ ,  $p < 1.98$ ), Shannon-Wiener diversity index ( $t = 2.00$ ,  $p < 0.05$ ) and evenness ( $t = 2.01$ ,  $p < 0.05$ ) on carbon sequestration in two sacred groves of Kathmandu valley was reported by Shrestha *et al.* (2016). A study on the forest carbon storage and species richness in FSC certified and non-certified community forest in Dolakha district, mean carbon stock of FSC certified community forest was higher (123.59 Mg/h) than the non-certified community forest (77.56 Mg/h) whereas forest carbon stock is favorably associated to species richness and negatively related to ecological threat index (Charmakar *et al.*, 2021).

## 2.5 Soil Carbon Stock

Soils are important players in the global carbon budget and greenhouse effect (Jha *et al.*, 2003). Several factors influence soil organic carbon including climate, vegetation type, nutrient availability, disturbance, land use and management practices (Six and Jastrow, 2002; Baker, 2007). It is highly altered by land use changes both quantitatively and qualitatively; nevertheless, better forest and cultivated soil management can increase the SOC pool (Shrestha, 2007). To keep the carbon balance in check, soil organic carbon supplies must be protected, and forest soils must be managed to increase carbon sequestration (Ostle *et al.*, 2009). *Quercus* and *Rhododendron* trees are excellent organic carbon sequesters in soil than Pine (Martin *et al.*, 2010). Within the same altitudinal zone and topographic, edaphic, and climatic conditions, mixed species forests have higher quantities of SOC than single species

dominated forests (Maraseni and Pandey, 2014). Organic C stock in forest floor generally increased with stand age. SOC was found decreasing with soil depth (Mishra, 2010).

SOC contents in different land-use types of Mardi watershed was estimated by Shrestha (2002) and reported highest SOC in the topsoil (0–10 cm depth) of grazing land with 34 t/ha followed by the cultivated upland (Bari) (20 t/ha), forestland (14 t/ha) and level terraces (Khet). A study on soil organic carbon stocks under different forest types in Pokhara khola sub watershed, Dhading estimated total soil carbon stock 42.523 t/ha in all forest types, Shorea forest 62%, *Schima-Castanopsis* forest 25%, *Pinus-Shorea* forest 5.5% and degraded forest 7.5 (Pradhan *et al.*, 2012). This study showed that soil organic carbon was higher in the upper layer (0–20) cm in all forest types and rapidly declined below the (20–40) cm depth.

Total SOC stock in Bhedawari forest of Nawalpur district was calculated as 33.91 t/ha and also reported that aspect had made a significant influence ( $p = 0.002$ ) on SOC stock (Adhikari and Ghimire, 2019). In the northern aspect ( $36.83 \pm 1.34$  t/ha), the total SOC was higher than in the southern aspect ( $30.98 \pm 1.22$  t/ha).

## 2.6 Studies on Sacred Groves of Nepal

The study conducted in the Lumbini sacred grove recorded total 65 tree species, out of which 39 were indigenous (Bhattarai and Baral, 2008). This study had reflected the importance of sacred grove in ex-situ conservation of trees as the majority of them were produced by plantation.

In the Phytosociological Assessment of Sacred Groves in Kathmandu Nepal, three different forest types viz, *Schima-Pyrus* dominated by *Schima wallichii* (IVI = 81.4), *Myrsine-Persea* dominated by *Myrsine capitellata* (IVI = 142.0) and *Quercus-Myrsine* with dominant species *Quercus glauca* (IVI = 138.5) were identified on the basis of importance value in Pashupati sacred grove and only one type of forest dominated by *Neolitsea cuipala* in Bajrabarahi sacred grove (Shrestha *et al.*, 2015). The Shannon-Weiner species diversity index, evenness and number of tree species of Pashupati sacred grove were higher than that of Bajrabarahi sacred grove. Sharma *et al.* (2015) recorded 21 species of tree, including two species of shrub in two different types of forests, Rhododendron and oak in the study of Forest diversity and carbon sequestration in Resunga sacred grove, Gulmi, Nepal. Comparing the forest type, Rhododendron forest was more diverse ( $H = 1.0$ ) than oak forest ( $H = 0.9$ ). Similarly, tree species were more evenly distributed (0.87) in the oak forest than that of *Rhododendron* forest (0.77). Average vegetation carbon stocks in the Resunga sacred grove (RSG) was estimated to

be 127.75 t/ha whereas the vegetation carbon stock of Rhododendron forest was lower (101.8 t/ha) than that of oak forest (153.8 t/ha) (Sharma *et al.*, 2015).

A study on the carbon sequestration potential of two sacred groves in Kathmandu valley viz, Pashupati sacred grove (PSG) and Bajrabarahi sacred grove (BSG), tree species of both sacred groves sequestered 15.08 metric tons of carbon in total. The carbon stock in *Quercus-Myrsine* forest was high but it was low in *Schima-Pyrus* forest (Shrestha *et al.*, 2016). Altogether 23 tree species were recorded from PSG whereas only 19 tree species were recorded from BSG (Shrestha *et al.*, 2020). The diversity indices were higher in PSG than in BSG.

Despite the above mentioned studies, detail knowledge on plant species composition, carbon stock and its relationship with species diversity in sacred groves of Kathmandu district is still lacking currently. Thus this research work was carried out in Swayambhu and Dakshinkali sacred groves of Kathmandu district to fulfill a research gap.

## CHAPTER 3: MATERIALS AND METHODS

### 3.1 Study Area

Study area is located in Kathmandu district, Central Nepal. This district is located from 27°27'E to 27°49'E longitude and 85°10'N to 85°32'N latitude at an elevation of approximately 1,400 metres (4,600 feet) above sea level. It covers an area of 395 km<sup>2</sup>. Present study was carried out in Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG) of Kathmandu district.

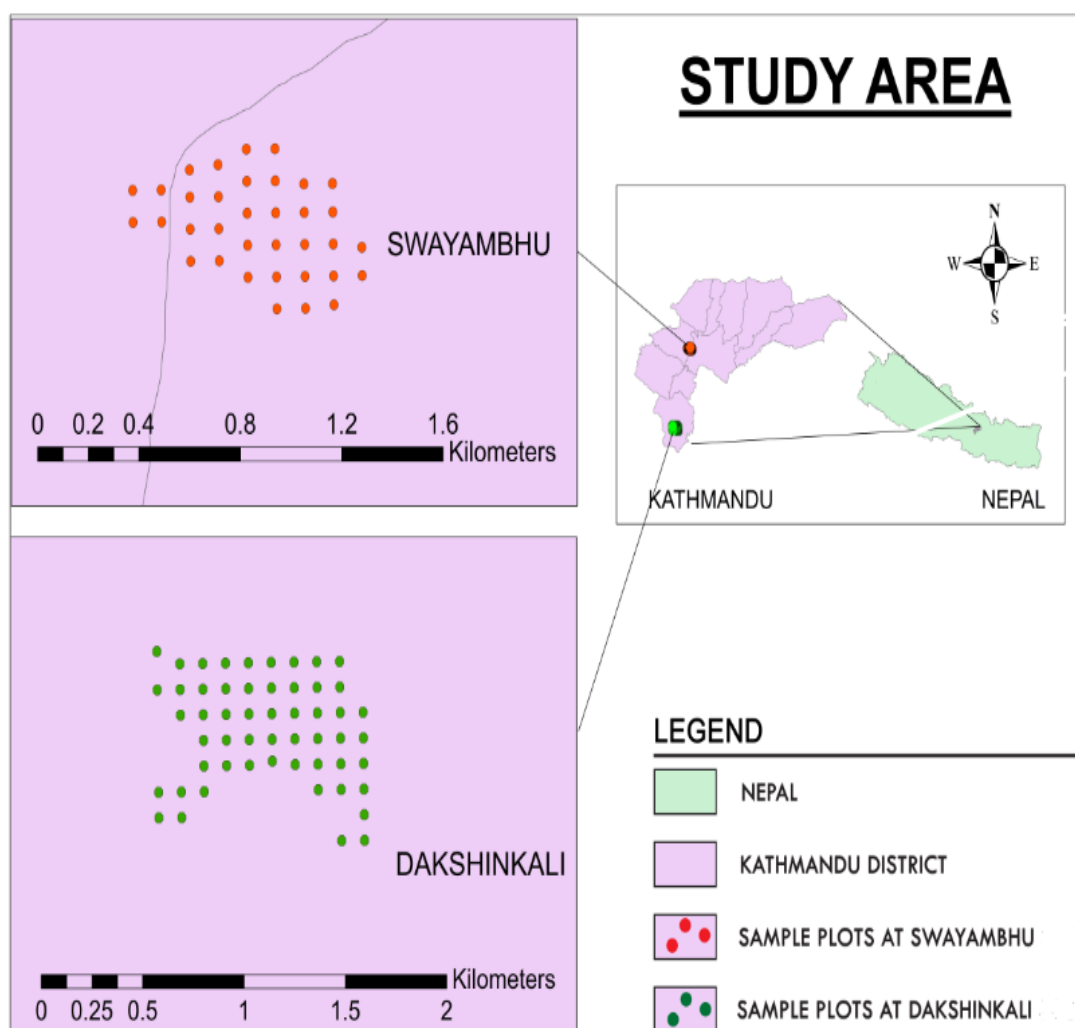


Fig 1: Map of the study area showing sampling plots.

### 3.2 Climate

Climate of study area varies from subtropical to lower temperate. The average maximum temperature ranged from 19.93°C to 30.57°C and temperature was highest in the month of June whereas average minimum temperature ranged from 2.69°C to 20.27°C and the least

temperature was recorded in the month of January. The average annual rainfall was highest in the months of July and August. Least mean rainfall was recorded in the months of November and December. Average monthly rainfall was 125.26 mm and average annual rainfall was 1503.11 mm (Fig 2).

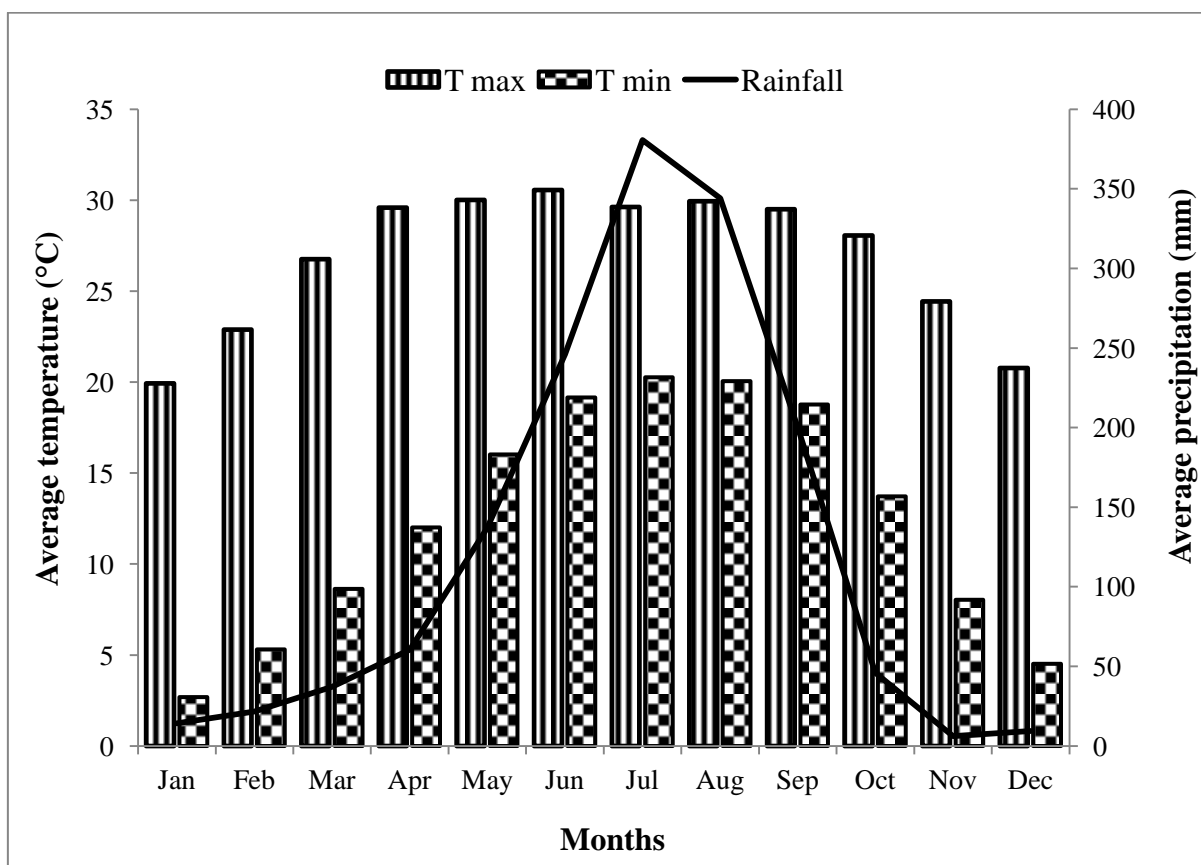


Fig 2: Average maximum-minimum temperature and rainfall of last 30 years (1989-2019) of Airport station, Kathmandu.

(Source: Department of Hydrology and Meteorology, GoN, Kathmandu, Nepal)

### 3.2.1 Swayambhu Sacred Grove (SSG)

Swayambhu sacred grove is one of the holiest chaitya for Buddhism located in the northwest of the Kathmandu city lying at 27°43'1.19"N, 85°17'15.90"E and ranges from about 1350 m to 1405 m of altitude. This sacred grove has its unique significance and listed in world heritage site by UNESCO in 1979. For the Buddhist Newars, Swayambhu occupies central position in mythological history and origin myth as well as day to day religious practice. It was formerly considered that the hilltop was an extension of Nagarjun Mountain, but it has now been encroached upon and standing as urban forest under the influence of human communities. The hillock's forest land area (including monuments) has been decreased to

approximately 31.38 hectare due to human encroachment, such as development activities and residential area growth. Exotic and naturalized species now occupy the majority of the forest, mainly on the southern slope. It possesses diverse sub-tropical vegetation and wildlife. Swayambhu's flora is unique in that it has been an important plant gathering location since the beginning of Botanical research in Nepal in 1802/03 AD (Ranjitkar and Chaulagain, 2004). The Federation of Swayambhu Management and Conservation (FSCM), a government entity, is primarily responsible for the grove's management.

### **3.2.2 Dakshinkali Sacred Grove (DSG)**

Dakshinkali is a sacred grove located 22 kilometers south of Kathmandu, which lies at 27°37'11"N, 85°15'04"E and an elevation of 1550 m. It is a native divinity emblem dedicated to the Goddess Kali, benevolent mother who protects her devotees and children from mishaps and misfortunes. Kali is regarded by Hindus as the greatest, dark feminine power tasked with destroying evil. People worship her as a mother figure during religious festivals and wedding rituals, as well as whenever they are in need of comfort. Individuals have long been involved in the grove's cautious and courteous upkeep. It covers an area of 56 hectare and is managed by a local community "Dakshinkali Area Development Committee". This sacred grove located in semi-urban area of Kathmandu is a home to a diverse range of aquatic and terrestrial plants and wildlife, as well as significant water supplies that are available to nearby families via tap water.

## **3.3 Methods**

### **3.3.1 Reconnaissance and Preparation of Field Sampling**

The designated study sites, SSG and DSG were surveyed first to collect general information about topographies, slopes, aspects, major vegetation types. The exact study strategies were designed afterwards. Prior to field work, preliminary field visit was conducted in May, 2019 to test the designed field data sheet, familiarized with the technique plot centre navigation by using uploaded coordinates in GPS and tree height measurement using clinometer. All the necessary instruments were gathered to accomplish field visit and data collection.

### **3.3.2 Sampling Design and Data Collection**

Field data for this study were collected from June to August 2019 by using a systematic random sampling method. Although the herbs are seasonal and needs to be studied seasonwise, data of only one season were collected for the study including herbs. Forest

boundary of the study area was delineated and sample plots were created with help of Google earth image in parallel transects traversing north-south direction at 100 m interval. There were 9 parallel transects at SSG and 10 parallel transects at DSG. During sample plot creation, first plot was placed 25 m inside the forest margin randomly to reduce edge effect and other plots were placed subsequently at 100 m distance from each other. Altogether 89 sample plots were created (35 in SSG and 54 in DSG) according to the sampling design. Out of which 77 plots were sampled (30 in SSG and 47 in DSG) and 12 were inaccessible. The coordinates of sample plots were uploaded in GPS and concentric circular plots were established in the field by navigating the plot centre with the help of GPS coordinates (FRA/DFRS, 2014).

Circular plot of 10 m radius (area 314.2857 m<sup>2</sup>) was laid out from the centre of the plot with the help of measuring tape and rope. A concentric circular plot of 5m radii (area 78.5714 m<sup>2</sup>) was laid within each quadrat for sampling of saplings and shrubs. For the ground layer *i.e.*, woody seedlings and herbaceous species, 1 m radius sub plot (area 3.14286 m<sup>2</sup>) was laid in the plot centre and one each in East and West directions (FRA/DFRS, 2014). Species enrouted inside each plot was recorded and coverage was noted by using visual estimation method. Likewise, for regeneration saplings were considered as young trees with diameter 2 to 5 cm and height > 1.3 m. Similarly, tree seedlings were those with diameter < 2 cm and height < 1.3 m as recommended by FRA/DFRS (2015).

Within each plot, diameter of each tree was measured at the breast height (1.37 m) with the help of DBH tape starting from the eastern edge and working inwards marking each tree to prevent accidentally counting it twice. Angle between observer and tree was measured with the help of clinometer and distance between tree and observer was measured with the help of measuring tape. Tree with DBH less than 5 cm was excluded for carbon stock measurement (Chave *et al.*, 2005). Canopy cover (%) for each plot was estimated visually from the centre of the plot. Anthropogenic disturbances such as road construction, rubbish dumping, picnic spot, permanent structure, erosion, fencing, access track within each plot were also recorded in the data sheet. Individual tree which was logged, cut or burnt, fallen dead in each plot were counted to study anthropogenic disturbances of tree and vegetation. Slope and aspect was taken with the help of clinometer. The tree height of each tree was determined by using clinometer and trigonometric ratio.

### **3.3.3 Soil Sampling**

Soil samples were collected from five soil pits (15 cm×15 cm×15 cm), one in the plot centre while other four in N, E, W and S directions (FRA/DFRS, 2014), 10 m far from plot centre. The collected soil samples (200 g from each pit) were mixed thoroughly and about 200 g of composite soil was packed in a zipper bag. The soil samples were air dried and stored in air tight zipper bags until laboratory analysis. Soil sample for estimation of bulk density was collected separately from the plot centre using core sampler of volume 356.5179 cm<sup>3</sup> (Metallic cylinder with diameter 5.5 cm and height 15 cm).

### **3.3.4 Plant Collection, Herbarium Preparation and Identification**

Specimens of trees, shrubs, herbs and pteridophytes encountered in sampling plots were collected, tagged and pressed in the field using newspaper and herbarium press. The local names of most of the specimens were recorded by consulting with local people and for scientific name Shrestha (1998) was consulted. Colour of the flower (only available), fruit, fragrance or any special features of the plants collected was noted in the field note book. When the plant specimens were completely dry, they were mounted on herbarium sheet of 16.5" × 11" using glue and labeled in accordance to Press *et al.* (2000). The herbarium specimens were identified using references such as Rajbhandari and Rai (2017) and also with the help of taxonomic experts. The herbarium specimens were also tallied with the specimens of National Herbarium and Plant Laboratories, Godawari (KATH). For the nomenclature of specimens, Annotated checklist of the flowering plants of Nepal was followed (Press *et al.*, 2000).

## **3.4 Soil Analysis**

Soil samples were analyzed at the research laboratory in the Department of Botany, Amrit Campus.

### **3.4.1 Soil Organic Carbon Estimation**

Organic carbon content in the soil was calculated by Walkley and Black's rapid titration method (1934). Soil sample was sieved through fine sieve (0.5 mm). Then 0.5 g fine sieved soil sample was taken in a 500 ml conical flask and 10 ml of 1N K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> and 20 ml of conc. H<sub>2</sub>SO<sub>4</sub> (containing 1.25% Ag<sub>2</sub>SO<sub>4</sub>) was added with gentle swirling. The digestion reaction being exothermic, the flask was left for about 30 minutes to cool down to room temperature. To that mixture 200 ml distilled water, 10 ml orthophosphoric acid and 1 ml diphenylamine

indicator solution were added and shaken well. Then the mixture was titrated against ferrous ammonium sulphate solution (0.5 N) with constant stirring until the colour changes from blue-violet to bright green. The volume of ferrous ammonium sulphate solution used for titration was noted. Concurrent reading of three replications of each soil sample was taken for soil carbon estimation. A blank titration (without soil) was carried out at every lot of 20 samples in a similar manner as the control system (Ranjitkar, 2010).

Volume of 0.5N ferrous ammonium sulphate solution used for blank titration: B

Volume of 0.5N ferrous ammonium sulphate consumed with soil: C

Normality of ferrous ammonium sulphate: N

$$\text{Estimated percent carbon in soil (\% C)} = N \frac{B-C}{\text{Weight of soil (g)}} \times 0.003 \times 100 \quad (\text{Gupta, 2000})$$

$$\text{Organic carbon (\% OC)} = \text{organic carbon estimated (\% C)} \times 1.3$$

$$\text{Soil organic matters (\% OM)} = \text{organic carbon} \times 1.724$$

In this procedure, incomplete oxidation of the organic matter takes place. Therefore, the organic carbon obtained by above method was multiplied by a factor 1.3 based on assumptions that there is 77% recovery. To determine organic matter content of soil, this organic carbon was multiplied by Van Bemmelen factor of 1.724 (Gupta, 2000).

### 3.4.2 Bulk Density

Soil bulk density at 15 cm depth was determined using core sampler of volume 356.5179 cm<sup>3</sup> (Metallic cylinder with diameter 5.5 cm and height 15 cm). The soil samples were collected without disturbing the natural structure. The samples were oven-dried at 70°C until constant weight to determine dry weight (Subedi *et al.*, 2010). The weight of oven dried soil samples divided by its volume gave the bulk density.

$$\text{Bulk density } (\rho) = \frac{\text{Oven dried weight of soil}}{\text{Volume of soil corer}}$$

### 3.5 Analysis of Plant Community Structure

Quantitative analysis of community structure was done using Zobel *et al.* (1987) as follows:

### 3.5.1 Density and Relative Density (RD)

Density is the numerical strength of a species where the total number of individuals of each species in all the quadrats is divided by the product of total number of quadrats studied and area of single quadrat. Density is calculated by the equation:

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

Relative density is the study of numerical strength of a species in relation to a total number of individuals of all the species and it is calculated as:

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

### 3.5.2 Frequency and Relative Frequency (RF)

Frequency deals about degree of dispersion of individual species in an area and usually expressed in terms of percentage and can be calculated as:

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

Relative frequency is the degree of dispersion of individual species in relation to the dispersion of all the species occurred and calculated as:

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

### 3.5.3 Percentage cover and Relative cover (RC)

Percentage cover was calculated to describe canopy coverage in percentage of each plant species around its habitat and calculated as:

$$\text{Average Coverage} = \frac{\text{Total coverage of species}}{\text{Total no.of quadrats}}$$

Relative coverage is the coverage of an individual species in relation to the total coverage of the all the species and calculated as:

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

### 3.5.4 Importance Value Index (IVI), Diversity Index and Evenness

The importance value index (IVI) is a metric for determining how dominant a species is in a certain forest. It was calculated by using formula given by Zobel *et al.* (1987).

$$\text{Importance Value Index (IVI)} = \text{RD} + \text{RF} + \text{RC}$$

Where, RD= Relative density

RF= Relative frequency

RC= Relative cover

### 3.5.5 Plant Diversity Index and Evenness

Diversity indices are numerical representations of biodiversity in several dimensions (richness, evenness, and dominance). The Shannon-Wiener index was used to calculate the diversity of plant species by using the given formula.

$$\text{Shannon-Wiener Index (H)} = - \sum \text{Pi}(\ln\text{Pi}) \quad (\text{Shannon and Wiener, 1963})$$

Where, Pi= proportion of individual species

$$\text{Evenness} = \frac{\text{H}}{\text{Hmax}}$$

Where, H= Shannon-Wiener Index

Hmax = Ln (Species richness)

### 3.5.6 Index of Similarity (IS) and Maturity Index

The index of similarity determines the degree of resemblance between two stands based on quantitative characteristics of species found in both. It was calculated by using formula given by Sorenson (1948).

$$\text{IS} = \frac{2W}{A+B} \times 100 \quad (\text{Sorenson, 1948})$$

Where, W = Number of common species in two stands/communities

A = Total number of species in stand/community A

B = Total number of species in stand/community B

The maturity index determines the degree of maturity of plant communities based on the frequency percentage of each species and the number of species present in the habitat. The higher the frequency percentage of each species and the smaller the number of species, the more mature the plant community. The value of maturity index must vary between 0 and 100 and for forest it generally varies from 11 to 20 (Pichi-Sermolli, 1948). It was calculated by using formula given by Pichi-Sermolli (1948).

$$\text{Maturity Index} = \frac{\text{Sum of frequencies of individual species in the habitat}}{\text{Total number of species in the habitat}} \quad (\text{Pichi-Sermolli, 1948})$$

### 3.5.7 Regeneration Status of Forest

The Density-Diameter (D-D) curve and seedling/ sapling/ tree density relation was used to study regeneration status of trees. The D-D curve was plotted for each individual tree based on the DBH class. The criteria used to evaluate the regeneration status of trees were as follows: a) 'good', if seedling > sapling > trees, b) 'fair', if seedling > sapling ≤ trees, c) 'poor', if a species survives in only sapling stage but not as seedlings, d) 'none', if a species is absent in both sapling and seedling stages, e) 'new' if a species has no adults, but only saplings or seedlings or both (Shankar, 2001). For the determination of regeneration status of forest, density of seedling, sapling and trees of each species was calculated separately and compared with community forestry inventory guideline. The regeneration is good if seedlings density is above 5000 per hectare, fair if between 2000 and 5000 per hectare and poor if less than 2000 per hectare. Similarly, the regeneration is good if sapling density is above 2000 per hectare, fair if between 800 and 2000 per hectare and poor if less than 800 per hectare (MFSC, 2002). Density was calculated by using the formula given by Zobel *et al.* (1987). Count of total plant was obtained by the summation of the number of plants from all sampling plots.

$$\text{Density (stem/ha)} = \frac{\text{Total number of individual of each species in each life form}}{\text{Total number of plots studied} \times \text{size of plot (m}^2\text{)}} \times 10000$$

### 3.5.8 Basal Area

Basal area is defined as total cross-sectional area of all stems in a stand measured at breast height expressed as a unit of land area (typically square meter per hectare). Basal area of species is considered as a measure of its dominance. Larger the basal area higher is its dominance. The basal area of a tree species was computed using the following method after measuring the diameter of an individual tree at breast height (1.37 m).

$$\text{Basal area (BA)} = \frac{\pi (\text{dbh})^2}{4} \quad (\text{Zobel } et al., 1987)$$

Basal area of trees in each quadrat was obtained by the summation of BA of all trees in the quadrat.

### 3.6 Estimation of Biomass and Carbon Stock

#### 3.6.1 Tree Biomass Estimation

The allometric models developed for the sub-tropical moist forest (annual precipitation 1,500-3,500 mm) by Chave *et al.*, (2005) was used for estimation of the above - ground biomass of tree (dbh  $\geq$  5 cm) (AGTB).

$$\text{AGTB} = 0.0509\rho D^2H \quad (\text{Chave } et al., 2005)$$

Where,

AGTB = above ground tree biomass (kg)

$\rho$  = wood specific gravity ( $\text{g/cm}^3$ )

D = diameter of tree at breast height (cm)

H = height of tree (m)

The wood specific gravity was extracted from global data-base (Zanne *et al.*, 2009). Root to shoot ratio value of 1:5 (20% of AGTB) was used to find below-ground biomass (Mac Dicken, 1997).

#### 3.6.2 Tree Carbon Stock Estimation

The biomass stock densities were converted to carbon stock densities (weight of carbon in the tree) by using the IPCC (2006) carbon fraction of 0.47. Total carbon stock density (in  $\text{kg/m}^2$ ) of tree in sacred grove was calculated by summing up above-ground and below-ground carbon stock. This value was converted to ton/ha by multiplying it with 10 (GoN, 2011). The weight of  $\text{CO}_2$  is  $\text{C} + 2 \times \text{O} = 43.99915$ . Hence the ratio of  $\text{CO}_2$  to C is calculated as:  $43.99915/12.001118 = 3.6663$ . Therefore, weight of carbon in the tree was multiplied by 3.67 to determine the weight of carbon dioxide sequestered (Sharma *et al.*, 2014). The percentage contribution of C-stock of each species in a forest was calculated by dividing the amount of carbon stock (t/ha) of all species in the forest by the sum of carbon stock of a particular species on the same forest.

$$\text{Carbon stock (\%)} = \frac{\text{Carbon stock of a particular tree species}}{\text{Sum of carbon stock of all tree species}} \times 100$$

### 3.6.3 Soil Carbon Stock Estimation

The soil carbon stock of air dried composite soil sample of each sample plot was calculated using the equation given below

$$\text{Soil carbon stock (C t/ha)} = \rho \times d \times \% \text{ C} \quad (\text{Pearson } et \text{ al.}, 2007)$$

Where,  $\rho$  = Soil bulk density ( $\text{g cm}^{-3}$ )

$d$  = depth at which the sample is taken (cm)

$\% \text{ C}$  = soil organic carbon (%)

### 3.7 Data Analysis Method

Ms-Excel 2010, the Statistical Package for Social Sciences (SPSS) version 25.0 and R software were used to conduct all statistical analyses. The data was first checked for normality using the SPSS 25.0 edition of the software (Shapiro test). The Shapiro-Wilk test of normality ( $p > 0.05$ ) was used to determine the normality of the data and non-normal data was transformed by Log or root transformation method before mentioning normality.

- Independent sample t-test was used to compare the mean values of total species richness, diversity index, evenness and tree carbon stock of two sacred groves.
- Diversity and evenness among different forest layer of two study sites were compared using Wilcoxon Signed Ranks Test.
- Mann-Whitney U Test was used to compare mean values of soil carbon stock between two study sites.
- Correlation among all the variables used in the study was studied using correlation coefficient matrix. The correlation of tree carbon stock with diversity, species richness, DBH and basal area of tree was investigated using Pearson's correlation analysis. The association was examined using linear regression analysis.

## CHAPTER 4: RESULT

### 4.1 Plant Diversity and Other Community Attributes

#### 4.1.1 Plant Species Richness

In the present study, 115 species of vascular plants which belong to 57 families and 104 genera were recorded in the Swayambhu sacred grove (SSG) among which 65 species were herbs followed by 30 species of trees and 19 species of shrubs (Fig 3). The richest family was Asteraceae with 12 species. A total of 184 species were recorded in the Dakshinkali sacred grove (DSG) belonging to 77 families and 159 genera (Annex: 2.1). Among these recorded species, 110 species were herbs followed by 40 species of trees and 34 species of shrubs (Fig 3). Poaceae was the richest family with 14 species in the Dakshinkali sacred grove (DSG) and *Drynaria propinqua*, *Selliguea oxyloba*, *Pyrrhosia stenophylla* and *Lepisorus scolopendrium* were epiphytic pteridophytes hence only listed (Annex: 2.1).

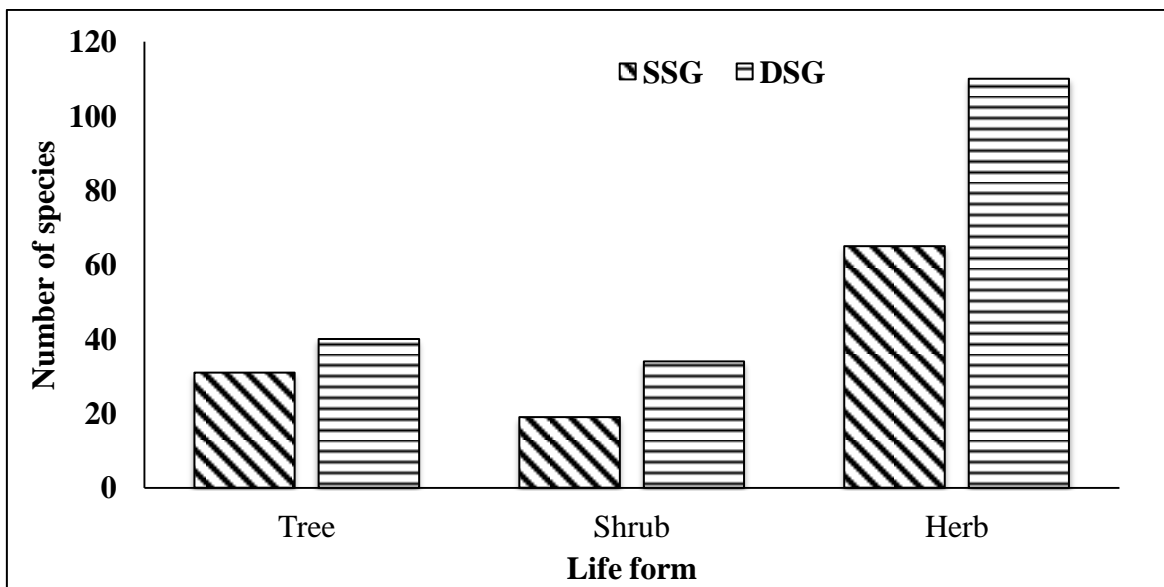


Fig 3: Total number of species by their life forms in Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

There was significant difference in mean values of total species richness ( $p = 0.000$ , Table 1), tree species richness ( $p = 0.030$ , Table 1), shrub species richness ( $p = 0.000$ , Table 1, Annex: 3.1) and herb species ( $p = 0.000$ , Table 1) between SSG and DSG. DSG had higher species richness than SSG.

Table1: Independent Samples T-test of tree species richness, shrub species richness, herb species richness and total species richness between Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

Independent Samples Test		
Variables	<i>p-value</i>	<i>t-value</i>
Tree species richness	0.030	2.279
Shrub species richness	0.000	-7.356
Herb species richness	0.000	-16.108
Total species richness	0.000	-6.29
Significant at the 0.05 level (2-tailed)		

#### 4.1.2 Plant Diversity and Evenness

The value of Shannon-Weiner diversity index (H) of total plant species was found to be higher in DSG (H = 3.975, Fig 4) than in SSG (H = 3.213, Fig 4). Value of evenness was also found to be higher in DSG (E = 0.788, Fig 4) in comparison to SSG (E = 0.649, Fig 4). T-test also showed significant difference in mean values of Shannon-Weiner diversity index (H) ( $p = 0.000$ , Table 2, Annex: 3.2) and evenness ( $p = 0.000$ , Table 2) of total plant species between SSG and DSG.

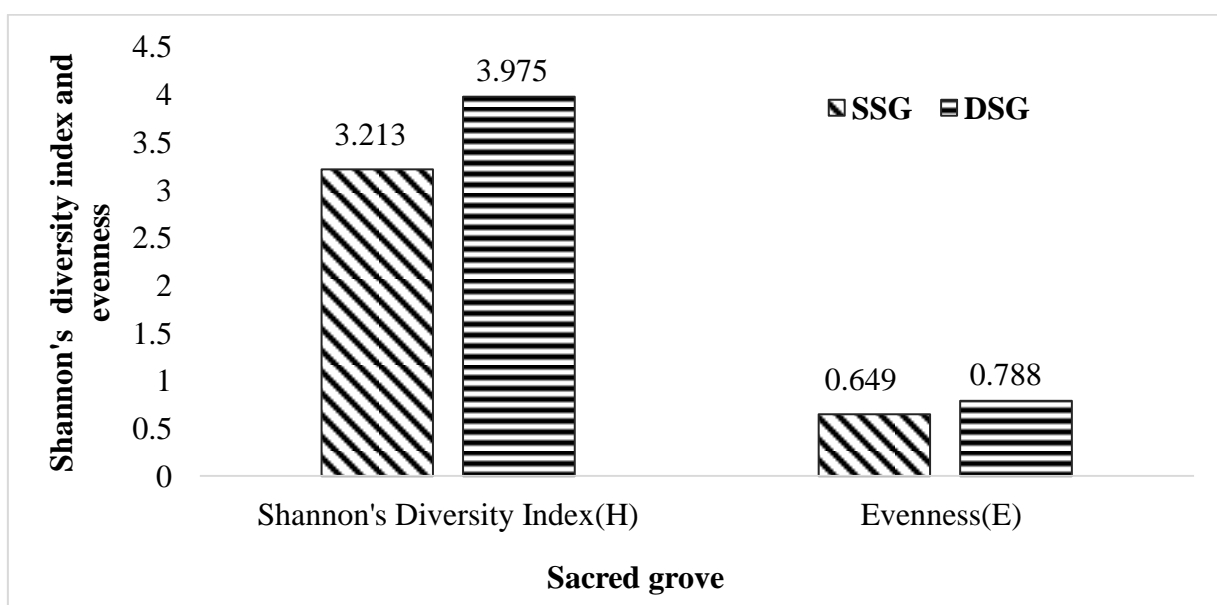


Fig 4: Shannon-Weiner diversity index (H) and evenness of total plant species between Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

Table 2: Independent Samples Test of Shannon-Weiner diversity index (H) and evenness of total plant species between Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

<b>Independent Samples Test</b>		
<b>Variables</b>	<b><i>p-value</i></b>	<b><i>t-value</i></b>
Shannon's Diversity Index(H)	0.000	-7.597
Evenness(E)	0.000	-5.185
Significant at the 0.05 level (2-tailed)		

The values of Shannon-Weiner diversity index (H) for trees, shrubs and herbs were 1.844, 2.169 and 2.654 respectively in SSG while 2.095, 3.481 and 3.719 in DSG. Values of evenness were 0.542, 0.5960 and 0.619 respectively in SSG and 0.568, 0.837 and 0.766 respectively in DSG for trees, shrubs and herbs (Table 3). Population mean ranks of total plant diversity (T\_H) was significantly different with tree diversity (Tr\_H) ( $p = 0.000$ ) and shrub diversity (Sh\_H) ( $p = 0.000$ ) but not with herb diversity (Hb\_H) ( $p = 1.000$ ) while total evenness (T\_E) showed significant difference with evenness of herb (Hb\_E) ( $p = 0.001$ ) but insignificant difference with evenness of trees (Tr\_E) ( $p = 0.102$ ) and shrubs (Sh\_E) ( $p = 0.504$ ) in SSG. Population mean ranks of total plant diversity (T\_H) was significantly different with tree diversity (Tr\_H) ( $p = 0.000$ ), shrub diversity (Sh\_H) ( $p = 0.000$ ) and herb diversity (Hb\_H) ( $p = 0.000$ ) whereas total evenness (T\_E) showed significant difference with evenness of trees (Tr\_E) ( $p = 0.003$ ) and shrubs (Sh\_E) ( $p = 0.002$ ) but insignificant difference with evenness of herb (Hb\_E) ( $p = 0.180$ ) in DSG (Annex: 3.3) .

Table 3: Values of Shannon's Diversity Index and Evenness for trees, shrubs-sapling and herbs-seedling of Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

<b>Forest Layer</b>	<b>Shannon's Diversity Index (H)</b>	<b>Evenness</b>	<b>Sacred grove</b>
Tree	1.844	0.542	SSG
	2.095	0.568	DSG
Shrub	2.169	0.596	SSG
	3.481	0.837	DSG
Herb	2.654	0.619	SSG
	3.719	0.766	DSG

### 4.1.3 Importance Value Index (IVI)

In SSG, *Pinus roxburghii* had highest IVI (93.90) followed by *Schima wallichii* (89.54), *Pyrus pashia* (24.68) and *Ficus benjamina* (8.02) whereas *Michelia champaca* had lowest IVI (1.33) among trees (Annex: 4.1). Among shrubs, *Justicia adhatoda* had highest IVI (55.77) followed by *Lantana camara* (40.80), *Cyathula tomentosa* (39.76) and *Boehmeria platyphylla* (25.45) whereas species like *Cestrum nocturnum*, *Hibiscus* sp., *Syzygium cumini* (sapling) were found to have lowest IVI (1.23) (Annex: 4.2). Similarly in herb layer, *Oplismenus burmannii* had highest IVI (71.50) followed by *Bidens pilosa* (34.03), *Achyranthes bidentata* (30.16) and *Eupatorium adenophorum* (26.67) whereas *Crassocephalum crepidioides* had lowest IVI (0.26) (Annex: 4.3).

In DSG, *Pinus roxburghii* had highest IVI (106.93) followed by *Schima wallichii* (48.93), *Alnus nepalensis* (37.45) and *Castanopsis indica* (13.36) whereas species like *Cedrus deodara*, *Maesa chisia* and *Rhus javanica* were found to have lowest IVI value (0.59) among trees (Annex: 4.4). In shrub layer, *Phyllanthus parvifolius* had highest IVI (29.01) followed by sapling of *Schima wallichii* (26.56), sapling of *Lyonia ovalifolia* (19.04) and *Urena lobata* (14.94) whereas *Cassia floribunda* had lowest IVI (0.41) (Annex: 4.5). Likewise in herb layer, *Oplismenus burmannii* had highest IVI (32.21) followed by *Capillipedium assimile* (20.07), *Scutellaria discolor* (18.19) and *Eupatorium adenophorum* (14.93) whereas species like *Centella asiatica*, *Trifolium repens*, *Drosera* sp., *Persicaria lapathifolia* were found to have lowest IVI (0.14) (Annex: 4.6).

Table 4: Plant species having highest IVI of Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

Name of species	Life form	IVI	
		SSG	DSG
<i>Pinus roxburghii</i>	Tree	93.90	106.93
<i>Justicia adhatoda</i>	Shrub	55.77	-
<i>Phyllanthus parvifolius</i>	Shrub	-	29.01
<i>Oplismenus burmannii</i>	Herb	71.50	32.21

### 4.1.4 Maturity Index, Density and Similarity Index

Values of maturity indices of trees (12.67) and herbs (7.31) were found to be higher in SSG than that of DSG i.e trees (10.64) and herbs (5.15) respectively but the value of maturity index

of shrubs was found slightly higher in DSG (11.65) than that of SSG (11.58) (Table 5). Density of trees (876 stem/ha), shrubs (3734 stem/ha) and herbs (965575 stem/ha) were comparatively higher in DSG than in SSG which had trees (560 stem/ha), shrubs (1650 stem/ha) and herbs (145596 stem/ha) respectively (Table 5). Similarity index for trees, shrubs and herbs between SSG and DSG were 20%, 16.67% and 20.35% respectively (Table 5).

Table 5: Maturity index, density (stem/ha) and similarity index of trees, shrubs and herbs of two sacred groves (SSG and DSG).

Forest Layer	Maturity Index	Density(stem/ha)	Simiarity index (%)	Sacred grove
Tree	12.67	560	20%	SSG
	10.64	876		DSG
Shrub	11.58	1650	16.67%	SSG
	11.65	3734		DSG
Herb	7.31	145596	20.35%	SSG
	5.15	965575		DSG

#### 4.1.5 Forest Disturbances

From the analysis of disturbance types, access road within plot was found to have highest occurrence in SSG followed by dumping of rubbish, fencing, permanent structures and picnic spot in SSG whereas in DSG, erosion had highest occurrence followed by road construction, picnic spot, cut stumps and permanent structure (Fig 5). Erosion, road construction and forest fire were not found to be occurred in SSG.

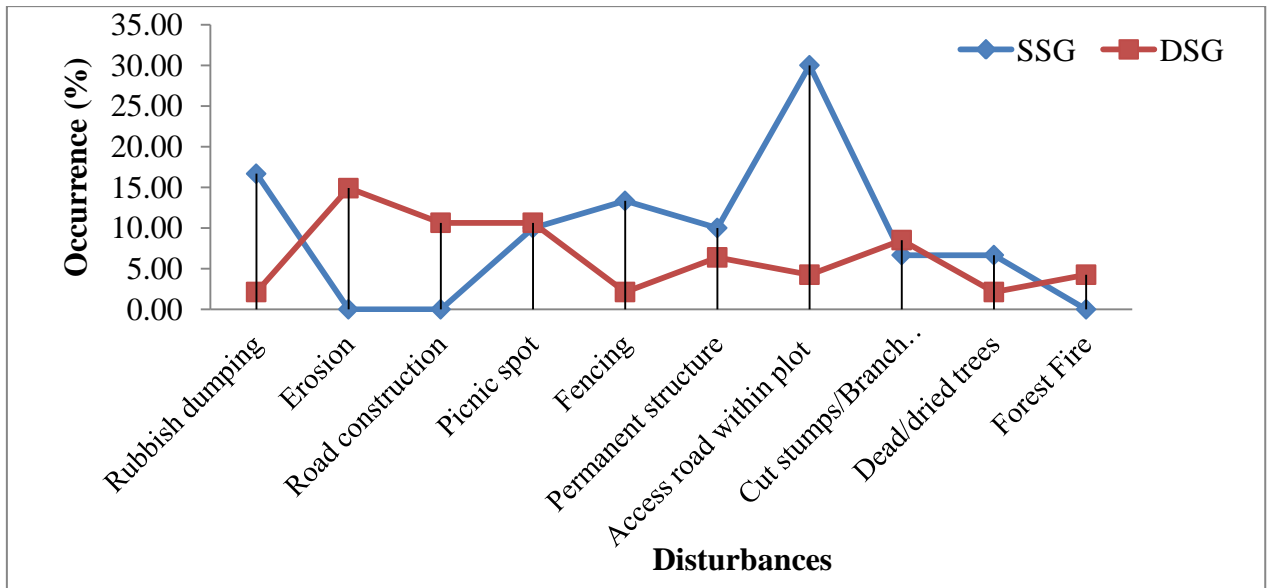


Fig 5: Occurrence of forest disturbances in two sacred groves (SSG and DSG).

## 4.2 Forest Regeneration

### 4.2.1 Regeneration Status of trees

In the present study, it was found that maximum species of trees were in none regenerating condition in both sacred groves i.e. 45.5% in SSG and 32.6% in DSG (Fig 6). Likewise, 30.3% species showed poor regeneration status, 15.2% species showed fair regeneration status in SSG whereas 25.6% species showed poor regeneration status, 25.6% showed fair regeneration in DSG. None of the species had good regeneration status in SSG while 9.3% species showed good regeneration status in DSG. Similarly, 9.1% species in SSG and 7.0% species in DSG were new species (Fig 6). Species like *Choerospondias axilaris*, *Myrica esculenta*, *Eurya acuminata* and *Bauhinia variegata* had good regeneration status in DSG (Annex 4.4).

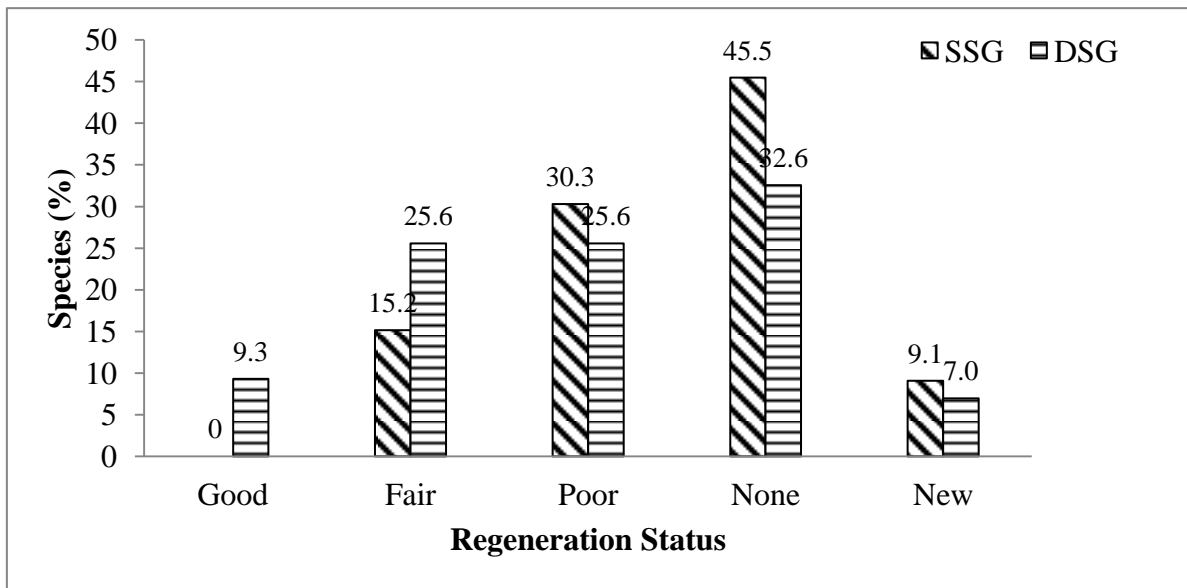


Fig 6: Regeneration status of trees in Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

Total density of seedling, sapling and tree was found to be higher in DSG than in SSG which were 2008 stem/ha, 1836 stem/ha and 876 stem/ha respectively in DSG whereas 566 stem/ha, 259 stem/ha and 560 stem/ha respectively in SSG (Fig 7).

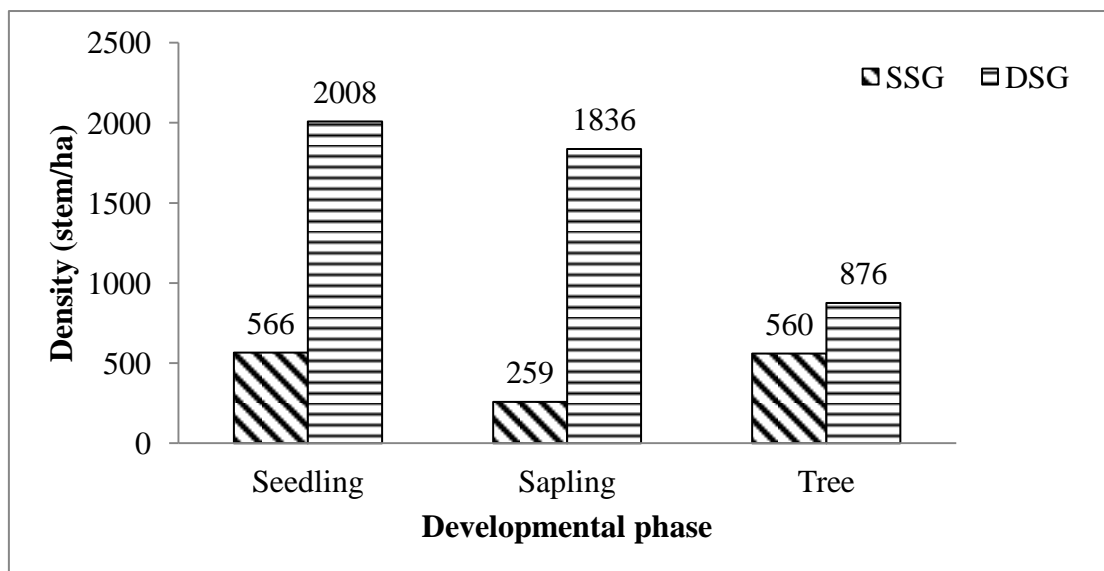


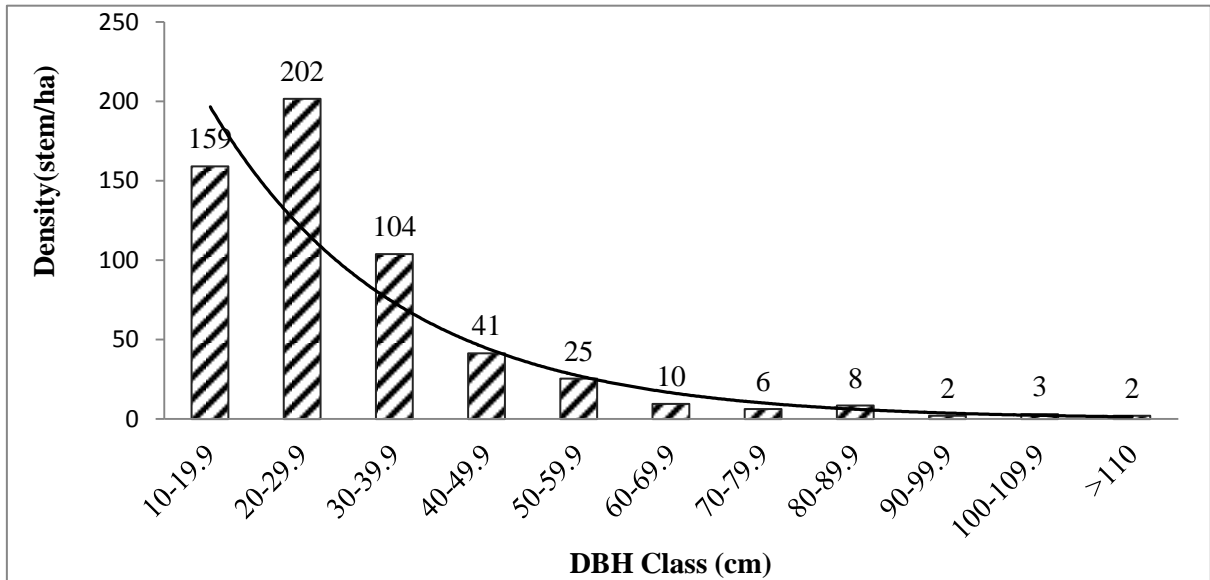
Fig 7: Distribution of trees at different phases showing regeneration status of species found in Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

#### 4.2.2 Density Diameter Relationship

The Density-Diameter (D-D) curve for tree species ( $\geq 10$  cm diameter) showed reverse J-shaped size class distribution in DSG with highest density (424 stem/ha) in DBH class (10-

19.9) cm (Fig 8 b) whereas in SSG it showed slight increase in density of trees from DBH class (10-19.9) cm to (20-29.9) cm and then subsequent decrease in density with increase in DBH of trees with highest density (202 stem/ha) in DBH class (20-29.9) cm in SSG (Fig 8 a).

a)



b)

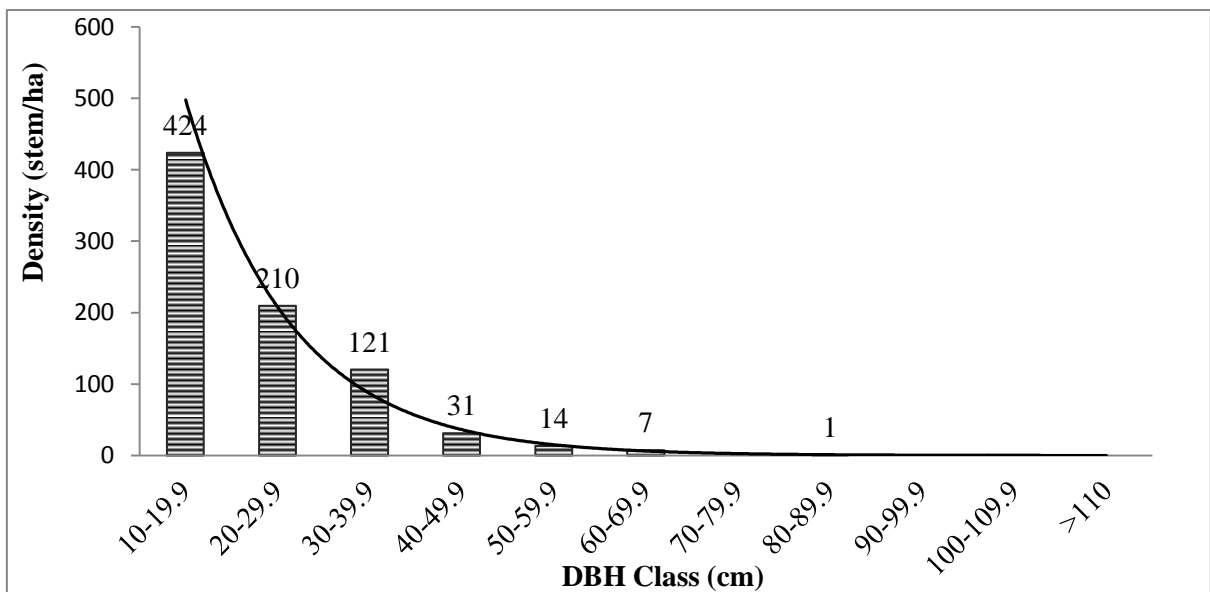


Fig 8: Density diameter relationship of trees  $\geq 10$  cm (a) Swayambhu sacred grove (SSG) and (b) Dakshinkali sacred grove (DSG).

#### 4.2.3 Height Class Distribution of Trees

Distribution of trees in different height class showed variation between SSG and DSG. In SSG, there were relatively taller trees with maximum number of trees in height class (5-9.9)

m i.e. 591 stem/ha whereas in DSG number of trees was more in height class (10-19.9) m i.e. 540 stem/ha. The number of trees was lowest in height class (20-29.9) m in DSG i.e.27 stem/ha and in SSG, it was lowest in height class (40-59.9) m i.e. 27 stem/ha (Fig 9).

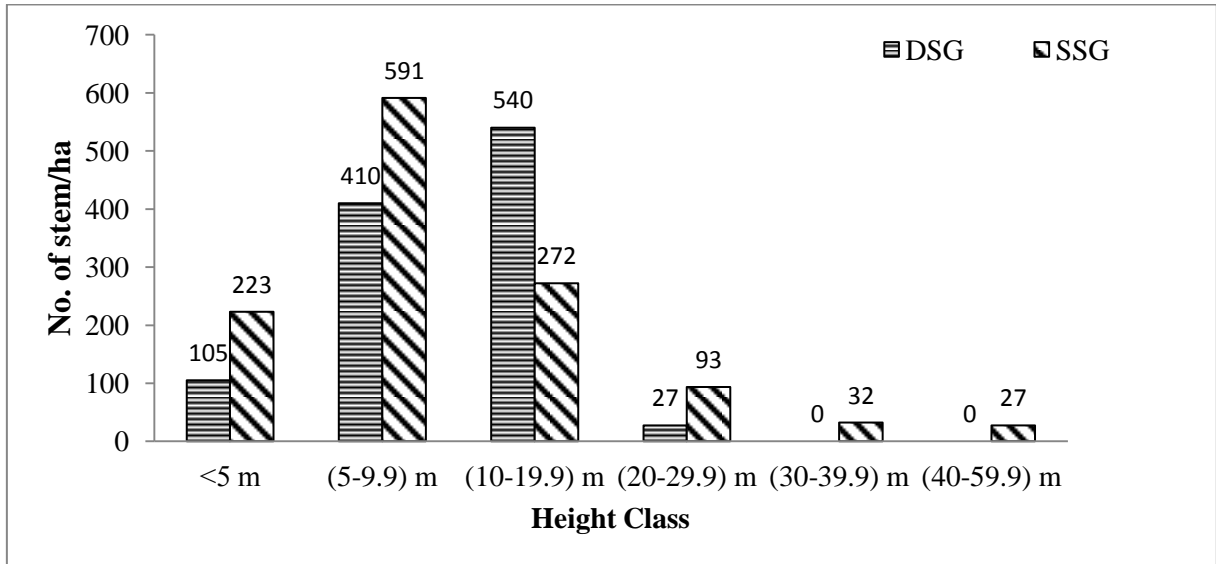


Fig 9: Height class distribution of trees in Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

#### 4.2.4 Basal Area of Trees

Total basal area of all species was found higher in SSG (49.58 m<sup>2</sup>/ha) in comparison to DSG (44.04 m<sup>2</sup>/ha) and average basal area of SSG and DSG was 1.65 m<sup>2</sup>/ha and 1.10 m<sup>2</sup>/ha respectively. In SSG, *Schima wallichii* (22.04 m<sup>2</sup>/ha) had highest basal area followed by *Pinus roxburghii* (15.66 m<sup>2</sup>/ha) and *Pyrus pashia* (2.19 m<sup>2</sup>/ha) (Fig 10, Annex: 4.1) while in DSG the basal area of *Pinus roxburghii* (20.12 m<sup>2</sup>/ha) was measured highest followed by *Alnus nepalensis* (8.87 m<sup>2</sup>/ha) and *Schima wallichii* (6.38 m<sup>2</sup>/ha) (Annex: 4.4).

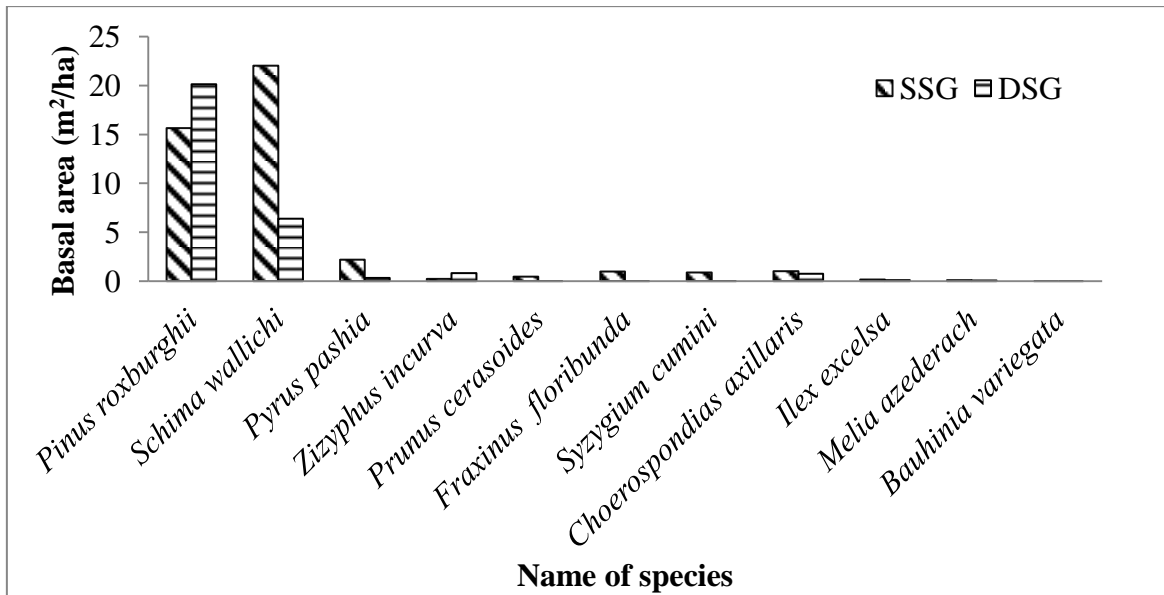


Fig 10: Basal area of common tree species of Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

### 4.3 Carbon Stock

#### 4.3.1 Tree Carbon Stock

Total tree biomass of SSG was found to be 242.045 t/ha with 201.7 t/ha in above ground and 40.3 t/ha in below ground biomass (Annex: 5.1) while in DSG the total tree biomass was recorded 169.926 t/ha with 141.6 t/ha in the above ground and 28.3 t/ha in the below ground (Annex: 5.2). Among all species, *Schima wallichii* had highest total biomass 100.483 t/ha with 83.736 t/ha in above ground and 16.747 t/ha in the below ground followed by *Pinus roxburghii* with total biomass 44.998 t/ha in SSG whereas in DSG, *Pinus roxburghii* had highest total biomass 88.286 t/ha with 73.572 t/ha in above ground and 14.714 t/ha in the below ground followed by *Alnus nepalensis* having total biomass 34.536 t/ha (Table 6).

Table 6: Above ground tree biomass (AGTB), below ground tree biomass (BGTB), total biomass and Carbon stock of major and common tree species in two sacred groves (SSG and DSG).

Name of Species	AGTB of SSG (t/ha)	BGT of SSG (t/ha)	Total Biomass of SSG (t/ha)	Cstock of SSG (t/ha)	AGTB of DSG (t/ha)	BGTB of DSG (t/ha)	Total Biomass of DSG (t/ha)	Cstock of DSG (t/ha)
<i>Pinus roxburghii</i>	37.498	7.500	44.998	21.149	73.572	14.714	88.286	41.494
<i>Schima wallichii</i>	83.736	16.74	100.483	47.227	16.872	3.374	20.247	9.516
		7						
<i>Alnus nepalensis</i>	-	-	-	-	28.780	5.756	34.536	16.232
<i>Castanopsis indica</i>	-	-	-	-	5.061	1.012	6.073	2.854
<i>Celtis australis</i>	0.017	0.003	0.021	0.010	2.638	0.528	3.165	1.488
<i>Zizyphus incurva</i>	1.121	0.224	1.346	0.632	2.169	0.434	2.603	1.223
<i>Choerospondias axilaris</i>	6.112	1.222	7.334	3.447	2.121	0.424	2.546	1.196
<i>Pinus patula</i>	-	-	-	-	1.840	0.368	2.208	1.038
<i>Pyrus pashia</i>	13.187	2.637	15.824	7.437	0.629	0.126	0.754	0.355
<i>Ficus benjamina</i>	14.357	2.871	17.229	8.098	-	-	-	-
<i>Stranvaesia nussia</i>	13.065	2.613	15.678	7.369	-	-	-	-
<i>Fraxinus floribunda</i>	5.994	1.199	7.193	3.381	0.064	0.013	0.077	0.036
<i>Syzygium cumini</i>	6.000	1.200	7.201	3.384	0.015	0.003	0.018	0.009
<i>Ilex excelsa</i>	0.650	0.130	0.780	0.367	0.341	0.068	0.409	0.192
<i>Bauhinia variegata</i>	0.031	0.006	0.037	0.017	0.028	0.006	0.034	0.016

Total tree carbon stock measured from this study was  $113.76 \pm 1.687$  t/ha for SSG and  $79.87 \pm 1.113$  t/ha for DSG (Fig 11). The mean value of tree carbon stock was 3.792 t/ha and 1.997 t/ha respectively in SSG and DSG (Annex: 5.1 and Annex: 5.2). There was significant

difference ( $p = 0.021$ , Annex: 7.1) in mean values of tree carbon stock between two sacred groves.

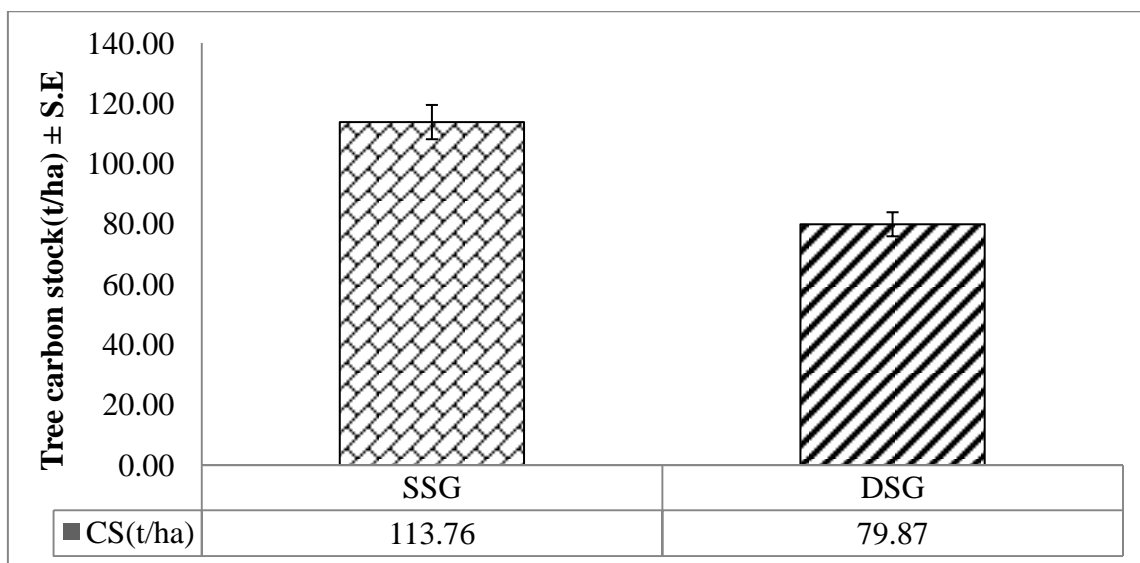


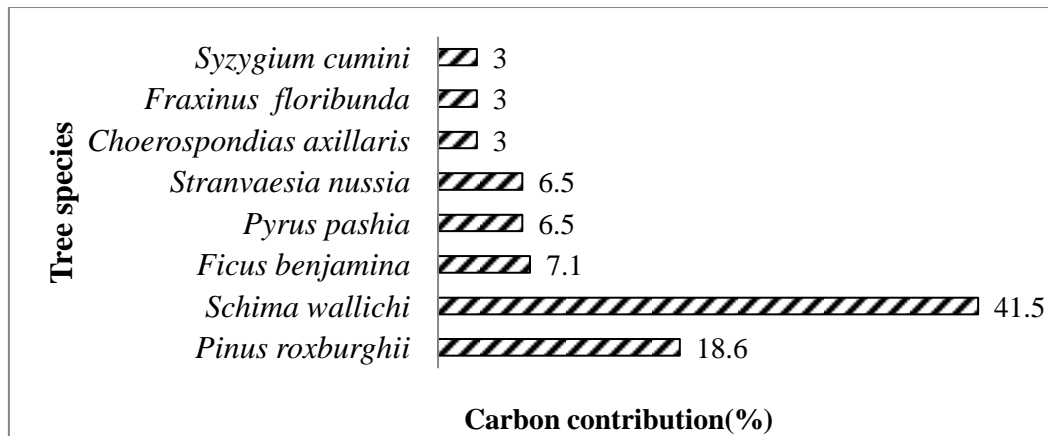
Fig 11: Total tree carbon stock (t/ha) for Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG). Error bars denote standard error around the carbon stock.

#### 4.3.2 Contribution of Species in Tree Carbon Stock

*Schima wallichii* had the highest carbon contribution (41.5%) followed by *Pinus roxburghii* (18.6%), *Ficus benamina* (7.1%), *Pyrus pashia* (6.5%), *Stranvaesia nussia* (6.5%), *Choerospondias axillaris* (3%), *Fraxinus floribunda* (3%) and *Syzygium cumini* (3%) in SSG (Fig 12 a) whereas in DSG *Pinus roxburghii* (52%), *Schima wallichii* (11.9%), *Alnus nepalensis* (20.3%), *Castanopsis indica* (3.6), *Celtis australis* (1.9%), *Choerospondias axillaris* (1.5%), *Zizyphus incurva* (1.5%) and *Pinus patula* (1.3%) were major species in carbon contribution (Fig 12 b).

Average carbon contributions of tree species were highly variable in both the sacred groves. The value ranged between (0.001-41.51%) in SSG (Annex: 5.1) and (0.003-51.956%) in DSG (Annex: 5.2).

a)



b)

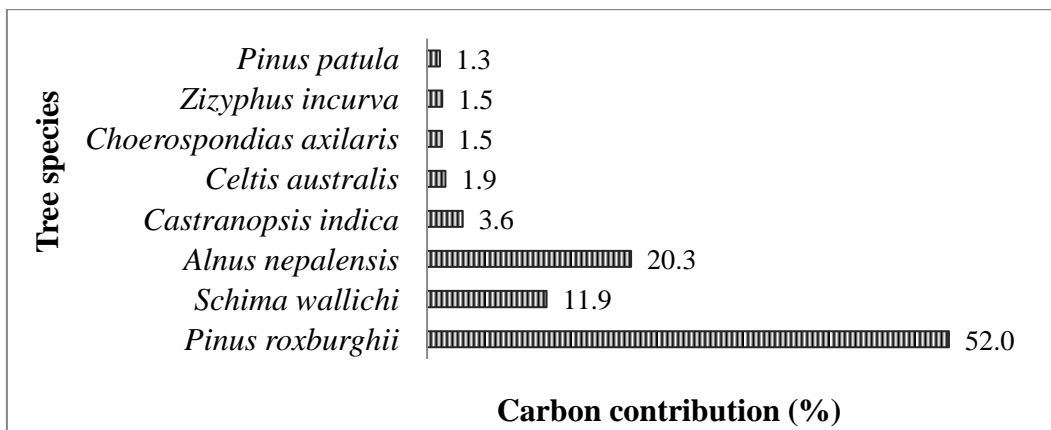


Fig 12: Tree species with major contribution on carbon stock (a) Swayambhu sacred grove (SSG) (b) Dakshinkali sacred grove (DSG).

#### 4.3.3 Soil Carbon Stock

Total soil carbon stock of SSG and DSG were found  $18.31 \pm 0.01$  t/ha and  $17.93 \pm 0.01$  t/ha respectively (Fig 13). Mann-Whitney U test showed significant difference ( $p = 0.00$ , Annex: 7.2) in mean ranks of soil carbon stock (t/ha) of two sacred groves.

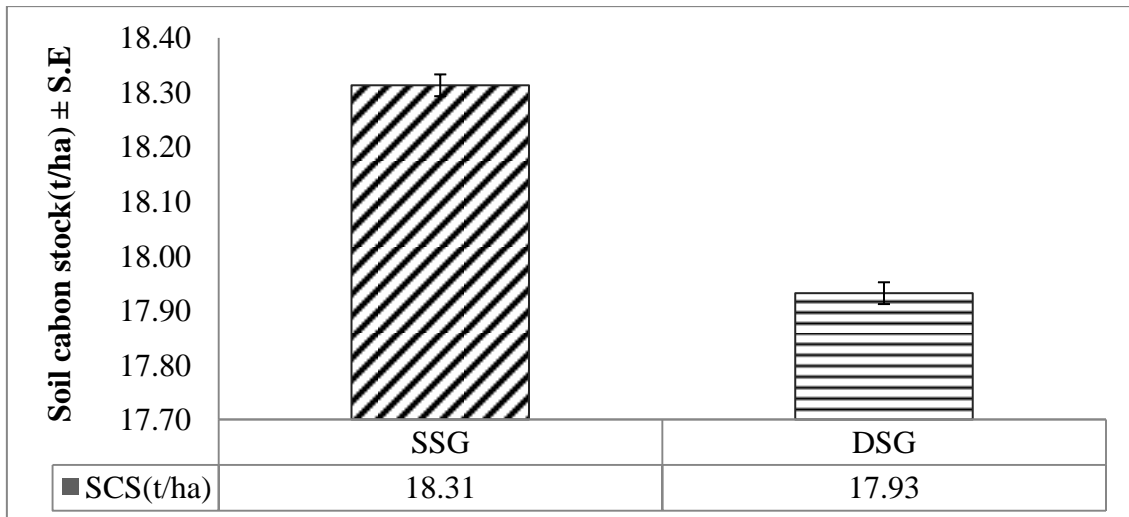


Fig 13: Total soil carbon stock (t/ha) of Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

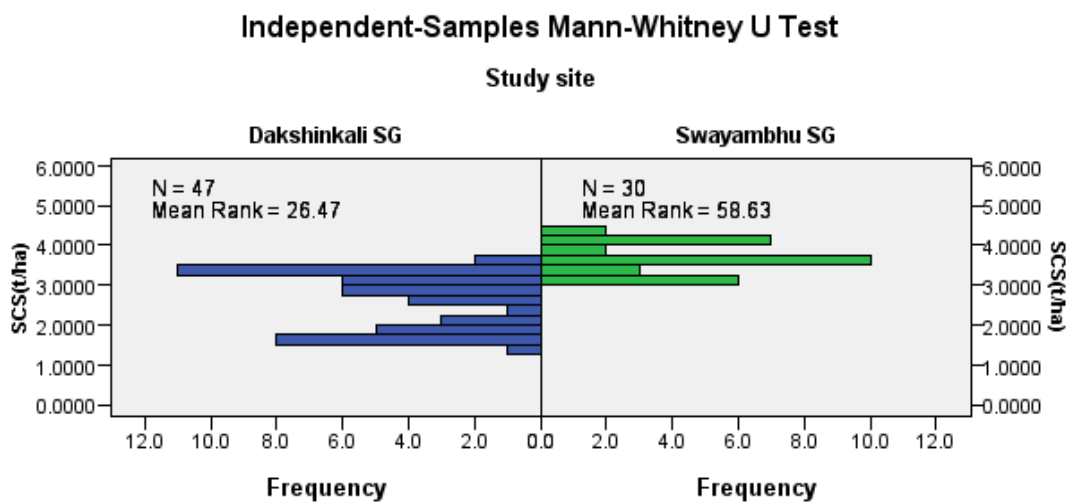


Fig 14: Independent Sample Mann-Whitney U Test for soil carbon stock (t/ha) between Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

#### 4.4 Summary of Variables

Values of total plant diversity (T\_H), total evenness (T\_E) and total species richness (T\_Spprh) were not homogeneous throughout the studied plots. The value of total plant diversity varied from 2.03 to 3.05 with an average of 2.60 whereas evenness varied from 0.66 to 1.00 with an average of 0.85. Maximum of 26 species were recorded from some plots and minimum of 10 species recorded from other plots (Table 7).

Table 7: Summary of variables used during study

Study site	Swayambhu sacred grove (SSG)						Dakshinkali sacred grove (DSG)				
Variables	Short form	Max	Min	Mea n	Stde v	Std_ error	Max	Min	Mea n	Stde v	Std_ error
Total Plant Diversity	T_H	3.05	2.03	2.60	0.24	0.04	2.64	1.09	2.02	0.37	0.04
Total Evenness	T_E	1.00	0.66	0.85	0.07	0.01	0.88	0.58	0.75	0.10	0.01
Total Species richness	T_Spp rh	26	10	15.9	4.30	0.79	27	14	21.77	3.45	0.50
Diversity of trees	Tr_H	2.02	0	0.68	0.60	0.11	2.06	0	1.10	0.48	0.07
Evenness of trees	Tr_E	0.99	0	0.54	0.41	0.07	0.98	0	0.75	0.21	0.03
Species richness of trees	Tr_Sp prh	10	1	2.93	2.05	0.37	10	1	4.47	1.87	0.27
Diversity of shrub layer	Sh_H	1.76	0	1.03	0.53	0.10	2.20	0.69	1.76	0.30	0.04
Evenness of shrub layer	Sh_E	0.99	0	0.72	0.31	0.06	1.29	0.52	0.90	0.10	0.02
Species richness of shrub layer	Sh_Sp prh	8	1	4.07	1.98	0.36	11	2	7.36	1.81	0.26
Diversity of herb layer	Hb_H	2.64	1.09	2.02	0.37	0.07	2.46	0.61	1.97	0.35	0.05
Evenness of herb layer	Hb_E	0.88	0.45	0.72	0.12	0.02	1.00	0.02	0.82	0.18	0.03
Species richness of herb layer	Hb_S pprh	14	4	9.37	2.82	0.52	28	10	21.64	3.85	0.56
Tree Carbon Stock (t/ha)	CS	47.2	0.00				41.4	0.00			
		3	2	3.79	9.24	1.69	9	3	2.00	7.04	1.11

Soil Carbon Stock (t/ha)	SCS	0.65	0.56	0.61	0.02	0.00	0.49	0.26	0.38	0.07	0.01
Bulk Density (g/cm <sup>3</sup> )	BD	1.33	0.97	1.13	0.10	0.02	1.22	0.75	1.02	0.14	0.02
Organic Matter (%)	OM	7.05	5.15	6.27	0.53	0.10	5.76	2.52	4.44	1.16	0.17
Soil Organic Carbon (%)	SOC	4.09	2.99	3.64	0.31	0.06	3.34	1.46	2.58	0.67	0.10

#### 4.5 Correlation among Variables

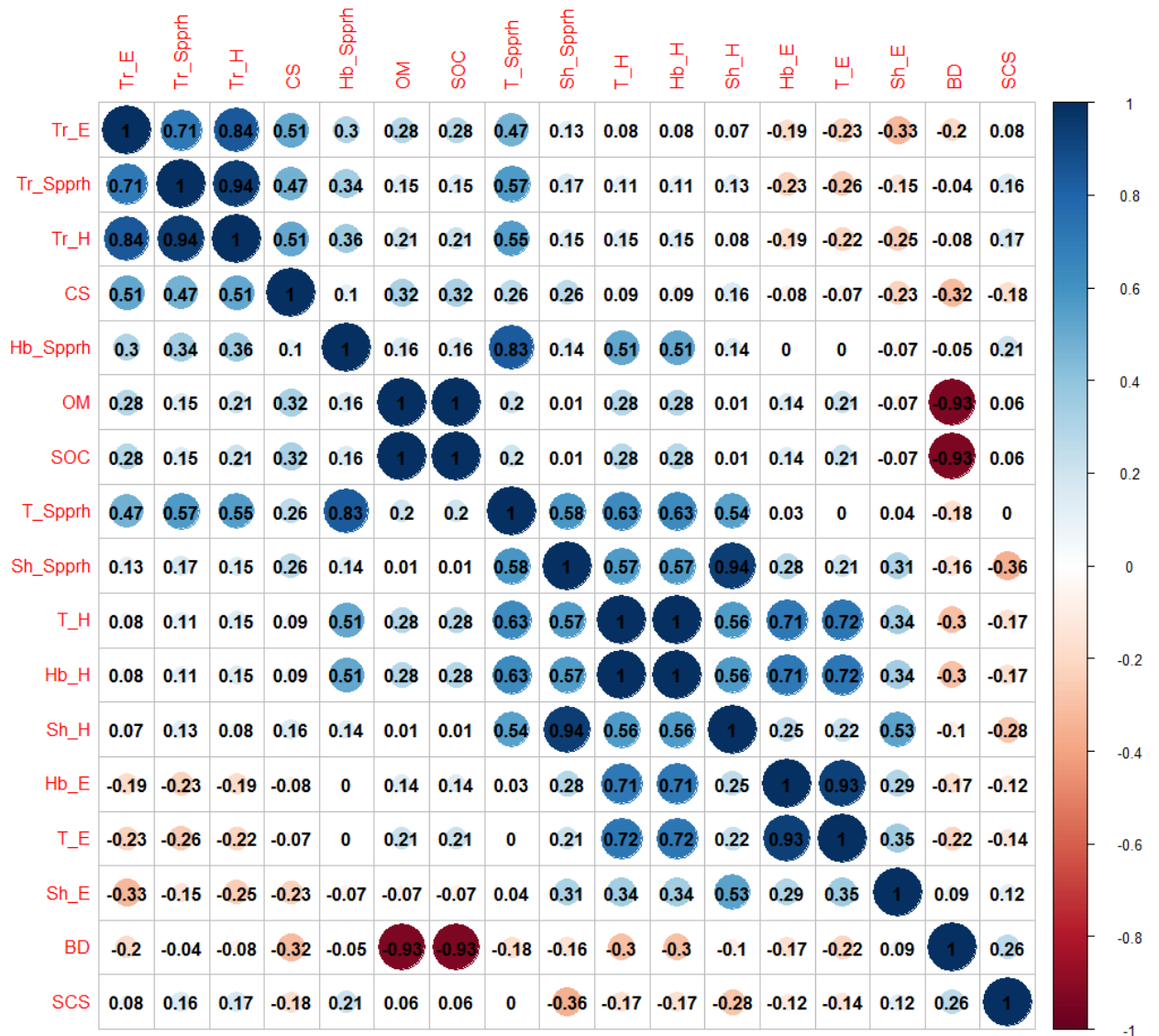
In SSG, diversity index of total plant species showed very strong positive correlation with diversity index of herbs ( $r = 1$ ) and positive correlation with diversity index of shrubs ( $r = 0.56$ ) whereas very weak positive correlation with diversity index of trees ( $r = 0.15$ ) (Table 8 a). Similarly, total evenness showed strong positive correlation with evenness of herbs ( $r = 0.93$ ) and weak positive correlation with evenness of shrubs ( $r = 0.35$ ), weak negative correlation with evenness of trees ( $r = -0.23$ ) (Table 8 a). Likewise, total species richness showed strong positive correlation with herb species richness ( $r = 0.83$ ) and positive correlation with shrub species richness ( $r = 0.58$ ) and tree species richness ( $r = 0.57$ ) (Table 8 a). Tree carbon stock showed positive correlation with diversity and evenness of trees ( $r = 0.51$ ) as well as with species richness of trees ( $r = 0.47$ ) whereas weak negative correlation with bulk density ( $r = -0.32$ ) (Table 8 a). Soil carbon stock showed weak positive correlation with bulk density ( $r = 0.26$ ), tree diversity ( $r = 0.17$ ) and tree species richness ( $r = 0.16$ ) whereas there was very weak negative correlation of soil carbon stock with tree carbon stock ( $r = -0.18$ ). Soil organic carbon showed strong positive correlation with organic matter and soil organic carbon ( $r = 1$ ). Bulk density showed strong negative correlation with organic matter and soil organic carbon ( $r = -0.93$ ) (Table 8 a).

There was positive correlation of diversity index of total plant species and diversity index of herbs ( $r = 0.71$ ) in DSG but it showed weak positive correlation with diversity of trees ( $r = 0.31$ ) and shrubs ( $r = 0.28$ ). Total evenness showed very strong positive correlation with evenness of herbs ( $r = 1$ ) whereas weak positive relation with evenness of shrubs ( $r = 0.27$ ) and trees ( $r = 0.15$ ). Similarly, total species richness showed very strong positive correlation with herb species richness ( $r = 1$ ) and weak positive correlation with shrub species richness ( $r = 0.33$ ). Tree carbon stock showed weak positive correlation with total species richness ( $r =$

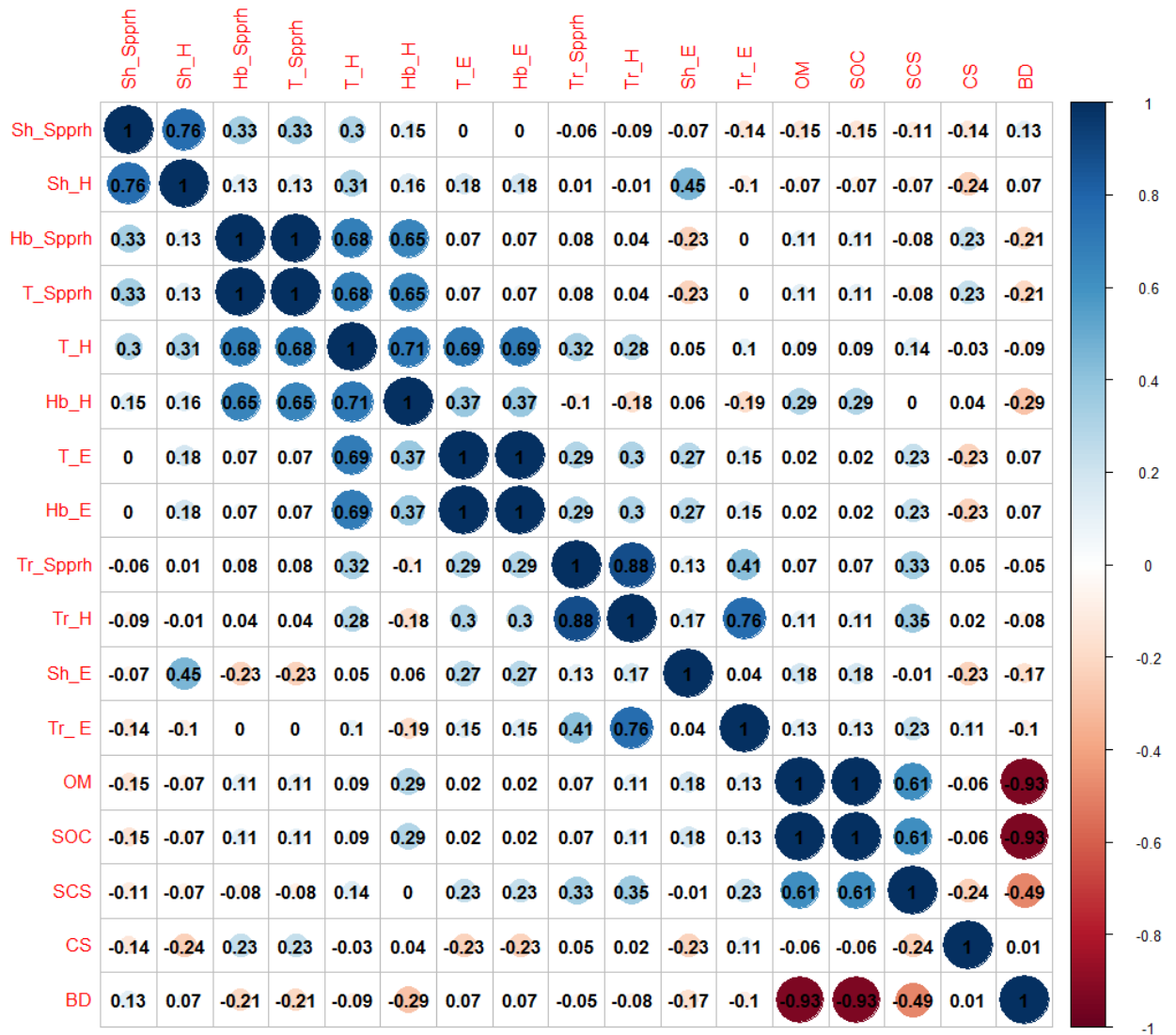
0.23) and tree diversity ( $r = 0.11$ ) whereas it showed weak negative correlation with soil carbon stock ( $r = -0.24$ ). Soil carbon stock showed strong positive correlation with organic matter and soil organic carbon ( $r = 0.61$ ) but negative correlation with bulk density ( $r = -0.49$ ). Bulk density showed strong negative correlation with organic matter and soil carbon stock ( $r = -0.93$ ) (Table 8 b).

Table 8: Correlation coefficient matrix among variables used for the study a) Swayambhu sacred grove (SSG) and b) Dakshinkali sacred grove (DSG). The darkly shaded blue color indicates the strong positive correlation while lightly shaded blue portion shows low positive correlation. Likewise, deeply shaded red color shows strong negative correlation while lightly shaded red portion shows low negative correlation.

a)



b)

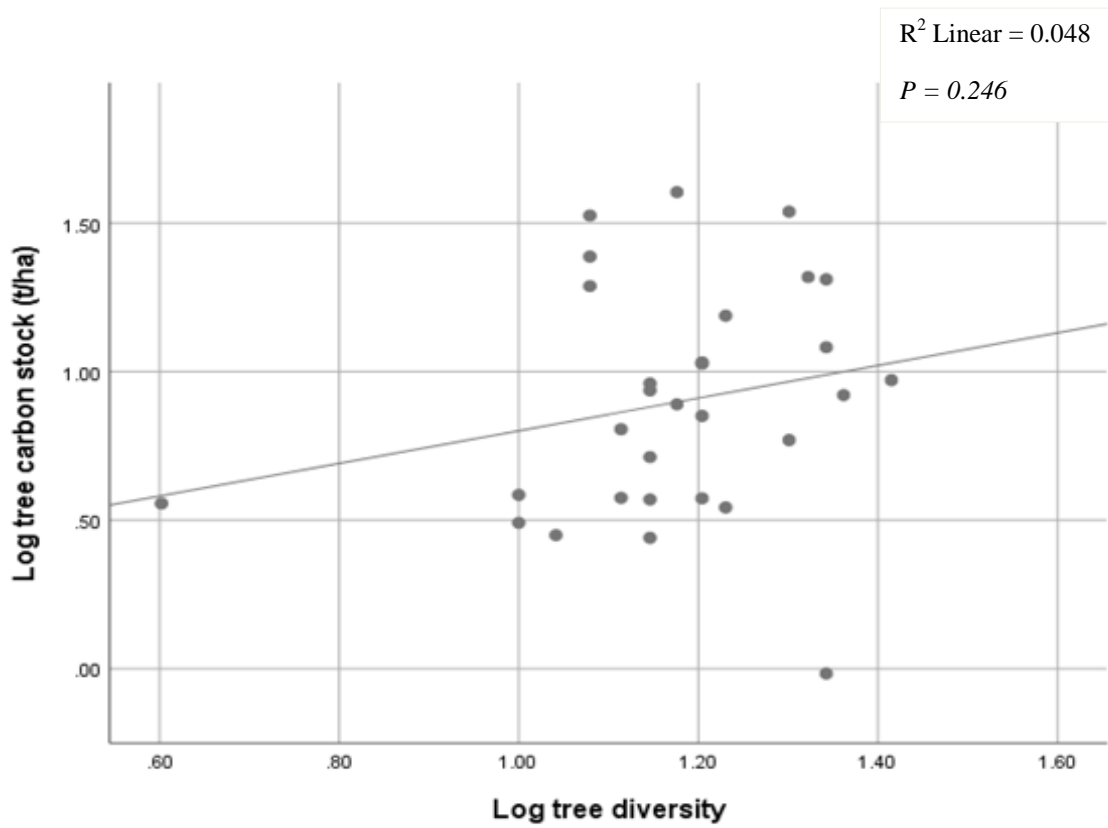


## 4.6 Relationship of Tree Carbon Stock with Diversity and Basal Area

### 4.6.1 Relation of Carbon Stock with Diversity Index

Pearson's correlation test showed non-significant weak positive correlation of carbon stock with diversity index in SSG ( $r = 0.219$ ,  $p = 0.246$ , Annex: 7.3) but in DSG it showed non-significant weak negative correlation between carbon stock and diversity index ( $r = -0.201$ ,  $p = 0.177$ , Annex: 7.4). Regression analysis also showed very weak and non-significant positive relationship of carbon stock with diversity index in both sacred groves i.e. SSG ( $R^2 = 0.048$ ,  $p = 0.246$ , Fig 15 a) and DSG ( $R^2 = 0.040$ ,  $p = 0.177$ , Fig 15 b).

a)



b)

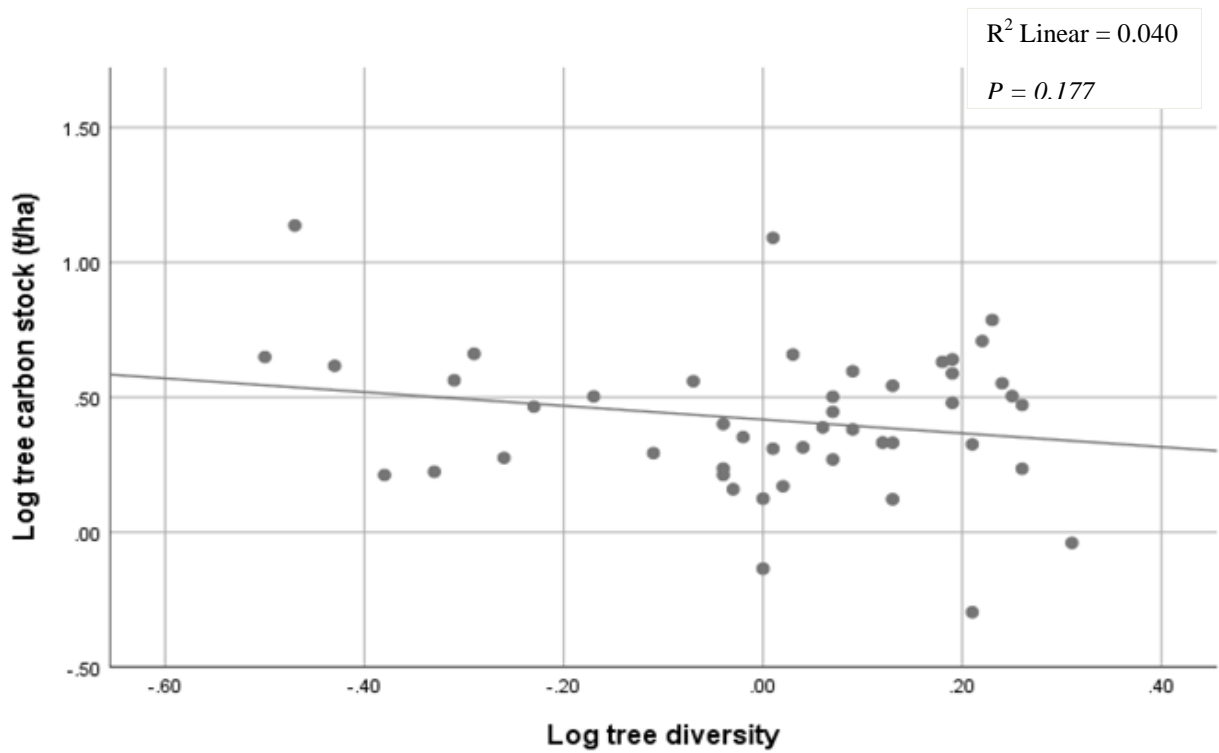
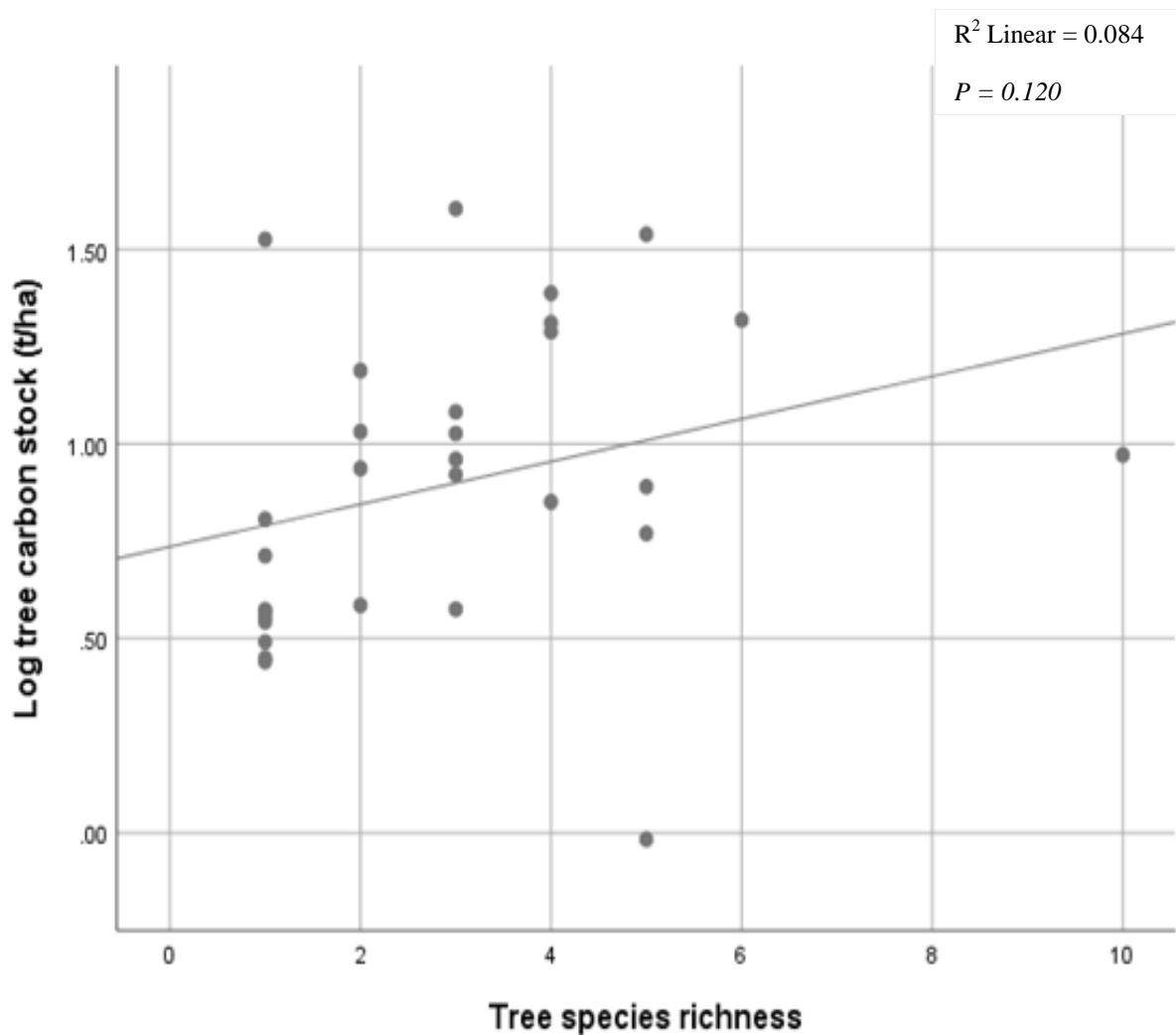


Fig 15: Relation of carbon stock with diversity index a) Swayambhu sacred grove (SSG) and b) Dakshinkali sacred grove (DSG). The fitted line is based on linear regression model.

#### 4.6.2 Relation of Carbon Stock with Species Richness

Likewise diversity index, carbon stock showed non-significant weak positive correlation with species richness in SSG ( $r = 0.290$ ,  $p = 0.120$ , Annex: 7.3) and very weak non-significant negative correlation in DSG ( $r = -0.077$ ,  $p = 0.607$ , Annex: 7.4) by Pearson's correlation test. Similarly regression analysis also showed very weak non-significant positive relation of carbon stock with species richness in both sacred groves viz. SSG ( $R^2 = 0.084$ ,  $p = 0.120$ , Fig 16 a) and DSG ( $R^2 = 0.006$ ,  $p = 0.607$ , Fig 16 b).

a)



b)

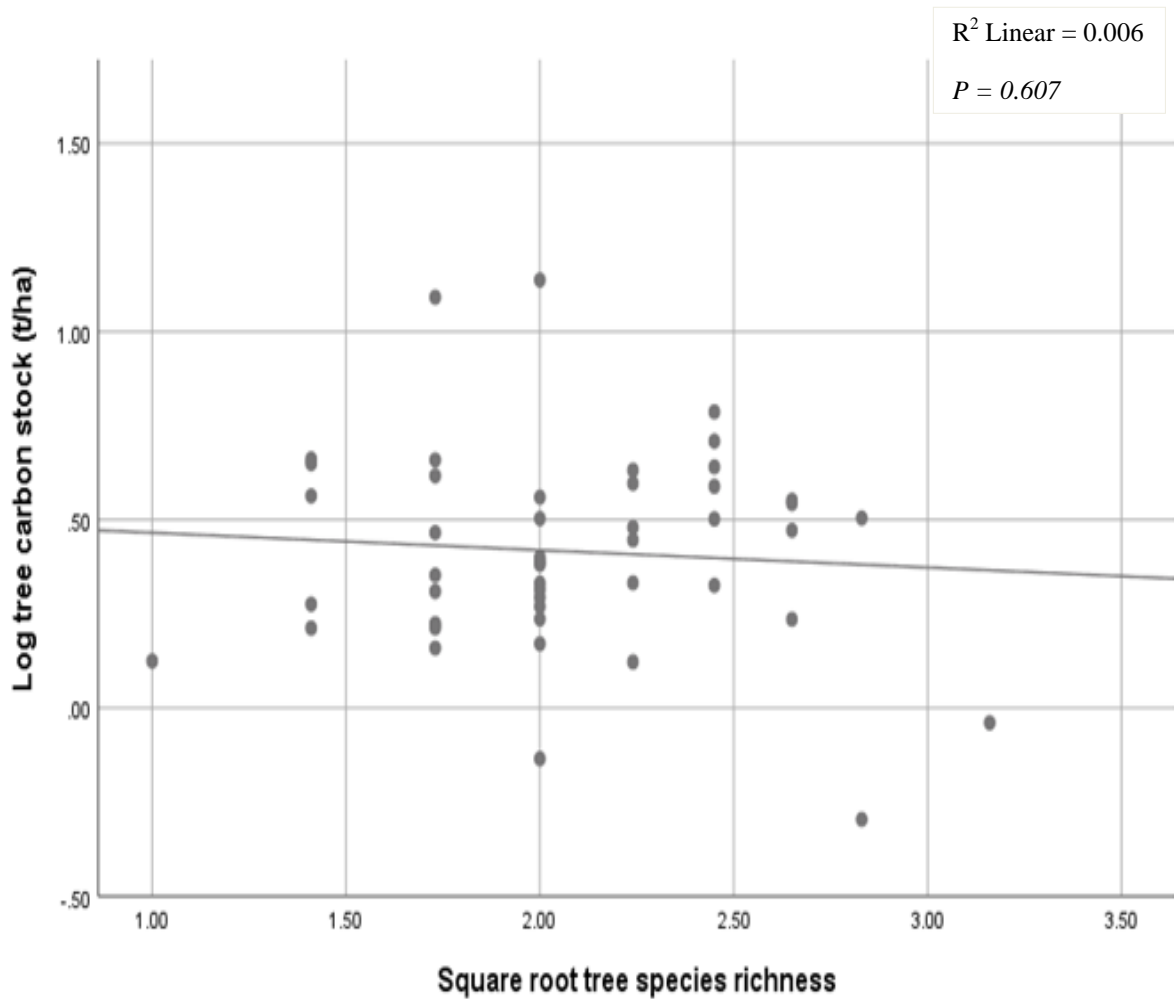
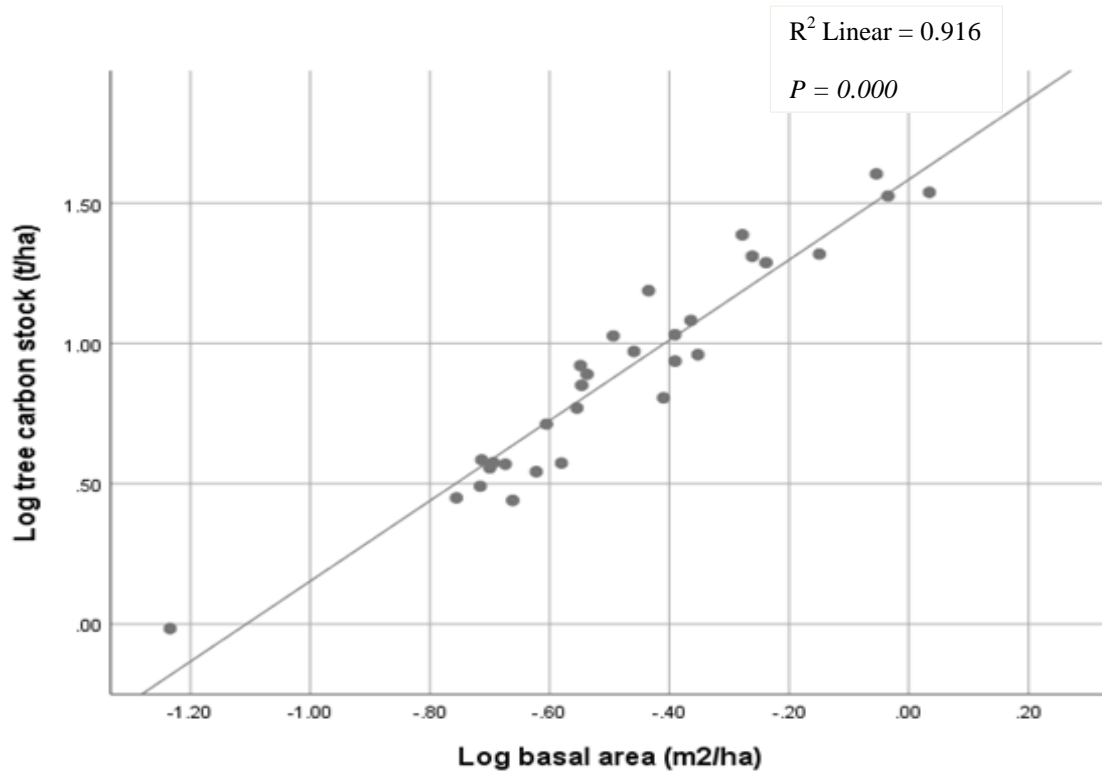


Fig 16: Relation of carbon stock with species richness a) Swayambhu sacred grove (SSG) and b) Dakshinkali sacred grove (DSG). The fitted line is based on linear regression model.

#### 4.6.3 Relation of Carbon Stock with Basal Area

Pearson's correlation test and regression analysis both showed strong positive and significant relationship of carbon stock with basal area in both study sites ( $p = 0.000$ ). Pearson's correlation coefficient for SSG ( $r = 0.957$ , Annex: 7.3) was slightly higher than that of DSG ( $r = 0.925$ , Annex: 7.4).  $R^2$  value was higher in SSG ( $R^2 = 0.916$ , Fig 17 a) than in DSG ( $R^2 = 0.856$ , Fig 17 b).

a)



b)

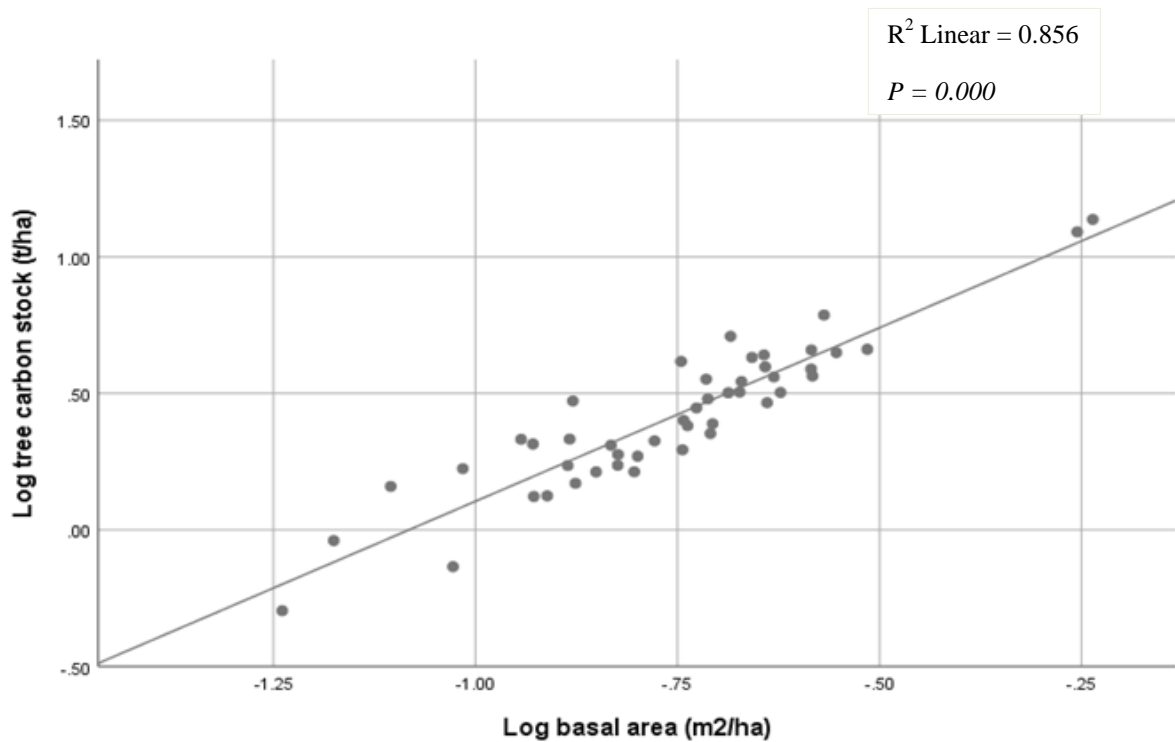
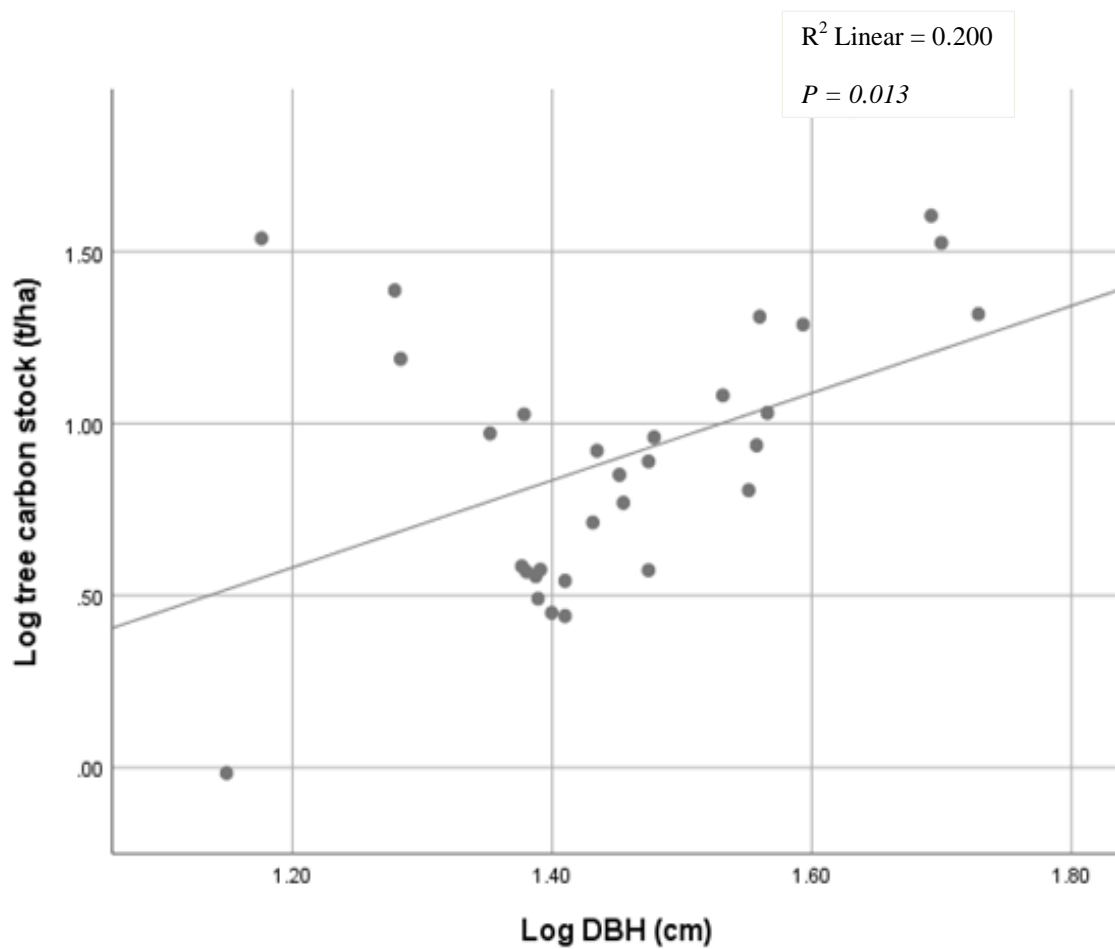


Fig 17: Relation of carbon stock with basal area a) Swayambhu sacred grove (SSG) and b) Dakshinkali sacred grove (DSG). The fitted line is based on linear regression model.

#### 4.6.4 Relation of Carbon Stock with DBH

Carbon stock increased with increase in DBH of trees in both sacred groves. Pearson's correlation test showed significant positive correlation of carbon stock with DBH in SSG ( $r = 0.447$ ,  $p = 0.013$ , Annex: 7.3) but in DSG it showed significant strong positive correlation with DBH ( $r = 0.919$ ,  $p = 0.000$ , Annex: 7.4). Regression analysis also showed positive and significant but weak correlation of carbon stock with DBH in SSG ( $R^2 = 0.200$ ,  $p = 0.013$ , Fig 18 a). However it showed significant strong positive relationship between carbon stock and DBH in DSG ( $R^2 = 0.844$ ,  $p = 0.000$ , Fig 18 b).

a)



b)

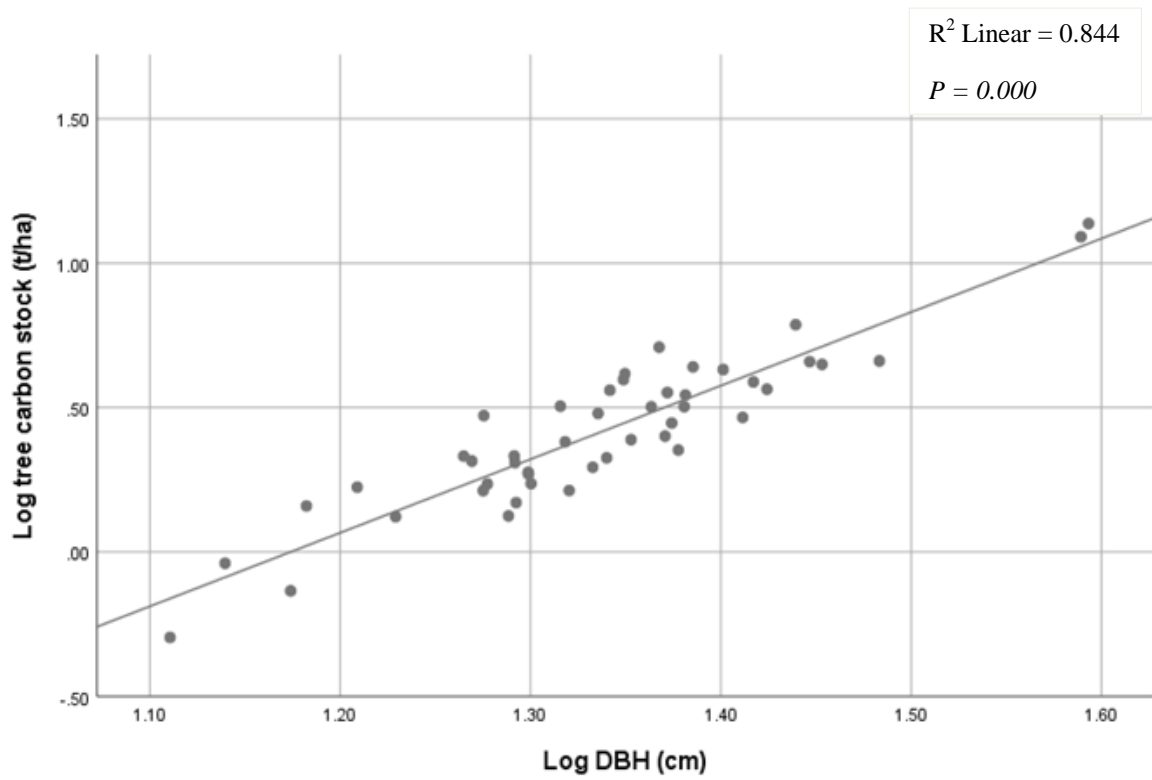


Fig 18: Relation of carbon stock with DBH a) Swayambhu sacred grove (SSG) and b) Dakshinkali sacred grove (DSG). The fitted line is based on linear regression model.

## CHAPTER 5: DISCUSSION

### 5.1 Plant Diversity and Other Community Attributes

Species diversity is the combination of species evenness and species richness which is regulated by the long term factors such as community stability and evolutionary time as heterogeneity of both microclimate and macroclimate affecting diversification among different communities (Krebs, 1972). Plant species richness of community managed sacred grove, DSG was found to be higher than in SSG which is managed by government. Shannon-Weiner diversity index (H) of total plant species was found to be higher in DSG (H = 3.975) than in SSG (H = 3.213). Plants were found to be more evenly distributed in DSG (E = 0.788) as compared to SSG (E = 0.649). T-test also showed significant difference in mean values of Shannon-Weiner diversity index (H) and evenness of total plant species between SSG and DSG. This might be due to the high understory plant diversity as it showed positive correlation with total plant diversity in both sacred groves. Frequency of access road within plots was recorded highest in SSG which might have affected the understory plant diversity due to trampling by humans. Trampling can exert enough pressure on soil to bring changes in plant species composition and diversity through compaction especially when such urban forests are lots near settlements (Bhujju and Ohsawa, 2001). The result of present study is similar to the PenG-CHenG *et al.* (2012) which reported higher diversity of plants in suburban forest than urban forest of Central China especially due to high diversity of understory plants because the species diversity of shrub and herb layers in urban forests is significantly affected by a gradient caused by visitor flow rate, shrub coverage, aspect, and neighboring land types. Herbs had higher diversity and species richness than shrubs and trees in both sacred groves. Higher species diversity of herbs in the areas with less shrub cover due to response of herbs to low availability of shrubs was also discovered by Berlow *et al.* (2003).

*Pinus roxburghii* had highest IVI in both sacred groves (i.e. 93.90 in SSG and 106.93 in DSG) followed by *Schima wallichii* (i.e. 89.54 in SSG and 48.93 in DSG) among all species of trees. In the Pashupati and Bajrabarahi sacred grove of Kathmandu valley, IVI of *Schima wallichii* was found highest (Shrestha *et al.*, 2015) which belong to the same climatic region. This result is dissimilar to the result of Shrestha *et al.* (2015), the reason might be the afforestation which is one of the effective management practices for conservation of plant diversity in these sacred groves (Ranjitkar and Chaulagain, 2004). Among shrubs, *Justicia adhatoda* had highest IVI (55.77) in SSG and *Phyllanthus parvifolius* had highest IVI (29.01) in DSG. Likewise among herbs, *Oplismenus burmannii* had highest IVI in both sacred groves (i.e.

71.50 in SSG and 32.21 in DSG). These plant species are dominant species of the study site and might possess ecological success, good regeneration and greater ecological amplitude (Shameem and Kangaroo, 2011). Values of maturity index of tree and herb was found higher in SSG than DSG while that of shrub was more or less equal in both sacred groves. High value of maturity index in SSG indicates that plant community of SSG is more mature than that of DSG (Pichi-Sermolli, 1948).

From the present study, total basal area of tree species was found higher in SSG (49.58 m<sup>2</sup>/ha) in comparison to DSG (44.04 m<sup>2</sup>/ha). Density of trees (876 stem/ha) were comparatively higher in DSG than the density of trees (560 stem/ha) in SSG. From this result, DSG can be considered as younger and regenerating forest in comparison to SSG as the lower basal area, biomass and higher density shows that the forest are younger and in state of regeneration (Giri *et al.*, 1999).

## **5.2 Regeneration**

Regeneration is the determinant factor for the sustainability of forests. The sustainable forest must have good regeneration, proper age class (age-gradation), normal increment and normal growing stock (Subedi, 2011). From the present study, it was found that maximum species of trees were in none regenerating condition in both sacred groves (i.e. 45.5% in SSG and 32.6% in DSG). Species like *Choerospondias axilaris*, *Myrica esculenta*, *Eurya acuminata* and *Bauhinia variegata* had good regeneration status in DSG but none of the species had good regeneration status in SSG. Regeneration of trees in SSG might have been affected by anthropogenic disturbances such as access road within plot, dumping of rubbish, fencing, permanent structure which were found to have higher frequency in SSG during field study. Manifold anthropogenic activities have significant impact on the regeneration status of flora in sacred groves (Bharathi and Prasad, 2017).

In the present study, the total density of seedling, sapling and tree was found higher in DSG which is least disturbed site in comparison to SSG. The population with sufficient number of seedlings and saplings depicts satisfactory regeneration behavior, while inadequate number of seedlings and saplings of the species in a forest indicates poor regeneration (Tripathi and Khan, 2007). It showed fair regeneration status of trees in DSG and poor regeneration status in SSG according to the Community Forestry Inventory Guideline 2002, (MFSC, 2002). Similar result was found in Pashupati and Bajrabarahi sacred groves by Shrestha *et al.* (2015).

There were nil trees in height class (30-39) m and (40–59.9) m in DSG whereas in SSG it was 32 in height class (30-39) m and 27 in (40–59.9) m height class which also represents that trees of SSG were much older than trees of DSG. The Density-Diameter (D-D) curve for tree species ( $\geq 10$  cm diameter) showed reverse J-shaped size class distribution in DSG whereas in SSG it showed slight increase in density of trees from DBH class (10-19.9) cm to (20-29.9) cm and then decreased subsequently with increase in DBH of trees. This denotes that DSG is young regenerating forest possessing good regeneration potential as the forest site in which distribution of diameter class is such that maximum number of individuals is present at seedling stage showing reverse J- shaped curve signifies the good regeneration potential (Chauhan *et al.*, 2008).

### 5.3 Tree Carbon Stock

Total tree biomass of SSG was found 242.045 t/ha with 201.7 t/ha in above ground and 40.3 t/ha in below ground biomass while in DSG the total tree biomass was recorded 169.926 t/ha with 141.6 t/ha in the above ground and 28.3 t/ha in the below ground in the present study. The present finding is lower than estimates (548.92 t/ha) of Dhakal *et al.* (2017) in Gokarna protected forest of Kathmandu. This might be due to difference in forest age, forest structure and plant species present in the area (Subedi and Shakya, 1988; Brown *et al.*, 1989; Dixon *et al.*, 1994).

Total carbon stock of SSG was 113.76 t/ha and DSG was  $79.87 \pm 1.113$  t/ha which was lower than findings of Shrestha (2009) in *Schima-Castanopsis* forest (178.52 t/ha) in Mid-hills of western Nepal and Chapako Community Forest (152.04 t/ha) of Kathmandu district (Mishra, 2010). Value of total tree carbon stock was found be higher in SSG than in DSG. There was statistical significant difference ( $p = 0.021$ ) in mean values of tree carbon stock between two sacred groves. The reason for high carbon stock in SSG might be due to maturity of forest as the maturity index of trees was found slightly higher in SSG (12.67) than DSG (10.64) in the present study (Table 5). Carbon stock is much higher in older, mature forests than young, regenerating forest (Luyssaert *et al.*, 2008).

*Schima wallichii* was the highest contributor of carbon stock in SSG (41.5%) while in DSG, *Pinus roxburghii* (52%) was the highest contributor of carbon stock. This could be due to higher basal area of these species than other species (i.e. *Schima wallichii* 22.04 m<sup>2</sup>/ha in SSG and *Pinus roxburghii* 20.12 m<sup>2</sup>/ha in DSG). *Pinus roxburghii*, *Ficus benjamina*, *Pyrus pashia*, *Stranvaesia nussia*, *Choerospondias axillaris*, *Fraxinus floribunda* and *Syzygium cumini* are

other major carbon contributing species in this sacred grove. However in DSG, *Schima wallichii*, *Alnus nepalensis*, *Castranopsis indica*, *Celtis australis*, *Choerospondias axilaris*, *Zizyphus incurva* and *Pinus patula* were other major species in carbon contribution in DSG. These species also possessed higher basal area, DBH and height than the other species. Correlation and regression analysis also showed strong positive and significant relationship of carbon stock with basal area and DBH of trees in both sacred groves. The above result indicated that tree species having higher value of basal area and DBH contributes more in carbon stock. Similar type of result was obtained by Thapa Magar and Shrestha (2015) in community managed hill Sal forest of Central Nepal. The study of tree carbon in the sacred groves of Central India also found positive correlation of tree carbon stock with basal area of trees (Dar *et al.*, 2019). Average carbon contributions of tree species were highly variable in both the sacred groves. This might be due to the variation in total basal area, tree density, richness and diversity of tree species as these are most important variables affecting biomass carbon stock in major forest types in Central Himalaya (Kaushal and Baishya, 2021).

#### **5.4 Soil Carbon Stock**

In the present study, total soil carbon stock of SSG and DSG was found 18.31 t/ha and 17.93 t/ha respectively. This result is slightly higher than SOC stock (14 t/ha) of forestland (0 - 10 cm depth) than the study of Shrestha (2002) which might be due to slight difference in depth of sampled soil as the soil carbon increase with soil depth (0 - 20 cm) and then decreases rapidly below the (20 - 40) cm depth (Pradhan *et al.*, 2012). Though total soil carbon was nearly equal but mean ranks of soil carbon stock (t/ha) was found significantly different between two sacred groves. This might be due to difference in age of stand because results of regeneration study showed that the forest of DSG was less mature and regenerating than SSG. Organic C stock in forest floor generally increases with stand age and decreases with soil depth (Mishra, 2010). Soil carbon stock increased with increase in organic matter and soil organic carbon in both sacred groves. In the present study, soil organic carbon and organic matter showed negative correlation with bulk density. This finding was similar with the observation of Reintam *et al.* (2005) which reported decrease in bulk density with increase in soil organic matter. Chaudhari *et al.* (2013) also found negative relationships of bulk density with all soil properties (Si, C, CaCO<sub>3</sub>, OMC, total macro and total micro nutrient content) except with sand content (S). Besides texture and OMC, the nutrient concentration was also the most effective factor that affected the bulk density of soils. Increase in soil carbon and organic matter leads to change in the nutrient concentration of soil.

## 5.5 Tree Carbon Stock, Species Richness and Diversity

In the present study, with the increase in species richness and Shannon wiener's diversity index, there was no significant increase in tree carbon stock. Tree carbon stock showed non-significant weak positive correlation with species richness ( $r = 0.290$ ,  $p = 0.120$ ) and diversity index ( $r = 0.219$ ,  $p = 0.246$ ) in SSG but it showed non-significant weak negative correlation with species richness ( $r = -0.077$ ,  $p = 0.607$ ) and diversity index ( $r = -0.201$ ,  $p = 0.177$ ) in DSG. Similar type of result was obtained by Mandal *et al.* (2013) in the study of carbon stock in three collaborative forest of Terai region. Day *et al.* (2014) showed a weak significant correlation between tree biomass and tree species diversity ( $r = 0.21$ ,  $p = 0.03$ ) in a study done in Central African Rainforests. The stem density and species richness of pioneer species were negatively correlated with increasing biomass in a study in Borneo forest of Indonesia (Imai *et al.*, 2014). Aryal *et al.* (2018) reported that the total carbon and biomass carbon were negatively related to the diversity and the density of trees. Some researches have shown the positive relationship of tree carbon stock with species richness and diversity. Unlike the present result, Shrestha *et al.* (2016) reported significant effect of tree species richness ( $t = 1.98$ ,  $p < 1.98$ ), Shannon-Wiener diversity index ( $t = 2.00$ ,  $p < 0.05$ ) and evenness ( $t = 2.01$ ,  $p < 0.05$ ) on carbon sequestration in Pashupati and Bajrabarahi sacred groves of Kathmandu valley. Chisholm *et al.* (2013) reported a positive correlation between the species richness and productivity in a study of tropical and temperate forests at small spatial scales (20 m  $\times$  20 m). Cardinale *et al.* (2011) also found positive relationship between species richness, productivity and biomass from meta-analysis. Vila *et al.* (2007) explained that carbon storage can be determined in part by species diversity. Therefore, species richness and diversity are the weak predictors of the tree carbon stock in the SSG and DSG.

## CHAPTER 6: CONCLUSION AND RECOMMENDATION

### 6.1 Conclusion

Altogether 115 species of vascular plants belonging to 57 families and 104 genera were recorded in the SSG. Out of which, 30 species were trees, 19 species were shrubs and 65 species were herb. In DSG, 184 species of vascular plants belonging to 77 families and 159 genera were recorded. Out of which, 40 species were trees, 34 species were shrubs and 110 species were herbs. Shannon-Weiner diversity index (H) and evenness was found higher in DSG than the SSG and there was significant difference in mean values of Shannon-Weiner diversity index and evenness of total plant species between SSG and DSG. Species richness and diversity index of herbs was highest in both the sacred groves.

The tree carbon stock (113.76 t/ha) and soil carbon stock (18.31 t/ha) were higher in SSG than tree carbon stock (79.87 t/ha) and soil carbon stock (17.93 t/ha) of DSG. *Pinus roxburghii* was the dominant species in both the study site. *Schima wallichii* was the major contributor of tree carbon stock in SSG but *Pinus roxburghii* was the highest carbon contributing species in DSG. Access road within plot was major disturbance in SSG whereas in DSG, erosion had highest frequency. Other disturbances found to be frequently occurring in both sacred groves were dumping of rubbish, fencing, permanent structures and picnic spots.

Density of seedling (2008 stem/ha), sapling (1836 stem/ha) and tree (876 stem/ha) was found to be higher in DSG than the density of seedling (566 stem/ha), sapling (259 stem/ha) and tree (560 stem/ha) in SSG. The Density-Diameter (D-D) curve for tree species showed reverse J-shaped size class distribution in DSG which indicated good regeneration status of trees in DSG in comparison to SSG.

Tree carbon stock showed non-significant weak positive correlation with species richness ( $r = 0.290$ ,  $p = 0.120$ ) and diversity index ( $r = 0.219$ ,  $p = 0.246$ ) in SSG but it showed non-significant weak negative correlation with species richness ( $r = -0.077$ ,  $p = 0.607$ ) and diversity index ( $r = -0.201$ ,  $p = 0.177$ ) in DSG.

## **6.2 Recommendation**

- I. These sacred groves can be included in REDD+ scheme so that the local community and government entity managing these sacred groves could obtain the benefits of carbon credit trade.
- II. Small paths, picnic spots and gathering of any kind should be practiced in allocated areas only not hampering the plants.

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# ANNEXES

## Annex 1

Data sheets used during field sampling

### Plant Diversity and Carbon Stock in Swayambhu and Dakshinkali Sacred Groves of Kathmandu District, Central Nepal

#### Data sheet for tree species

Date: ..... Transect No: ..... Plot No: ..... Plot size: .....  
 Locality: ..... Forest Type: ..... Aspect: ..... Slope: .....  
 Latitude: ..... Longitude: ..... Elevation: .....  
 Tree canopy (%): ..... Ground vegetation cover (%): .....  
 Disturbance: .....

S N	Scientific name of Tree species	Local name	DBH (cm)	Estimated height (m)	Remarks
1					
2					
3					
.					

#### Data sheet for shrub species

Site: ..... Main Plot no: ..... Quadrat no: .....  
 Altitude: ..... Plot size: ..... canopy cover (%): .....

S N	Scientific name of species	Local name	No. of species	Coverage (%)	Remarks
1					
2					
3					
.					

#### Data sheet for herb species

Site: ..... Main Plot no: ..... Quadrat no: .....  
 Altitude: ..... Plot size: .....

S N	Scientific name of species	Local name	No. of species	Coverage (%)	Remarks
1					
2					
3					
.					

## Annex 2.

### 2.1 List of plant species of Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG) with their life forms.

S.N	Family	Name of species	Life Form	SSG	DSG
1	Acanthaceae	<i>Justicia adhatoda</i> L.	S	√	
2	Acanthaceae	<i>Justicia procumbens</i> L.	H	√	√
3	Acanthaceae	<i>Strobilanthes</i> sp.	H		√
4	Acanthaceae	<i>Barleria</i> sp.	H		√
5	Aceraceae	<i>Acer oblongum</i> Wall.ex DC.	T	√	√
6	Agavaceae	<i>Agave</i> sp.	S		√
7	Alangiaceae	<i>Alangium chinense</i> (Lour.) Harms	T		
8	Alismataceae	<i>Sagittaria</i> sp.	H		
9	Amaranthaceae	<i>Cyathula tomentosa</i> (Roth) Moq.	S	√	
10	Amaranthaceae	<i>Achyranthes bidentata</i> Blume	H	√	√
11	Amaranthaceae	<i>Amaranthus</i> sp.	H	√	
12	Amaranthaceae	<i>Amaranthus spinosus</i> L.	H	√	√
13	Amaranthaceae	<i>Achyranthes aspera</i> L.	H	√	
14	Amaranthaceae	<i>Alternanthera sessilis</i> (L.) DC.	H	√	√
15	Anacardiaceae	<i>Choerospondias axillaris</i> (Roxb.) B. L. Burtt & A. W. Hill	T	√	√
16	Anacardiaceae	<i>Rhus succedanea</i> L.	T		√
17	Anacardiaceae	<i>Rhus</i> sp.	T		√
18	Anacardiaceae	<i>Rhus javanica</i> Miller	T		√
19	Anthericaceae	<i>Chlorophytum nepalense</i> (Lindl.) Baker	H		√
20	Apiaceae	<i>Centella asiatica</i> (L.) Urb.	H		√
21	Aquifoliaceae	<i>Ilex excelsa</i> (Wall.) Hook. f.	T	√	√
22	Araceae	<i>Arisaema</i> sp.	H	√	√
23	Araceae	<i>Remusatia vivipara</i> (Roxb.) Schott	H	√	
24	Araceae	<i>Amorphophallus bulbifer</i> (Schott) Blume	H	√	
25	Araceae	<i>Colocasia esculenta</i> (L.) Schott	H	√	√
26	Araceae	<i>Alocasia</i> sp.	H		√
27	Araliaceae	<i>Hedera</i> sp.	H	√	
28	Asteraceae	<i>Eupatorium adenophorum</i> Spreng.	H	√	√
29	Asteraceae	<i>Bidens pilosa</i> L.	H	√	√
30	Asteraceae	<i>Dichrocephala integrifolia</i> (L. f.) Kuntze	H	√	
31	Asteraceae	<i>Tagetes erecta</i> L.	H	√	
32	Asteraceae	<i>Galinsoga parviflora</i> Cav.	H	√	√
33	Asteraceae	<i>Conyza bonariensis</i> (L.) Cronquist	H	√	√
34	Asteraceae	<i>Bidens bipinnata</i> L.	H	√	
35	Asteraceae	<i>Ageratum conyzoides</i> L.	H	√	√
36	Asteraceae	<i>Artemisia indica</i> Willd.	H	√	√
37	Asteraceae	<i>Xanthium strumarium</i> L.	H	√	
38	Asteraceae	<i>Elephantopus scaber</i> L.	H	√	
39	Asteraceae	<i>Crassocephalum crepidioides</i> (Benth.) S. Moore	H	√	√
40	Asteraceae	<i>Ageratum houstonianum</i> Mill.	H		√
41	Asteraceae	<i>Anaphalis busua</i> (Buch.-Ham. ex D. Don) DC.	H		√
42	Asteraceae	Unidentified 2	H		√
43	Asteraceae	<i>Taraxacum officinale</i> Wigg.	H		√
44	Begoniaceae	<i>Begonia rubro-venia</i> Hook.	H		√
45	Begoniaceae	<i>Begonia picta</i> Sm.	H		√
46	Berberidaceae	<i>Berberis</i> sp.	S		√
47	Berberidaceae	<i>Mahonia nepaulensis</i> DC.	S		√
48	Betulaceae	<i>Alnus nepalensis</i> D. Don	T		√
49	Betulaceae	<i>Betula alnoides</i> Buch.-Ham. ex D. Don	T		√
50	Bignoniaceae	<i>Jacaranda mimosifolia</i> D. Don	T		√
51	Boraginaceae	<i>Cynoglossum zeylanicum</i> (Vahl ex Hornem.) Thunb.ex Lehm.	H	√	√

52	Buxaceae	<i>Sarcococca coriacea</i> (Hook.) Sweet	S	√	√
53	Buxaceae	<i>Sarcococca hookeriana</i> Baill.	S		√
54	Cactaceae	<i>Cereus peruvianus</i> (L.) Mill.	S		√
55	Cannabaceae	<i>Cannabis sativa</i> L.	H	√	
56	Caryophyllaceae	<i>Drymaria diandra</i> Blume	H	√	√
57	Caryophyllaceae	<i>Stellaria media</i> (L.) Vill.	H		√
58	Casuarinaceae	<i>Casuarina equisetifolia</i> L.	T		√
59	Chenopodiaceae	<i>Chenopodium album</i> L.	H	√	
60	Commelinaceae	<i>Commelina benghalensis</i> L.	H	√	√
61	Convolvulaceae	<i>Ipomoea purpurea</i> (L.) Roth.	H	√	√
62	Cucurbitaceae	<i>Momordica cochinchinensis</i> (Lour.) Spreng.	H	√	
63	Cucurbitaceae	<i>Diplocyclos palmatus</i> (L.) C. Jeffrey	H	√	
64	Cyperaceae	<i>Cyperus cyperinus</i> (Retz.) Suringar	H	√	√
65	Cyperaceae	<i>Carex filicina</i> Nees	H		√
66	Davalliaceae	<i>Nephrolepis cordifolia</i> (L.) K. Presl.	H (Pteridophyte)	√	√
67	Dennstaedtiaceae	<i>Microlepia khasiyana</i> (Hook.) C. Presl.	H (Pteridophyte)	√	
68	Dennstaedtiaceae	<i>Dennstaedtia zeylanica</i> (Sw.) Zink ex Fraser-Jenk. & Kandel	H (Pteridophyte)		√
69	Dioscoreaceae	<i>Dioscorea bulbifera</i> L.	H	√	√
70	Droseraceae	<i>Drosera</i> sp.	H		√
71	Dryopteridaceae	<i>Tectaria macrodonata</i> (J.Sm.) C.Chr.	H (Pteridophyte)	√	√
72	Dryopteridaceae	<i>Dryopteris cochleata</i> (D. Don) C. Chr.	H (Pteridophyte)	√	√
73	Equisetaceae	<i>Equisetum</i> sp.	H (Pteridophyte)		√
74	Ericaceae	<i>Rhododendron arboreum</i> Sm.	T		√
75	Ericaceae	<i>Lyonia ovalifolia</i> (Wall.) Drude	T		√
76	Ericaceae	<i>Gaultheria</i> sp.	S		√
77	Euphorbiaceae	<i>Sapium insigne</i> (Royle) Benth.ex Hook. f.	T		√
78	Euphorbiaceae	<i>Phyllanthus emblica</i> L.	T		√
79	Euphorbiaceae	<i>Phyllanthus parvifolius</i> Buch.-Ham. ex D. Don	S		√
80	Euphorbiaceae	<i>Phyllanthus glaucus</i> Wall.ex Mull. Arg.	S		√
81	Euphorbiaceae	<i>Euphorbia</i> sp.	S	√	√
82	Euphorbiaceae	<i>Ricinus communis</i> L.	H	√	√
83	Fabaceae	<i>Albizia lebbek</i> (L.) Benth.	T		√
84	Fabaceae	<i>Albizia procera</i> (Roxb.) Benth.	T		√
85	Fabaceae	<i>Bauhinia variegata</i> L.	T	√	√
86	Fabaceae	<i>Cassia floribunda</i> Cav.	S		√
87	Fabaceae	<i>Cassia tora</i> L.	H	√	
88	Fabaceae	<i>Desmodium multiflorum</i> DC.	S		√
89	Fabaceae	<i>Desmodium elegans</i> DC.	S		√
90	Fabaceae	<i>Desmodium</i> sp.	S		√
91	Fabaceae	<i>Desmodium laxiflorum</i> DC.	H		√
92	Fabaceae	<i>Desmodium heterocarpon</i> (L.) DC.	H		√
93	Fabaceae	<i>Desmodium microphyllum</i> (Thunb.) DC.	H		√
94	Fabaceae	<i>Trifolium repens</i> L.	H		√
95	Fagaceae	<i>Castanopsis indica</i> (Roxb.) Miq.	T		√
96	Fagaceae	<i>Castanopsis tribuloides</i> (Sm.) A. DC.	T		√
97	Fagaceae	<i>Quercus glauca</i> Thunb.	T		√
98	Flacourtiaceae	<i>Xylosma controversum</i> Clos	T	√	
99	Flacourtiaceae	<i>Flacourtia</i> sp.	T	√	
100	Gentianaceae	<i>Swertia nervosa</i> (G. Don) C. B. Clarke	H		√
101	Gleicheriaceae	<i>Dicranopteris linearis</i> (Burm. f.) Underw.	H		√
102	Hydrangeaceae	<i>Dichroa febrifuga</i> Lour.	S		√
101	Hypoxidaceae	<i>Hypoxis aurea</i> Lour.	H		√
103	Lamiaceae	<i>Scutellaria discolor</i> Colebr.	H	√	√
104	Lamiaceae	<i>Perilla frutescens</i> (L.) Britton	H		√
105	Lauraceae	<i>Cinnamomum tamala</i> (Buch.-Ham.) Nees & Eberm.	T	√	
106	Lauraceae	<i>Persea duthiei</i> (King ex Hook. f.) Kosterm.	T		√
107	Leeaceae	<i>Leea crispa</i> Royen ex L.	S		√

108	Loganiaceae	<i>Buddleja asiatica</i> Lour.	S	√	
109	Lythraceae	<i>Lagerstroemia indica</i> L.	T	√	
110	Magnoliaceae	<i>Michelia champaca</i> L.	T	√	
111	Malvaceae	<i>Abutilon indicum</i> (L.) Sweet	H	√	
112	Malvaceae	<i>Sida</i> sp.	H	√	
113	Malvaceae	<i>Hibiscus rosa-sinensis</i> L.	S	√	
114	Malvaceae	<i>Urena lobata</i> L.	S	√	√
115	Melastomataceae	<i>Melastoma</i> sp.	S		√
116	Meliaceae	<i>Melia azederach</i> L.	T	√	√
117	Menispermaceae	<i>Stephania glandulifera</i> Miers	H	√	√
118	Menispermaceae	<i>Stephania elegans</i> Hook. f. & Thomson	H		√
118	Menispermaceae	<i>Tinospora sinensis</i> (Lour.) Merr.	H	√	
119	Moraceae	<i>Morus alba</i> Miq.	T	√	√
120	Moraceae	<i>Ficus benjamina</i> L.	T	√	
121	Moraceae	<i>Ficus lacor</i> Buch.-Ham.	T	√	
122	Moraceae	<i>Ficus benghalensis</i> L.	T	√	
123	Moraceae	<i>Ficus religiosa</i> L.	T	√	
124	Moraceae	<i>Maclura cochinchinensis</i> (Lour.) Corner	T	√	
125	Myricaceae	<i>Myrica esculenta</i> Buch.-Ham. ex D. Don	T		√
126	Myrsinaceae	<i>Myrsine capitellata</i> Wall.	T		√
127	Myrsinaceae	<i>Maesa chisia</i> Buch.-Ham. ex D. Don	T		√
128	Myrsinaceae	<i>Maesa macrophylla</i> (Wall.) A. DC.	S		√
129	Myrtaceae	<i>Eucalyptus</i> sp.	T		√
130	Myrtaceae	<i>Syzygium cumini</i> (L.) Skeels	T	√	√
131	Myrtaceae	<i>Psidium guajava</i> L.	T	√	
132	Nyctaginaceae	<i>Mirabilis jalapa</i> L.	H	√	
133	Oleaceae	<i>Fraxinus floribunda</i> Wall.	T	√	√
134	Oleaceae	<i>Ligustrum</i> sp.	T	√	
135	Oleaceae	<i>Jasminum officinale</i> L.	S	√	√
136	Oleaceae	<i>Jasminum humile</i> L.	S	√	√
137	Oleaceae	<i>Jasminum</i> sp.	S	√	
138	Orchidaceae	<i>Malaxis</i> sp.	H		√
139	Orchidaceae	<i>Malaxis acuminata</i> D. Don	H		√
140	Orchidaceae	<i>Brachycorythis obcordata</i> (Lindl.) Summerh.	H		√
141	Oxalidaceae	<i>Oxalis corniculata</i> L.	H	√	√
142	Oxalidaceae	<i>Oxalis latifolia</i> Humb.	H		√
143	Pinaceae	<i>Pinus roxburghii</i> Sargent	T	√	√
144	Pinaceae	<i>Pinus patula</i> Scheide.ex Schltdl&Cham.	T		√
145	Pinaceae	<i>Pinus wallichiana</i> A. B. Jacks.	T		√
146	Pinaceae	<i>Cedrus deodara</i> (Roxb. ex D.Don) G.Don	T		√
147	Plantaginaceae	<i>Plantago major</i> L.	H		√
148	Poaceae	<i>Oplismenus burmannii</i> (Retz.) P. Beauv.	H	√	√
149	Poaceae	<i>Eragrostis nigra</i> Nees ex Steud.	H	√	√
150	Poaceae	<i>Eleusine indica</i> (L.) Gaertn.	H	√	√
151	Poaceae	<i>Hemarthria compressa</i> (L. f.) R. Br.	H		√
152	Poaceae	<i>Thysanolaena maxima</i> (Roxb.) Kuntze	H		√
153	Poaceae	<i>Capillipedium assimile</i> (Steud.) A. Camus	H		√
154	Poaceae	<i>Microstegium</i> sp.	H		√
155	Poaceae	<i>Imperata cylindrica</i> (L.) P. Beauv.	H		√
156	Poaceae	<i>Eriochloa procera</i> (Retz.) C.E.Hubb.	H		√
157	Poaceae	<i>Pogonatherum paniceum</i> (Lam.) Hack.	H		√
158	Poaceae	<i>Cynodon dactylon</i> (L.) Pers.	H		√
159	Poaceae	<i>Chrysopogon gryllus</i> (L.) Trin.	H		√
160	Poaceae	<i>Saccharum spontaneum</i> L.	H		√
161	Poaceae	<i>Sporobolus</i> sp.	H		√
162	Polygonaceae	<i>Polygonum</i> sp.	H	√	√
163	Polygonaceae	<i>Rumex nepalensis</i> Spreng.	H		√
164	Polygonaceae	<i>Persicaria capitata</i> (Buch.-Ham. ex D. Don) H. Gross	H		√

165	Polygonaceae	<i>Rumex acetosa</i> L.	H		√
166	Polygonaceae	<i>Persicaria lapathifolia</i> (L.) Gray	H		√
167	Polypodiaceae	<i>Microsorium membranaceum</i> (D. Don) Ching	H (Pteridophyte)		√
168	Polypodiaceae	<i>Polypodioides lachnopus</i> (Wall. ex Hook.) Ching	H (Pteridophyte)		√
169	Polypodiaceae	<i>Drynaria propinqua</i> (Wall. ex Mett.) J. Sm. J.	H (Pteridophyte) *		√
170	Polypodiaceae	<i>Selliguea oxyloba</i> (Wall. ex Kunze) Fraser-Jenk.	H (Pteridophyte) *		√
171	Polypodiaceae	<i>Pyrrosia stenophylla</i> (Bedd.) Ching	H (Pteridophyte) *		√
172	Polypodiaceae	<i>Lepisorus scolopendrium</i> (Buch.-Ham. ex D. Don) Mehra & Bir	H (pteridophyte) *		√
173	Proteaceae	<i>Grevillea robusta</i> A. Cunn. ex R. Br.	T	√	√
174	Pteridaceae	<i>Coniogramme pubescens</i> Hieron.	H (Pteridophyte)	√	
175	Pteridaceae	<i>Aleuritopteris albomarginata</i> (C.B. Clarke) Ching	H (Pteridophyte)	√	√
176	Pteridaceae	<i>Pteris biaurita</i> L.	H (Pteridophyte)	√	√
177	Pteridaceae	<i>Adiantum caudatum</i> L.	H (Pteridophyte)	√	√
178	Pteridaceae	<i>Onychium</i> sp.	H (Pteridophyte)		√
179	Pteridaceae	<i>Onychium siliculosum</i> (Desv.) C. Chr.	H (Pteridophyte)		√
180	Rhamnaceae	<i>Zizyphus incurva</i> Roxb.	T	√	√
181	Rosaceae	<i>Pyrus pashia</i> Buch.-Ham. ex D. Don	T	√	√
182	Rosaceae	<i>Prunus cerasoides</i> D. Don	T	√	√
183	Rosaceae	<i>Stranvaesia nussia</i> (D. Don) Decne.	T	√	
184	Rosaceae	<i>Rubus elipticus</i> Sm.	S	√	√
185	Rosaceae	<i>Rosa brunonii</i> Lindl.	S		√
186	Rosaceae	<i>Pyracantha crenulata</i> (D. Don) M. Roem.	S		√
187	Rosaceae	<i>Neillia rubiflora</i> D. Don	S		√
188	Rosaceae	<i>Rubus acuminatus</i> Sm.	S		√
189	Rosaceae	Unidentified 1	S		√
190	Rosaceae	<i>Agrimonia pilosa</i> Ledeb.	H		√
191	Rosaceae	<i>Duchesnea indica</i> (Andrews) Focke	H		√
192	Rubiaceae	<i>Mussaenda roxburghii</i> Hook. f.	S		√
193	Rubiaceae	<i>Xeromphis</i> sp.	S		√
194	Rubiaceae	<i>Galium aparine</i> L.	H		√
195	Sambucaceae	<i>Sambucus hookeri</i> Rehder	S	√	
196	Sambucaceae	<i>Viburnum cylindricum</i> Buch.-Ham. ex D. Don	S		√
198	Sapindaceae	<i>Sapindus mukorossi</i> Geartn.	T	√	
199	Saurauiceae	<i>Saurauia napaulensis</i> DC.	T		√
200	Saururaceae	<i>Houttuynia cordata</i> Thunb.	H		√
201	Scrophulariaceae	<i>Mazus pumilus</i> (Burm. f.) Steenis	H	√	
202	Scrophulariaceae	<i>Lindenbergia</i> sp.	H		√
203	Selaginellaceae	<i>Sellaginella</i> sp.	H (Pteridophyte)		√
204	Smilacaceae	<i>Smilax</i> sp.	S	√	√
205	Solanaceae	<i>Cestrum nocturnum</i> L.	S	√	√
206	Solanaceae	<i>Datura suaveolens</i> Humb. & Bonpl. ex Willd.	S	√	
207	Solanaceae	<i>Solanum aculeatissimum</i> Jacq.	S	√	√
208	Solanaceae	<i>Lycopersicon esculentum</i> Mill.	H	√	
209	Solanaceae	<i>Solanum nigrum</i> L.	H	√	√
210	Solanaceae	<i>Nicandra physaloides</i> (L.) Gaertn.	H	√	
211	Solanaceae	<i>Solanum torvum</i> Sw.	S		√
212	Solanaceae	<i>Solanum nigrum</i> L.	H		√
213	Theaceae	<i>Schima wallichii</i> (DC.) Korth.	T	√	√
214	Theaceae	<i>Eurya acuminata</i> DC.	T		√
215	Thelypteridaceae	<i>Thelypteris dentate</i> (Forssk.) E.P. St. John	H (Pteridophyte)	√	
216	Thelypteridaceae	<i>Thelypteris</i> sp.	H (Pteridophyte)	√	
217	Thelypteridaceae	<i>Thelypteris procera</i> (D. Don) Fraser-Jenk.	H (Pteridophyte)		√
218	Tiliaceae	<i>Grewia optiva</i> J. R. Drumm. ex Burret	T	√	
219	Ulmaceae	<i>Celtis australis</i> L.	T	√	√
220	Urticaceae	<i>Boehmeria platyphylla</i> D. Don	S	√	√
221	Urticaceae	<i>Urtica dioica</i> L.	H	√	√
222	Urticaceae	<i>Pilea smilacifolia</i> Wedd.	H	√	√

223	Urticaceae	<i>Gonostegia hirta</i> (Blume) Miq.	H		√
224	Urticaceae	<i>Elatostema</i> sp.	H		√
225	Verbenaceae	<i>Lantana camara</i> L.	S	√	√
226	Verbenaceae	<i>Duranta repens</i> L.	S	√	√
227	Verbenaceae	<i>Clerodendrum</i> sp.	S	√	
228	Violaceae	<i>Viola</i> sp.	H		√
229	Vitaceae	<i>Parthenocissus semicordata</i> (Wall.) Planch.	H		√
230	Woodsiaceae	<i>Athyrium cuspidatum</i> (Bedd.) M.Kato	H (Pteridophyte)		√
231	Woodsiaceae	<i>Athyrium pectinatum</i> (Wall.) Presl	H (Pteridophyte)	√	√
232	Zingiberaceae	<i>Globba clarkei</i> Baker	H	√	√
233	Zingiberaceae	<i>Cautleya spicata</i> (Sm.) Baker	H	√	
234	Zingiberaceae	<i>Amomum</i> sp.	H		√
235	Zingiberaceae	<i>Hedychium</i> sp.	H		√
236	Zingiberaceae	<i>Curcuma angustifolia</i> Roxb.	H		√
H= herb, S=shrub, T=tree, *=Epiphytic pteridophytes √= presence of species on the study site					

**Annex 3**

3.1: Independent Samples T-test of species richness, shrub species richness, herb species richness and total species richness between SSG and DSG.

Independent Samples Test								
		Levene's Test for Equality of Variances			t-test for Equality of Means			
		Sig.	df	Sig. (2-tailed)	Mean Dif	Std.E Dif	95% Confidence Interval of the Difference	
							Lower	Upper
Tree species richness	Equal variances assumed	.000	77	.006	.8659	.3089	.2506	1.4812
	Equal variances not assumed		30.765	.030	.8659	.3799	.0909	1.6409
Shrub species richness	Equal variances assumed	.509	77	.000	-3.295	.439	-4.170	-2.420
	Equal variances not assumed		57.805	.000	-3.295	.448	-4.192	-2.398
Herb species richness	Equal variances assumed	.198	77	.000	-12.27	.815	-13.895	-10.648
	Equal variances not assumed		73.450	.000	-12.27	.762	-13.790	-10.753
Total species richness	Equal variances assumed	.233	77	.000	-5.866	.888	-7.635	-4.097
	Equal variances not assumed		52.115	.000	-5.866	.933	-7.737	-3.995

3.2: Independent Samples Test of Shannon-Weiner diversity index (H) and evenness of total plant species between SSG and DSG.

Independent Samples Test								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		Sig.	df	Sig. (2-tailed)	Mean Dif	Std.E Dif	95% Confidence Interval of the Difference	
							Lower	Upper
Shannon's Diversity Index(H)	Equal variances assumed	.026	75	.000	-.5777	.0695	-.7161	-.4394
	Equal variances not assumed		44.79	.000	-.5777	.0760	-.7309	-.4245
Evenness(E)	Equal variances assumed	.001	75	.000	-.1031	.0184	-.1397	-.0665
	Equal variances not assumed		46.62	.000	-.1031	.0199	-.1431	-.0631

3.3 Wilcoxon Signed Rank Test of total diversity and total evenness with diversity and evenness of trees, shrubs and herbs of SSG and DSG.

Test Statistics <sup>a</sup>						
Study Site SSG	T <sub>H</sub> -Tr <sub>H</sub>	T <sub>H</sub> -Sh <sub>H</sub>	T <sub>H</sub> -Hb <sub>H</sub>	T <sub>E</sub> -Tr <sub>E</sub>	T <sub>E</sub> -Sh <sub>E</sub>	T <sub>E</sub> -Hb <sub>E</sub>
Z	-4.782 <sup>b</sup>	-4.782 <sup>b</sup>	.000 <sup>c</sup>	-1.635 <sup>b</sup>	-.668 <sup>d</sup>	-3.260 <sup>b</sup>
Asymp. Sig. (2-tailed)	.000	.000	1.000	.102	.504	.001
Study Site DSG						
Z	-5.968 <sup>b</sup>	-5.968 <sup>b</sup>	-5.947 <sup>b</sup>	-2.952 <sup>b</sup>	-3.122 <sup>c</sup>	-1.342 <sup>b</sup>
Asymp.Sig. (2-tailed)	.000	.000	.000	.003	.002	.180

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. The sum of negative ranks equals the sum of positive ranks.

d. Based on positive ranks.

## Annex 4

### 4.1 Importance value index (IVI) of Tree species of SSG

S N	Name of species	Density	RD (%)	Count	Frequency	RF (%)	Basal area (m <sup>2</sup> /ha)	Dominance	RDo (%)	IVI (30%)	Regeneration status
1	<i>Pinus roxburghii</i>	259.9	46.40	18	60.00	15.79	15.66	16.61	31.59	93.9*	None
2	<i>Schima wallichii</i>	131.5	23.48	21	70.00	18.42	22.04	23.38	44.46	89.54	Poor
3	<i>Pyrus pashia</i>	56.21	10.04	12	40.00	10.53	2.19	2.32	4.42	24.68	Poor
4	<i>Grewia optiva</i>	11.67	2.08	2	10.00	2.63	0.73	0.77	1.47	6.96	Poor
5	<i>Zizyphus incurva</i>	11.67	2.08	6	20.00	5.26	0.24	0.25	0.48	5.97	Poor
6	<i>Prunus cerasoides</i>	11.67	2.08	5	16.67	4.39	0.47	0.50	0.95	6.44	None
7	<i>Fraxinus floribunda</i>	10.61	1.89	4	13.33	3.51	0.99	1.05	1.99	6.15	None
8	<i>Stranvaesia nussia</i>	8.48	1.52	2	10.00	2.63	0.93	0.99	1.88	6.81	Fair
9	<i>Syzygium cumini</i>	7.42	1.33	7	23.33	6.14	0.90	0.96	1.82	6.56	Poor
10	<i>Morus alba</i>	5.30	0.95	2	3.33	0.88	0.13	0.14	0.26	2.34	Fair
11	<i>Osmanthus fragans</i>	5.30	0.95	2	6.67	1.75	0.61	0.65	1.23	4.45	Poor
12	<i>Ficus benjamina</i>	5.30	0.95	4	13.33	3.51	1.82	1.93	3.67	8.02	Poor
13	<i>Choerospondias axillaris</i>	4.24	0.76	2	10.00	2.63	1.00	1.07	2.03	6.19	Fair
14	<i>Ligustrum sp.</i>	4.24	0.76	2	3.33	0.88	0.03	0.03	0.07	1.96	None
15	<i>Ilex excels</i>	3.18	0.57	2	3.33	0.88	0.17	0.18	0.35	2.05	None
16	<i>Acer oblongum</i>	2.12	0.38	1	3.33	0.88	0.37	0.39	0.75	2.26	Poor
17	<i>Ficus lacor</i>	2.12	0.38	1	3.33	0.88	0.43	0.46	0.87	2.39	None
18	<i>Ficus benghalensis</i>	2.12	0.38	1	6.67	1.75	0.13	0.14	0.26	2.91	Poor
19	<i>Sapindus mukorossi</i>	2.12	0.38	2	10.00	2.63	0.04	0.04	0.08	2.73	Fair
20	<i>Cinnamomum tamala</i>	2.12	0.38	2	6.67	1.75	0.03	0.03	0.06	2.71	None
21	<i>Celtis australis</i>	2.12	0.38	1	3.33	0.88	0.01	0.01	0.02	1.53	Poor
22	<i>Melia azederach</i>	2.12	0.38	2	6.67	1.75	0.09	0.10	0.19	1.70	None
23	<i>xylosma controversum</i>	1.06	0.19	1	3.33	0.88	0.01	0.01	0.01	1.34	None
24	<i>Ficus religiosa</i>	1.06	0.19	1	3.33	0.88	0.02	0.02	0.04	1.36	None
25	<i>Lagerstroemia indica</i>	1.06	0.19	2	6.67	1.75	0.01	0.01	0.02	1.34	Fair
26	<i>Flacourtia sp.</i>	1.06	0.19	1	3.33	0.88	0.31	0.32	0.62	1.94	None
27	<i>Grevillea robusta</i>	1.06	0.19	1	3.33	0.88	0.18	0.19	0.36	1.69	None
28	<i>Bauhinia variegata</i>	1.06	0.19	1	6.67	1.75	0.01	0.01	0.02	1.35	None
29	<i>Michelia champaca</i>	1.06	0.19	1	3.33	0.88	0.00	0.00	0.01	1.33**	None
30	<i>Maclura cochinchinensis</i>	1.06	0.19	1	6.67	1.75	0.03	0.03	0.06	1.39	None
	<b>Total</b>	<b>560</b>	<b>100</b>		<b>380</b>	<b>100</b>	<b>49.58</b>	<b>52.59</b>	<b>100</b>	<b>300</b>	
	<b>Highest</b>	<b>259.9</b>	<b>46.40</b>		<b>70</b>	<b>18.42</b>	<b>22.04</b>	<b>23.38</b>	<b>44.46</b>	<b>93.90</b>	
	<b>Lowest</b>	<b>1.06</b>	<b>0.19</b>		<b>3.33</b>	<b>0.88</b>	<b>0.00</b>	<b>0.00</b>	<b>0.01</b>	<b>1.33</b>	
	<b>Average</b>	<b>18.67</b>			<b>12.67</b>		<b>1.65</b>	<b>1.75</b>			

\*species having highest IVI \*\*species having lowest IVI

### 4.2 Importance value index (IVI) for shrub-saplings of SSG

SN	Name of species	No. of sp	RD (%)	RF (%)	RC (%)	IVI (%)
1	<i>Justicia adhatoda</i>	128	24.76	10.6	23.58	55.77*
2	<i>Morus alba</i> (sapling)	10	1.93	7.6	3.7	12.24
3	<i>Cestrum nocturnum</i>	1	0.19	1.5	0.21	1.23
4	<i>Boehmeria platyphylla</i>	57	11.03	9.8	5.34	25.45
5	<i>Jasminum humile</i>	13	2.51	3.8	5.16	11.81
6	<i>Celtis australis</i> (sapling)	7	1.35	3.8	1.6	5.44
7	<i>Choerospondias axillaris</i> (sapling)	1	0.19	0.8	0.35	1.37
8	<i>Myrica esculenta</i> (sapling)	2	0.39	1.5	0.49	2.53
9	<i>Zizypus incurva</i> (sapling)	4	0.77	0.8	1.19	2.79
10	<i>Psidium guajava</i> (sapling)	1	0.19	0.8	0.28	1.3
11	<i>Urena lobata</i>	31	6	5.3	3.56	15.34
12	<i>Sapindus mukorossi</i> (sapling)	4	0.77	0.8	1.4	3

13	<i>Sarcococca coriacea</i>	6	1.16	1.5	1.74	4.56
14	<i>Solanum aculeatissimum</i>	20	3.87	4.5	2.23	11.06
15	<i>Ricinus communis</i>	3	0.58	0.8	0.35	1.76
16	<i>Lantana camara</i>	57	11.03	11.4	18.21	40.8
17	<i>Durenta repens</i>	8	1.55	3.8	4.39	8.42
18	<i>Cyathula tomentosa</i>	95	18.38	12.9	8.16	39.76
19	<i>Ficus benghalensis</i> (sapling)	9	1.74	2.3	0.7	4.09
20	<i>Stranvaesia nussia</i> (sapling)	4	0.77	1.5	3.7	6.12
21	<i>Schima wallichii</i> (sapling)	7	1.35	1.5	2.23	5.24
22	<i>Osmanthus fragrans</i> (sapling)	1	0.19	0.8	0.28	1.3
23	<i>Grewia optiva</i> (sapling)	1	0.19	0.8	0.35	1.37
24	<i>Acer oblongum</i> (sapling)	3	0.58	1.5	1.19	3.42
25	<i>Pyrus pashia</i> (sapling)	1	0.19	0.8	0.28	1.3
26	<i>Lagerstroemia indica</i>	2	0.39	1.5	0.49	1.7
27	<i>Rubus ellipticus</i>	10	1.93	3.8	2.79	6.38
28	<i>Hibiscus rosa-sinensis</i>	1	0.19	0.8	0.21	1.23
29	<i>Elaeocarpus sphaericus</i> (sapling)	2	0.39	0.8	0.56	2.6
30	<i>Clerodendrum</i> sp.	16	3.09	4.5	2.51	8.09
31	<i>Syzygium cumini</i> (sapling)	1	0.19	1.5	0.21	1.23
32	<i>Datura suaveolens</i>	3	0.58	0.8	0.49	1.9
33	<i>Jasminum</i> sp.	1	0.19	0.8	0.7	1.72
34	<i>Jasminum officinale</i>	1	0.19	0.8	0.35	1.37
35	<i>Buddleja asiatica</i>	2	0.39	1.5	0.35	2.39
36	<i>Ficus benjamina</i> (sapling)	1	0.19	0.8	0.42	1.44
37	<i>Smilax</i> sp.	1	0.19	0.8	0.07	1.09**
38	<i>Sambucus hookeri</i>	2	0.39	1.5	0.21	1.42
	<b>Total</b>	<b>389</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>300</b>

\*species having highest IVI \*\*species having lowest IVI

#### 4.3 Importance value index (IVI) for herb-seedlings of SSG

SN	Name of species	No. of sp	RD (%)	RF (%)	RC (%)	IVI (%)
1	<i>Eupatorium adenophorum</i>	428	10.8	5.46	10.5	26.7
2	<i>Bidens pilosa</i>	476	12	9.83	12.3	34
3	<i>Achyranthes bidentata</i>	410	10.3	10.9	8.94	30.2
4	<i>Oplismenus burmannii</i>	1129	28.4	14.9	28.3	71.50*
5	<i>Solanum aculeatissimum</i>	35	0.88	3.71	1.44	6.03
6	<i>Cannabis sativa</i>	4	0.1	0.44	0.03	0.56
7	<i>Arisaema</i> sp.	4	0.1	0.87	0.11	1.09
8	<i>Amaranthus</i> sp.	259	6.51	3.06	5.26	14.8
9	<i>Globba clarkei</i>	318	7.99	5.46	8.37	21.8
10	<i>Morus alba</i> (seedling)	1	0.03	0.22	0.03	0.27
11	<i>Polygonum</i> sp.	69	1.73	1.75	1.05	4.53
12	<i>Dichrocephala integrifolia</i>	30	0.75	1.31	0.36	2.42
13	<i>Commelina benghalensis</i>	17	0.43	1.09	0.22	1.74
14	<i>Amaranthus spinosus</i>	12	0.3	0.66	0.26	1.21
15	<i>Remusatia vivipara</i>	35	0.88	1.75	0.77	3.39
16	<i>Eragrostis nigra</i>	8	0.2	0.44	0.06	0.7
17	<i>Amorphophallus bulbifer</i>	12	0.3	1.31	0.28	1.89
18	<i>Colocasia esculenta</i>	100	2.51	3.49	2.69	8.7
19	<i>Coniogramme pubescens</i>	3	0.08	0.22	0.04	0.33
20	<i>Stranvaesia nussia</i> (seedling)	1	0.03	0.22	0.03	0.27
21	<i>Dioscorea bulbifera</i>	20	0.5	1.53	0.56	2.59
22	<i>Boehmeria platyphylla</i> (seedling)	20	0.5	0.22	0.38	1.1
23	<i>Choerospondias axillaris</i> (seedling)	3	0.08	0.22	0.08	0.37

24	<i>Tagetes erecta</i>	2	0.05	0.22	0.05	0.32
25	<i>Gallinsoga parvifolia</i>	48	1.21	1.75	0.88	3.83
26	<i>Lycopersicum esculentum</i>	6	0.15	0.87	0.34	1.37
27	<i>Momordica cochinchinensis</i>	27	0.68	2.18	1.99	4.85
28	<i>Mirabilis jalapa</i>	53	1.33	1.97	2.14	5.44
29	<i>Urtica dioica</i>	16	0.4	1.97	0.68	3.04
30	<i>Drymaria diandra</i>	94	2.36	3.49	1.8	7.65
31	<i>Hedera</i> sp.	7	0.18	0.22	0.77	1.16
32	<i>Ipomoea purpurea</i>	17	0.43	1.53	1.66	3.61
33	<i>Athyrium pectinatum</i>	2	0.05	0.22	0.08	0.35
34	<i>Thelypteris dentata</i>	2	0.05	0.22	0.1	0.37
35	<i>Justicia procumbens</i>	4	0.1	0.22	0.26	0.57
36	<i>Solanum nigrum</i>	28	0.7	1.75	1.08	3.53
37	<i>Urena lobata</i> (seedling)	21	0.53	0.44	0.54	1.5
38	<i>Aleuritopteris albomarginata</i>	1	0.03	0.22	0.08	0.32
39	<i>Stephania glandulifera</i>	4	0.1	0.44	0.14	0.68
40	<i>Nephrolepis cordifolia</i>	2	0.05	0.22	0.23	0.5
41	<i>Sapindus mukorossi</i> (seedling)	2	0.05	0.22	0.06	0.33
42	<i>Conyza bonariensis</i>	40	1.01	0.44	1.28	2.72
43	<i>Eleusine indica</i>	1	0.03	0.22	0.03	0.27
44	<i>Bidens bipinnata</i>	3	0.08	0.22	0.26	0.55
45	<i>Tectaria macrodonata</i>	7	0.18	0.44	0.06	0.68
46	<i>Cautleya spicata</i>	5	0.13	0.66	0.23	1.01
47	<i>Pteris biaurita</i>	6	0.15	0.66	0.04	0.84
48	<i>Ageratum conyzoides</i>	24	0.6	0.44	0.18	1.22
49	<i>Microlepia khasiyana</i>	2	0.05	0.44	0.31	0.79
50	<i>Pilea smilacifolia</i>	2	0.05	0.22	0.08	0.35
51	<i>Sida</i> sp.	7	0.18	0.44	0.2	0.82
52	<i>Artemisia indica</i>	2	0.05	0.22	0.03	0.29
53	<i>Oxalis corniculata</i>	38	0.95	1.09	0.45	2.49
54	<i>Cassia tora</i>	2	0.05	0.22	0.01	0.28
55	<i>Abutilon indicum</i>	10	0.25	0.22	0.1	0.57
56	<i>Nicandra physaloides</i>	2	0.05	0.22	0.13	0.4
57	<i>Xanthium strumarium</i>	1	0.03	0.22	0.1	0.35
58	<i>Adiantum caudatum</i>	3	0.08	0.22	0.04	0.33
59	<i>Achyranthes aspera</i>	23	0.58	1.31	0.34	2.23
60	<i>Elephantopus scaber</i>	1	0.03	0.22	0.05	0.29
61	<i>Chenopodium album</i>	10	0.25	0.22	0.13	0.6
62	<i>Diplocyclos palmatus</i>	4	0.1	0.66	0.26	1.01
63	<i>Crassocephalum crepidioides</i>	1	0.03	0.22	0.01	0.26**
64	<i>Lagerstroemia indica</i> (seedling)	9	0.23	0.22	0.13	0.57
65	<i>Tinospora sinensis</i>	1	0.03	0.22	0.03	0.27
66	<i>Mazus pumilus</i>	3	0.08	0.22	0.08	0.37
67	<i>Dryopteris cochleata</i>	12	0.3	0.44	0.15	0.89
68	<i>Cynoglossum zeylanicum</i>	7	0.18	0.87	0.09	1.14
69	<i>Alternanthera sessilis</i>	10	0.25	0.66	0.22	1.12
70	<i>Scutellaria discolor</i>	11	0.28	0.44	0.15	0.87
71	<i>Cyperus cyperinus</i>	3	0.08	0.44	0.04	0.55
72	<i>Thelypteris</i> sp.	1	0.03	0.22	0.03	0.27
	<b>Total</b>	<b>3981</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>300</b>

\*species having highest IVI \*\*species having lowest IVI

#### 4.4 Importance value index (IVI) for Tree species of DSG

S N	Name of species	Density	RD (%)	Count	Frequency	RF (%)	Basal area (m <sup>2</sup> /ha)	Dominance	RDo (%)	IVI (300%)	Regeneration status
1	<i>Pinus roxburghii</i>	378.43	43.25	38	76.6	18.0	20.12	13.62	45.68	106.93*	Fair
2	<i>Schima wallichii</i>	157.06	17.95	35	70.2	16.5	6.38	4.32	14.48	48.93	Fair
3	<i>Alnus nepalensis</i>	85.98	9.83	16	31.9	7.5	8.87	6.00	20.13	37.45	Fair
4	<i>Rhododendron arboreum</i>	25.05	2.86	10	21.3	5.0	0.40	0.27	0.90	8.77	Fair
5	<i>Castanopsis indica</i>	31.82	3.64	13	25.5	6.0	1.64	1.11	3.72	13.36	Poor
6	<i>Myrsine capitellata</i>	33.85	3.87	11	21.3	5.0	0.62	0.42	1.42	10.29	Poor
7	<i>Lyonia ovalifolia</i>	23.69	2.71	9	19.1	4.5	0.28	0.19	0.64	7.85	Fair
8	<i>Celtis australis</i>	14.22	1.62	6	12.8	3.0	0.83	0.56	1.89	6.51	Fair
9	<i>Pyrus pashia</i>	11.51	1.32	10	14.9	3.5	0.33	0.23	0.76	5.58	Poor
10	<i>Sapium insigne</i>	10.15	1.16	6	12.8	3.0	0.29	0.20	0.66	4.82	Poor
11	<i>Zizyphus incurva</i>	28.43	3.25	6	12.8	3.0	0.81	0.55	1.84	8.09	Fair
12	<i>Choerospondias axilaris</i>	11.51	1.32	7	14.9	3.5	0.76	0.52	1.73	6.54	Good
13	<i>Pinus patula</i>	10.83	1.24	3	6.4	1.5	0.63	0.43	1.43	4.16	None
14	<i>Pinus wallichiana</i>	2.71	0.31	2	4.3	1.0	0.03	0.02	0.07	1.38	None
15	<i>Rhus succedanea</i>	7.45	0.85	5	10.6	2.5	0.15	0.10	0.34	3.69	Fair
16	<i>Castanopsis tribuloides</i>	4.06	0.46	4	8.5	2.0	0.16	0.11	0.37	2.83	Poor
17	<i>Myrica esculenta</i>	4.74	0.54	2	4.3	1.0	0.12	0.08	0.28	1.82	Good
18	<i>Saurauia napaulensis</i>	4.74	0.54	3	6.4	1.5	0.09	0.06	0.20	2.24	Poor
19	<i>Albizia procera</i>	4.06	0.46	2	4.3	1.0	0.12	0.08	0.27	1.74	Poor
20	<i>Persea duthiei</i>	2.71	0.31	1	2.1	0.5	0.23	0.15	0.51	1.32	Poor
21	<i>Grevillea robusta</i>	2.71	0.31	1	2.1	0.5	0.08	0.06	0.19	1.00	None
22	<i>Jacaranda mimosifolia</i>	2.03	0.23	2	4.3	1.0	0.12	0.08	0.27	1.50	None
23	<i>Eurya acuminata</i>	2.03	0.23	1	2.1	0.5	0.06	0.04	0.14	0.87	Good
24	<i>Eucalyptus sp.</i>	2.03	0.23	1	2.1	0.5	0.10	0.07	0.23	0.96	None
25	<i>Alangium chinensis</i>	1.35	0.15	1	2.1	0.5	0.08	0.05	0.18	0.83	None
26	<i>Ilex excelsa</i>	1.35	0.15	1	2.1	0.5	0.11	0.07	0.24	0.89	None
27	<i>Causuriana equisetifolia</i>	1.35	0.15	1	2.1	0.5	0.03	0.02	0.06	0.71	None
28	<i>Syzygium cumini</i>	1.35	0.15	1	2.1	0.5	0.01	0.01	0.03	0.68	None
29	<i>Bauhinia variegata</i>	1.35	0.15	1	2.1	0.5	0.02	0.01	0.05	0.70	Good
30	<i>Betula alnoides</i>	0.68	0.08	1	2.1	0.5	0.14	0.10	0.32	0.90	None
31	<i>Cedrus deodara</i>	0.68	0.08	1	2.1	0.5	0.01	0.00	0.01	0.59**	Poor
32	<i>Fraxinus floribunda</i>	0.68	0.08	1	2.1	0.5	0.03	0.02	0.07	0.65	None
33	<i>Maesa chisia</i>	0.68	0.08	1	2.1	0.5	0.00	0.00	0.01	0.59**	None
34	<i>Phyllanthus emblica</i>	0.68	0.08	1	2.1	0.5	0.28	0.19	0.62	1.20	Fair
35	<i>Quercus glauca</i>	0.68	0.08	1	2.1	0.5	0.02	0.01	0.04	0.62	Fair
36	<i>Prunus cerasoides</i>	0.68	0.08	1	2.1	0.5	0.01	0.01	0.03	0.61	Poor
37	<i>Melia azederach</i>	0.68	0.08	1	2.1	0.5	0.06	0.04	0.13	0.70	Poor
38	<i>Rhus sp.</i>	0.68	0.08	1	2.1	0.5	0.01	0.01	0.03	0.60	None
39	<i>Rhus javanica</i>	0.68	0.08	1	2.1	0.5	0.00	0.00	0.01	0.59**	Fair
40	<i>Albizia lebbek</i>	0.68	0.08	1	2.1	0.5	0.01	0.01	0.02	0.60	None
	<b>Total</b>	<b>876</b>	<b>100</b>		<b>425.5</b>	<b>100</b>	<b>44.04</b>	<b>29.82</b>		<b>300</b>	
	<b>Highest</b>	<b>378.43</b>	<b>43.25</b>		<b>76.6</b>	<b>18.0</b>	<b>20.12</b>	<b>13.62</b>	<b>45.68</b>	<b>106.93</b>	
	<b>Lowest</b>	<b>0.68</b>	<b>0.08</b>		<b>2.1</b>	<b>0.5</b>	<b>0.00</b>	<b>0.00</b>	<b>0.01</b>	<b>0.59</b>	
	<b>Average</b>	<b>21.90</b>	<b>2.50</b>	<b>5.25</b>	<b>10.64</b>	<b>2.50</b>	<b>1.10</b>	<b>0.75</b>	<b>2.50</b>	<b>7.50</b>	

\*species having highest IVI \*\*species having lowest IVI

#### 4.5 Importance value index (IVI) for shrub-saplings of DSG

SN	Name of species	No. of sp	RD (%)	RF (%)	RC (%)	IVI (%)
1	<i>Berberis sp.</i>	20	1.45	2.6	2.19	6.24
2	<i>Phyllanthus parvifolius</i>	167	12.1	5.2	11.71	29.01*
3	<i>Rubus sp.</i>	8	0.58	1.16	0.56	2.3
4	<i>Urena lobata</i>	86	6.23	4.91	3.79	14.94

5	<i>Celtis australis</i> (sapling)	27	1.96	3.18	1.99	7.12
6	<i>Durenta repens</i>	12	0.87	0.87	1.78	3.52
7	<i>Alangium chinense</i>	6	0.43	0.58	0.76	1.78
8	<i>Rubus ellipticus</i>	32	2.32	2.89	2.29	7.5
9	<i>Bauhinia variegata</i> (sapling)	8	0.58	0.58	0.81	1.97
10	<i>Schima wallichii</i> (sapling)	139	10.07	8.09	8.4	26.56
11	<i>Jasminum officinale</i>	16	1.16	1.73	1.09	3.99
12	<i>Castanopsis indica</i> (sapling)	47	3.41	3.47	3.97	10.84
13	<i>Cestrum nocturnum</i>	11	0.8	0.87	1.07	2.73
14	<i>Dichroa febrifuga</i>	1	0.07	0.58	0.03	0.68
15	<i>Rhododendron arboreum</i> (sapling)	64	4.64	3.47	4.33	12.43
16	<i>Lyonia ovalifolia</i> (sapling)	100	7.25	5.2	6.59	19.04
17	<i>Rhus javanica</i> (sapling)	32	2.32	3.18	2.34	7.84
18	<i>Rhus succedanea</i> (sapling)	19	1.38	2.02	1.53	4.93
19	<i>Pyrus pashia</i> (sapling)	38	2.75	5.2	3.39	11.34
20	<i>Melastoma</i> sp.	54	3.91	2.89	2.95	9.76
21	<i>Desmodium multiflorum</i>	3	0.22	0.29	0.51	1.02
22	<i>Desmodium elegans</i>	21	1.52	0.58	0.25	2.35
23	<i>Myrsine capitellata</i> (sapling)	50	3.62	2.89	2.9	9.41
24	<i>Saurauia napaulensis</i> (sapling)	3	0.22	0.58	0.25	1.05
25	<i>Sapium insigne</i> (sapling)	16	1.16	2.02	1.53	4.71
26	<i>Pinus roxburghii</i> (sapling)	19	1.38	1.73	0.92	4.03
27	<i>Maesa macrophylla</i>	26	1.88	2.89	2.39	7.17
28	<i>Rosa brunoni</i>	10	0.72	1.16	0.66	2.54
29	<i>Pyracantha crenulata</i>	2	0.14	0.58	0.2	0.93
30	<i>Jasminum humile</i>	5	0.36	0.87	0.51	1.74
31	<i>Cedrus deodara</i> (sapling)	1	0.07	0.29	0.25	0.62
32	<i>Quercus glauca</i> (sapling)	10	0.72	1.16	0.81	2.7
33	<i>Zizyphus incurva</i> (sapling)	24	1.74	1.45	2.04	5.22
34	<i>Neillia rubiflora</i>	5	0.36	0.29	0.76	1.41
35	<i>Phyllanthus glaucus</i>	7	0.51	0.58	0.66	1.75
36	<i>Smilax</i> sp.	25	1.81	2.31	1.22	5.35
37	<i>Sarcococca hookeriana</i>	3	0.22	0.29	0.25	0.76
38	<i>Persea duthiei</i> (sapling)	3	0.22	0.29	0.2	0.71
39	<i>Rubus acuminatus</i>	18	1.3	1.45	0.97	3.72
40	<i>Eurya acuminata</i> (sapling)	27	1.96	2.02	2.39	6.37
41	<i>Agave</i> sp.	14	1.01	0.58	0.76	2.36
42	<i>Lantana camara</i>	31	2.25	2.89	5.5	10.63
43	<i>Mahonia napaulensis</i>	2	0.14	0.29	0.41	0.84
44	<i>Boehmeria platyphylla</i>	6	0.43	0.29	0.25	0.98
45	<i>Diospyros virginiana</i> (sapling)	1	0.07	0.29	0.1	0.46
46	<i>Albizia</i> sp.(sapling)	6	0.43	1.16	0.61	2.2
47	<i>Cassia floribunda</i>	1	0.07	0.29	0.05	0.41**
48	<i>Ricinus communis</i>	3	0.22	0.29	0.25	0.76
49	<i>Solanum aculeatissimum</i>	7	0.51	1.16	0.41	2.07
50	<i>Viburnum cylindricum</i>	9	0.65	0.58	0.56	1.79
51	<i>Alnus nepalensis</i> (sapling)	36	2.61	1.73	3.26	7.6
52	<i>Myrica esculenta</i> (sapling)	3	0.22	0.29	0.1	0.61
53	<i>Mussaenda roxburghii</i>	12	0.87	1.16	1.12	3.15
54	<i>Choerospondias axilaris</i> (sapling)	3	0.22	0.87	0.51	1.59
55	<i>Melia azederach</i> (sapling)	5	0.36	0.58	0.36	1.3
57	<i>Cereus peruvianus</i>	3	0.22	0.29	0.41	0.91
56	<i>Prunus cerasoides</i> (sapling)	1	0.07	0.29	0.2	0.57
57	<i>Solanum torvum</i>	1	0.07	0.29	0.31	0.67
58	<i>Leea crispa</i>	12	0.87	0.58	1.02	2.47

59	<i>Maesa chisia</i>	4	0.29	0.29	0.76	1.34
60	<i>Xeromphis</i> sp.	7	0.51	0.58	0.36	1.44
61	<i>Gaultheria</i> sp.	36	2.61	1.73	1.07	5.41
62	<i>Castranopsis tribuloides</i> (sapling)	4	0.29	0.58	0.2	1.07
63	Unidentified 1	7	0.51	0.29	0.15	0.95
<b>Total</b>		<b>1379</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>300</b>

\*species having highest IVI \*\*species having lowest IVI

#### 4.6 Importance value index (IVI) for herb-seedlings of DSG

SN	Name of species	No. of sp	RD (%)	RF (%)	RC (%)	IVI (%)
1	<i>Cyperus cyperinus</i>	112	2.59	3.4	2.04	8.04
2	<i>Eupatorium adenophorum</i>	194	4.48	5.8	4.68	14.93
3	<i>Oplismenus burmanni</i>	537	12.4	7.9	11.9	32.21*
4	<i>Oxalis corniculata</i>	42	0.97	0.7	0.35	2.07
5	<i>Bidens pilosa</i>	231	5.33	3.4	4.22	12.98
6	<i>Hemarthria compressa</i>	7	0.16	0.2	0.17	0.55
7	<i>Achyranthus bidentata</i>	152	3.51	3.7	3.53	10.78
8	<i>Strobilanthes</i> sp.	2	0.05	0.1	0.04	0.19
9	<i>Ariseama</i> sp.	11	0.25	1.1	0.32	1.65
10	<i>Galium aparine</i>	32	0.74	1	0.55	2.25
11	<i>Tectaria macrodunata</i>	46	1.06	2.2	1.89	5.2
12	<i>Carex filicini</i>	51	1.18	1.9	1.11	4.21
13	<i>Berberis</i> sp. (seedling)	2	0.05	0.2	0.04	0.3
14	<i>Onychium</i> sp.	36	0.83	1.6	1.14	3.57
15	<i>Microsorium membranaceum</i>	2	0.05	0.1	0.06	0.21
16	<i>Amomum</i> sp.	42	0.97	2.4	2.2	5.52
17	<i>Solanum nigrum</i>	16	0.37	0.9	0.7	1.92
18	<i>Globba clarkei</i>	47	1.08	1.2	1.06	3.32
19	<i>Boehmeria platyphylla</i> (seedling)	48	1.11	2	3.04	6.18
20	<i>Urtica dioca</i>	37	0.85	1.5	1.97	4.32
21	<i>Colocasia</i> sp.	24	0.55	0.9	0.83	2.24
22	<i>Eragrostis nigra</i>	24	0.55	0.4	0.3	1.28
23	<i>Thysanolaena maxima</i>	3	0.07	0.3	0.61	1
24	<i>Smilax</i> sp.	1	0.02	0.1	0.02	0.15
25	<i>Begonia rubra venia</i>	5	0.12	0.3	0.16	0.59
26	<i>Parthenocissus semicordata</i>	6	0.14	0.5	0.2	0.87
27	<i>Melastoma</i> sp.	23	0.53	1.1	0.53	2.12
28	<i>Aleuritopteris albomarginata</i>	131	3.02	2.6	1.56	7.15
29	<i>Euphorbia</i> sp.	7	0.16	0.2	0.2	0.57
30	<i>Capillipedium assimile</i>	284	6.56	4.9	8.6	20.07
31	<i>Polygonum</i> sp.	28	0.65	0.9	0.89	2.39
32	<i>Microstegium</i> sp.	8	0.18	0.5	0.42	1.13
33	<i>Nephrolepis cordifolia</i>	55	1.27	1	1.59	3.82
34	<i>Sellaginella</i> sp.	57	1.32	1.5	1.47	4.28
35	<i>Phyllanthus parvifolius</i> (seedling)	95	2.19	3.5	2.15	7.87
36	<i>Dioscorea bulbifera</i>	21	0.48	1.4	1.11	2.98
37	<i>Scutellaria discolor</i>	440	10.16	3.5	4.51	18.19
38	<i>Imperata cylindrica</i>	215	4.96	2.4	5.34	12.65
39	<i>Lantana camara</i> (seedling)	6	0.14	0.2	0.12	0.47
40	<i>Centella asiatica</i>	1	0.02	0.1	0.01	0.14**
41	<i>Begonia picta</i>	12	0.28	0.6	0.19	1.11
42	<i>Ipomoea purpurea</i>	4	0.09	0.1	0.04	0.24
43	<i>Phyllanthus emblica</i> (seedling)	1	0.02	0.1	0.01	0.14**
44	<i>Onychium siliculosum</i>	36	0.83	1	0.56	2.35
45	<i>Desmodium</i> sp.	22	0.51	1	0.74	2.21

46	<i>Artemisia indica</i>	24	0.55	0.9	1.01	2.42
47	<i>Eriochloa procer</i>	36	0.83	1.1	0.68	2.58
48	<i>Pogonatherum paniceum</i>	93	2.15	1.2	1.86	5.18
49	<i>Pinus roxburghii</i> (seedling)	11	0.25	0.9	0.22	1.33
50	<i>Polypodioides lachnopus</i>	8	0.18	0.1	0.12	0.41
51	<i>Gallinsoga parviflora</i>	4	0.09	0.3	0.05	0.46
52	<i>Equisetum sp.</i>	39	0.9	0.6	0.54	2.08
53	<i>Cynodon dactylon</i>	50	1.15	0.7	1.03	2.93
54	<i>Stephania glandulifera</i>	8	0.18	0.5	0.22	0.94
55	<i>Pteris biaurita</i>	39	0.9	1.5	1.04	3.43
56	<i>Chrysopogon gryllus</i>	158	3.65	1.9	3.38	8.95
57	<i>Dryopteris cochleata</i>	5	0.12	0.2	0.07	0.4
58	<i>Rumex nepalensis</i>	3	0.07	0.1	0.07	0.25
59	<i>Desmodium laxiflorum</i>	17	0.39	0.9	0.73	1.98
60	<i>Trifolium repens</i>	1	0.02	0.1	0.01	0.14**
61	<i>Amaranthus spinosus</i>	1	0.02	0.1	0.02	0.15
62	<i>Alternanthera sessilis</i>	1	0.02	0.1	0.02	0.15
63	<i>Drymaria diandra</i>	16	0.37	0.2	0.18	0.77
64	<i>Bauhinia variegata</i> (seedling)	1	0.02	0.1	0.04	0.17
65	<i>Allocasia sp.</i>	7	0.16	0.4	0.15	0.74
66	<i>Morus alba</i> (seedling)	1	0.02	0.1	0.04	0.17
67	<i>Stellaria media</i>	5	0.12	0.2	0.1	0.43
68	<i>Perilla frutescens</i>	1	0.02	0.1	0.06	0.19
69	<i>Eleusine indica</i>	18	0.42	0.4	0.57	1.42
70	<i>Celtis australis</i> (seedling)	1	0.02	0.1	0.05	0.18
71	<i>Dennstaedtia zeylanica</i>	55	1.27	0.3	0.63	2.23
72	<i>Conyza bonariensis</i>	26	0.6	0.7	0.56	1.91
73	<i>Viola sp.</i>	22	0.51	0.9	0.29	1.66
74	<i>Hypoxis aurea</i>	8	0.18	0.1	0.05	0.34
75	<i>Commelina benghalensis</i>	25	0.58	0.6	0.51	1.73
76	<i>Desmodium microphyllum</i>	14	0.32	0.6	0.4	1.37
77	<i>Malaxis sp.</i>	2	0.05	0.1	0.02	0.18
78	<i>Gonostegia hirta</i>	22	0.51	0.3	0.42	1.24
79	<i>Lindenbergia sp.</i>	29	0.67	0.2	0.39	1.27
80	<i>Agrimonia pilosa</i>	3	0.07	0.2	0.06	0.34
81	<i>Urena lobata</i> (seedling)	2	0.05	0.2	0.02	0.28
82	<i>Ageratum haustonianum</i>	23	0.53	0.4	0.48	1.43
83	<i>Persicaria capitata</i>	6	0.14	0.2	0.07	0.43
84	<i>Schima wallichii</i> (seedling)	4	0.09	0.3	0.07	0.49
85	<i>Diplocyclos palmatus</i>	4	0.09	0.3	0.05	0.46
86	<i>Chlorophytum nepalense</i>	2	0.05	0.2	0.04	0.3
87	<i>Elatostema sp.</i>	6	0.14	0.2	0.11	0.46
88	<i>Zizyphus incurva</i> (seedling)	6	0.14	0.2	0.05	0.4
89	<i>Justicia procumbens</i>	35	0.81	0.9	0.57	2.24
90	<i>Anaphalis busua</i>	4	0.09	0.2	0.04	0.34
91	<i>Swertia nervosa</i>	1	0.02	0.1	0.02	0.15
92	<i>Dicranopteris linearis</i>	55	1.27	1.9	2.59	5.78
93	<i>Saccharum spontaneum</i>	8	0.18	0.2	0.34	0.74
94	<i>Thelypteris procer</i>	13	0.3	0.3	0.18	0.8
95	<i>Barleria sp.</i>	75	1.73	0.9	1.34	3.93
96	<i>Rumex acetosa</i>	1	0.02	0.1	0.06	0.19
97	<i>Adiantum caudatum</i>	7	0.16	0.2	0.06	0.44
98	<i>Rubus elipticus</i>	11	0.25	0.5	0.49	1.28
99	<i>Rhus succedenea</i> (seedling)	2	0.05	0.1	0.04	0.19
100	<i>Hedychium sp.</i>	6	0.14	0.6	0.98	1.76

101	Unidentified 2	7	0.16	0.1	0.17	0.44
102	<i>Pilea smilacifolia</i>	40	0.92	0.2	0.61	1.75
103	<i>Oxalis latifolia</i>	8	0.18	0.1	0.04	0.33
104	<i>Curcuma angustifolia</i>	2	0.05	0.1	0.11	0.26
105	<i>Sporobolus sp.</i>	20	0.46	0.6	1.39	2.49
106	<i>Woodfordia fruticosa</i> (seedling)	2	0.05	0.1	0.04	0.19
107	<i>Rhododendron arboreum</i> (seedling)	1	0.02	0.1	0.02	0.15
108	<i>Desmodium heterocarpon</i>	1	0.02	0.1	0.04	0.17
109	<i>Rhus javanica</i> (seedling)	3	0.07	0.3	0.12	0.51
110	<i>Ageratum conyzoides</i>	1	0.02	0.1	0.02	0.15
111	<i>Plantago major</i>	3	0.07	0.1	0.01	0.19
112	<i>Stephania elegans</i>	6	0.14	0.2	0.06	0.41
113	<i>Malaxis acuminata</i>	1	0.02	0.1	0.02	0.15
114	<i>Crassocephalum crepidiodes</i>	4	0.09	0.1	0.07	0.27
115	<i>Houttuynia cordata</i>	10	0.23	0.1	0.18	0.52
116	<i>Choerospondias axilaris</i> (seedling)	1	0.02	0.1	0.01	0.14**
117	<i>Sagittaria sp.</i>	6	0.14	0.1	0.09	0.33
118	<i>Jasminum officinale</i>	2	0.05	0.2	0.04	0.3
119	<i>Duchesnea indica</i>	5	0.12	0.1	0.05	0.27
120	<i>Rubus sp.</i> (seedling)	1	0.02	0.1	0.01	0.14**
121	<i>Quercus glauca</i> (seedling)	1	0.02	0.1	0.01	0.14**
122	<i>Lyonia ovalifolia</i> (seedling)	1	0.02	0.1	0.06	0.19
123	<i>Taraxacum officinalis</i>	3	0.07	0.1	0.05	0.22
124	<i>Athyrium cuspidatum</i>	6	0.14	0.2	0.12	0.47
125	<i>Alnus nepalensis</i> (seedling)	2	0.05	0.1	0.04	0.19
126	<i>Brachycorythis obcordata</i>	2	0.05	0.1	0.05	0.2
127	<i>Cynoglossum zeylanicum</i>	7	0.16	0.1	0.18	0.45
128	<i>Drosera sp.</i>	4	0.09	0.1	0.01	0.21
129	<i>Persicaria lapathifolia</i>	1	0.02	0.1	0.01	0.14**
	<b>Total</b>	<b>4332</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>300</b>

\*species having highest IVI \*\*species having lowest IVI

## Annex 5

### 5.1 Carbon stock of tree species of SSG

S N	Name of species	AGTB (t/ha)	BGTB (t/ha)	Total Biomass	Cstock (t/ha)	TC stock	CO <sub>2</sub> (t/ha)	CS (%)	Wood density (g/cm <sup>3</sup> )
1	<i>Pinus roxburghii</i>	37.5	7.5	45	21.15	663.7	2436	18.59	0.327
2	<i>Schima wallichii</i>	83.74	16.75	100.5	47.23	1482	5439	41.51	0.557
3	<i>Pyrus pashia</i>	13.19	2.637	15.82	7.437	233.4	856.5	6.54	0.661
4	<i>Grewia optiva</i>	4.406	0.881	5.288	2.485	77.99	286.2	2.18	0.646
5	<i>Zizyphus incurva</i>	1.121	0.224	1.346	0.632	19.85	72.8	0.56	0.680
6	<i>Prunus cerasoides</i>	1.847	0.369	2.217	1.042	32.69	120	0.92	0.420
7	<i>Fraxinus floribunda</i>	5.994	1.199	7.193	3.381	106.1	389.3	2.97	0.600
8	<i>Stranvaesia nussia</i>	13.07	2.613	15.68	7.369	231.2	848.6	6.48	0.603
9	<i>Syzygium cumini</i>	6	1.2	7.201	3.384	106.2	389.7	2.97	0.673
10	<i>Morus alba</i>	0.343	0.069	0.412	0.194	6.07	22.3	0.17	0.592
11	<i>Osmanthus fragans</i>	4.033	0.807	4.84	2.275	71.38	262	2	0.832
12	<i>Ficus benjamina</i>	14.36	2.871	17.23	8.098	254.1	932.6	7.12	0.468
13	<i>Choerospondias axillaris</i>	6.112	1.222	7.334	3.447	108.2	397	3.03	0.64
14	<i>Ligustrum sp.</i>	0.057	0.011	0.068	0.032	1	3.7	0.03	0.568
15	<i>Ilex excelsa</i>	0.65	0.13	0.78	0.367	11.51	42.2	0.32	0.490
16	<i>Acer oblongum</i>	2.639	0.528	3.167	1.488	46.7	171.4	1.31	0.603
17	<i>Ficus lacor</i>	2.405	0.481	2.886	1.357	42.57	156.2	1.19	0.340
18	<i>Ficus benghalensis</i>	0.664	0.133	0.797	0.375	11.76	43.2	0.33	0.511
19	<i>Sapindus mukorossi</i>	0.141	0.028	0.169	0.08	2.5	9.2	0.07	0.703
20	<i>Cinnamomum tamala</i>	0.091	0.018	0.109	0.051	1.61	5.9	0.05	0.510
21	<i>Celtis australis</i>	0.017	0.003	0.021	0.01	0.3	1.1	0.01	0.550
22	<i>Melia azederach</i>	0.304	0.061	0.364	0.171	5.37	19.7	0.15	0.496
23	<i>Xylosma controversum</i>	0.011	0.002	0.014	0.006	0.2	0.7	0.01	0.621
24	<i>Ficus religiosa</i>	0.025	0.005	0.03	0.014	0.45	1.6	0.01	0.443
25	<i>Lagerstroemia indica</i>	0.018	0.004	0.022	0.01	0.33	1.2	0.01	0.696
26	<i>Flacourtia sp.</i>	2.328	0.466	2.794	1.313	41.21	151.2	1.15	0.690
27	<i>Grevillea robusta</i>	0.455	0.091	0.546	0.257	8.06	29.6	0.23	0.500
28	<i>Bauhinia variegata</i>	0.031	0.006	0.037	0.017	0.55	2	0.02	0.606
29	<i>Michelia champaca</i>	0.003	0.001	0.004	0.002	0.06	0.2	0	0.450
30	<i>Maclura cochinchinensis</i>	0.161	0.032	0.193	0.091	2.85	10.5	0.08	0.852
	<b>Total</b>	<b>201.7</b>	<b>40.3</b>	<b>242</b>	<b>113.8</b>	<b>3570</b>	<b>13101</b>	<b>100</b>	
	<b>Avg</b>	<b>6.7</b>	<b>1.3</b>	<b>8.068</b>	<b>3.792</b>	<b>119</b>	<b>436.7</b>	<b>3.33</b>	

### 5.2 Carbon stock of tree species of DSG

S N	Name of Species	AGTB (t/ha)	BGTB (t/ha)	Total Biomass	Cstock (t/ha)	TCstock	CO <sub>2</sub> (t/ha)	CS (%)	Wood density (g/cm <sup>3</sup> )
1	<i>Pinus roxburghii</i>	73.57	14.71	88.286	41.494	2323.7	8527.9	51.956	0.327
2	<i>Schima wallichii</i>	16.87	3.374	20.247	9.516	532.89	1955.7	11.915	0.557
3	<i>Alnus nepalensis</i>	28.78	5.756	34.536	16.232	908.99	3336	20.324	0.41
4	<i>Rhododendron arboreum</i>	0.417	0.083	0.501	0.235	13.175	48.4	0.295	0.491
5	<i>Castanopsis indica</i>	5.061	1.012	6.073	2.854	159.84	586.6	3.574	0.595
6	<i>Myrsine capitellata</i>	1.173	0.235	1.407	0.661	37.043	135.9	0.828	0.7
7	<i>Lyonia ovalifolia</i>	0.382	0.076	0.458	0.215	12.056	44.3	0.27	0.677
8	<i>Celtis australis</i>	2.638	0.528	3.165	1.488	83.312	305.8	1.863	0.550
9	<i>Pyrus pashia</i>	0.629	0.126	0.754	0.355	19.855	72.9	0.444	0.661
10	<i>Sapium insigne</i>	0.372	0.074	0.446	0.21	11.741	43.1	0.263	0.372
11	<i>Zizyphus incurva</i>	2.169	0.434	2.603	1.223	68.503	251.4	1.532	0.680
12	<i>Choerospondias axilaris</i>	2.121	0.424	2.546	1.196	67.004	245.9	1.498	0.64
13	<i>Pinus patula</i>	1.84	0.368	2.208	1.038	58.124	213.3	1.3	0.450
14	<i>Pinus wallichiana</i>	0.027	0.005	0.033	0.015	0.868	3.2	0.019	0.430
15	<i>Rhus succedanea</i>	0.02	0.004	0.024	0.011	0.637	2.3	0.014	0.441
16	<i>Castanopsis tribuloides</i>	0.481	0.096	0.577	0.271	15.178	55.7	0.339	0.593

17	<i>Myrica esculenta</i>	0.221	0.044	0.265	0.125	6.977	25.6	0.156	0.58
18	<i>Saurauia napaulensis</i>	0.081	0.016	0.097	0.046	2.551	9.34	0.057	0.579
19	<i>Albizia procera</i>	0.191	0.038	0.229	0.108	6.027	22.1	0.135	0.565
20	<i>Persea duthiei</i>	0.779	0.156	0.935	0.439	24.607	90.3	0.55	0.460
21	<i>Grevillea robusta</i>	0.135	0.027	0.162	0.076	4.257	15.6	0.095	0.500
22	<i>Jacaranda mimosifolia</i>	0.259	0.052	0.311	0.146	8.195	30.1	0.183	0.507
23	<i>Eurya acuminata</i>	0.077	0.015	0.093	0.044	2.438	8.9	0.055	0.5
24	<i>Eucalyptus sp.</i>	0.34	0.068	0.408	0.192	10.746	39.4	0.24	0.602
25	<i>Alangium chinensis</i>	0.179	0.036	0.214	0.101	5.644	20.7	0.126	0.412
26	<i>Ilex excelsa</i>	0.341	0.068	0.409	0.192	10.762	39.5	0.241	0.490
27	<i>Causuriana equisetifolia</i>	0.096	0.019	0.115	0.054	3.029	11.1	0.068	0.790
28	<i>Syzygium cumini</i>	0.015	0.003	0.018	0.009	0.482	1.8	0.011	0.673
29	<i>Bauhinia variegata</i>	0.028	0.006	0.034	0.016	0.887	3.3	0.02	0.606
30	<i>Betula alnoides</i>	0.719	0.144	0.863	0.405	22.706	83.3	0.508	0.573
31	<i>Cedrus deodara</i>	0.008	0.002	0.01	0.005	0.264	0.9	0.006	0.470
32	<i>Fraxinus floribunda</i>	0.064	0.013	0.077	0.036	2.037	7.5	0.046	0.600
33	<i>Maesa chisia</i>	0.005	0.001	0.005	0.003	0.144	0.5	0.003	0.65
34	<i>Phyllanthus emblica</i>	1.303	0.261	1.564	0.735	41.163	151.1	0.92	0.680
35	<i>Quercus glauca</i>	0.059	0.012	0.071	0.033	1.856	6.8	0.041	0.768
36	<i>Prunus cerasoides</i>	0.02	0.004	0.024	0.011	0.622	2.3	0.014	0.420
37	<i>Melia azederach</i>	0.099	0.02	0.119	0.056	3.14	11.5	0.07	0.496
38	<i>Rhus sp.</i>	0.02	0.004	0.024	0.011	0.64	2.4	0.014	0.467
39	<i>Rhus javanica</i>	0.005	0.001	0.006	0.003	0.154	0.6	0.003	0.55
40	<i>Albizia lebbeck</i>	0.007	0.001	0.008	0.004	0.218	0.8	0.005	0.490
	<b>Total</b>	<b>141.6</b>	<b>28.3</b>	<b>169.93</b>	<b>79.865</b>	<b>4472.4</b>	<b>16414</b>	<b>100</b>	
	<b>Avg</b>	<b>3.5</b>	<b>0.7</b>	<b>4.248</b>	<b>1.997</b>	<b>111.81</b>	<b>410.4</b>	<b>2.5</b>	

## Annex 6

### 6. Soil parameters of SSG and DSG

Study Site		SSG				DSG			
Quadrat no.	Bulk Density (g/cm <sup>3</sup> )	SOC (%)	OM (%)	SCstock (t/ha)	Quadrat no.	Bulk Density (g/cm <sup>3</sup> )	SOC (%)	OM (%)	SCstock (t/ha)
1	1.195	3.588	6.186	0.643	1	1.165	1.71	2.947	0.299
2	1.127	3.705	6.387	0.626	3	1.11	1.687	2.908	0.281
3	1.04	3.725	6.421	0.581	4	1.15	1.658	2.858	0.286
4	1.142	3.609	6.222	0.618	5	1.161	1.755	3.026	0.306
5	1.326	2.988	5.151	0.594	6	1.163	1.716	2.958	0.299
6	1.132	3.609	6.222	0.613	7	1.078	2.769	4.774	0.448
7	1.123	3.705	6.387	0.624	8	0.828	3.253	5.608	0.404
8	1.028	4.035	6.956	0.622	9	0.84	3.244	5.592	0.409
10	1.01	4.013	6.918	0.608	10	1.042	3.062	5.278	0.479
11	1.014	4.026	6.94	0.612	11	0.745	3.343	5.762	0.374
12	1.285	3.392	5.847	0.654	12	1.088	2.808	4.841	0.458
13	0.985	4.052	6.985	0.599	13	1.073	2.828	4.875	0.455
14	1.03	3.905	6.731	0.603	14	0.839	3.231	5.569	0.407
15	0.967	4.088	7.047	0.593	15	0.881	3.064	5.282	0.405
18	1.036	3.725	6.421	0.579	16	1.079	2.729	4.705	0.442
19	1.245	3.434	5.919	0.641	17	1.02	3.139	5.412	0.48
20	1.033	3.89	6.706	0.603	18	1.125	1.541	2.656	0.26
21	1.162	3.484	6.006	0.607	19	0.83	3.228	5.565	0.402
22	1.188	3.666	6.32	0.653	20	1.157	2.048	3.53	0.355
24	1.125	3.834	6.61	0.647	21	1.054	2.477	4.269	0.392
25	1.018	4.01	6.912	0.612	23	0.846	3.267	5.631	0.414
26	1.217	3.368	5.806	0.615	24	1.198	1.502	2.589	0.27
27	1.172	3.432	5.917	0.603	25	1.221	1.463	2.521	0.268
28	1.191	3.354	5.782	0.599	26	0.833	3.314	5.713	0.414
29	1.072	3.588	6.186	0.577	29	1.047	3.101	5.345	0.487
30	1.297	3.181	5.484	0.619	30	1.093	1.736	2.992	0.285
32	1.084	3.42	5.896	0.556	31	0.845	3.217	5.546	0.408
33	1.205	3.32	5.724	0.6	32	0.844	3.212	5.537	0.407
34	1.293	3.02	5.206	0.586	33	1.067	2.73	4.707	0.437
35	1.07	3.9	6.724	0.626	34	1.071	2.631	4.536	0.423
-	-	-	-	-	35	1.074	2.028	3.496	0.327
-	-	-	-	-	36	1.194	1.755	3.026	0.314
-	-	-	-	-	37	1.063	2.73	4.707	0.435
-	-	-	-	-	38	0.843	3.27	5.637	0.413
-	-	-	-	-	39	1.214	1.71	2.947	0.311
-	-	-	-	-	40	0.844	3.301	5.691	0.418
-	-	-	-	-	41	0.861	3.332	5.744	0.43
-	-	-	-	-	42	1.09	2.711	4.673	0.443
-	-	-	-	-	43	0.834	3.219	5.55	0.403
-	-	-	-	-	44	0.853	3.27	5.637	0.418
-	-	-	-	-	45	1.178	1.833	3.16	0.324
-	-	-	-	-	46	0.832	3.236	5.579	0.404
-	-	-	-	-	47	1.094	2.022	3.485	0.332
-	-	-	-	-	49	1.168	1.788	3.082	0.313
-	-	-	-	-	50	1.089	1.762	3.037	0.288
-	-	-	-	-	53	1.066	2.808	4.841	0.449
-	-	-	-	-	54	1.069	2.856	4.923	0.458
<b>Total</b>				<b>18.313</b>	<b>Total</b>				<b>17.932</b>
<b>Average</b>	<b>1.127</b>	<b>3.635</b>	<b>6.267</b>	<b>0.61</b>	<b>Avg</b>	<b>1.018</b>	<b>2.576</b>	<b>4.441</b>	<b>0.382</b>
<b>SE</b>	<b>0.019</b>	<b>0.056</b>	<b>0.096</b>	<b>0.004</b>	<b>SE</b>	<b>0.02</b>	<b>0.098</b>	<b>0.169</b>	<b>0.01</b>

## Annex 7

7.1: Independent Samples Test of tree carbon stock between Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

Independent Samples Test								
		Levene's Test for Equality of Variances		t-test for Equality of Means				
		Sig.	df	Sig. (2-tailed)	Mean Diff	Std. Error Diff	95% Confidence Interval of the Difference	
							Lower	Upper
Log_CS (t/ha)	Equal variances assumed	0.021	77	0.000	0.48	0.07	0.33	0.63
	Equal variances not assumed		46.663	0.000	0.48	0.08	0.32	0.64

7.2: Independent Sample Mann-Whitney U Test for soil carbon stock (t/ha) between Swayambhu sacred grove (SSG) and Dakshinkali sacred grove (DSG).

Test Statistics <sup>a</sup>	
	Soil carbon stock (t/ha)
Mann-Whitney U	0.000
Wilcoxon W	1128.000
Z	-7.364
Asymp. Sig. (2-tailed)	0.000

a. Grouping Variable: Study Site

7.3 Pearson's Correlation test of tree carbon stock with tree diversity and species richness of SSG

Correlations						
		Log tree carbon stock (t/ha)	Log tree diversity	Tree species richness	Log basal area (m <sup>2</sup> /ha)	Log DBH (cm)
Log tree carbon stock (t/ha)	Pearson Correlation	1	.219	.290	.957	.447
	Sig. (2-tailed)		.246	.120	.000	.013
	N	30	30	30	30	30
Log tree diversity	Pearson Correlation	.219	1	.565	.169	-.008
	Sig. (2-tailed)	.246		.001	.371	.967
	N	30	30	30	30	30
Tree species richness	Pearson Correlation	.290	.565	1	.190	-.112
	Sig. (2-tailed)	.120	.001		.315	.555
	N	30	30	30	30	30
Log basal area (m <sup>2</sup> /ha)	Pearson Correlation	.957	.169	.190	1	.533
	Sig. (2-tailed)	.000	.371	.315		.002

	N	30	30	30	30	30
Log DBH (cm)	Pearson Correlation	.447	-.008	-.112	.533	1
	Sig. (2-tailed)	.013	.967	.555	.002	
	N	30	30	30	30	30

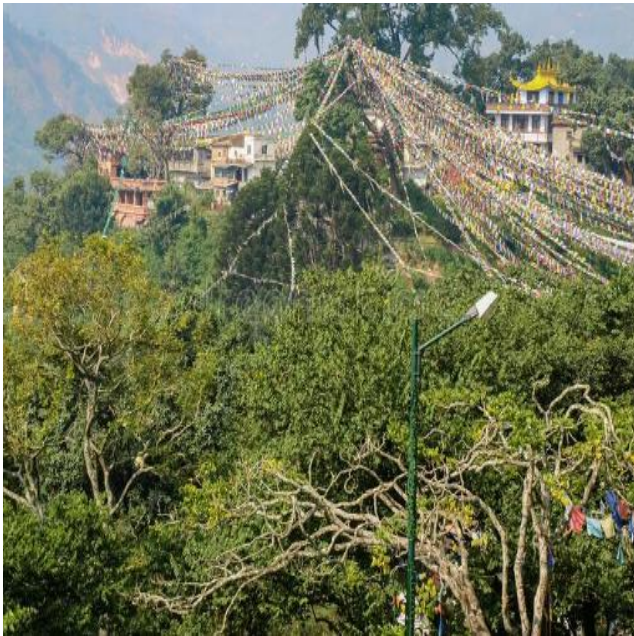
Correlation is significant at the 0.05 level (2-tailed).

7.4 Pearson's Correlation test of tree carbon stock with tree diversity and species richness of DSG.

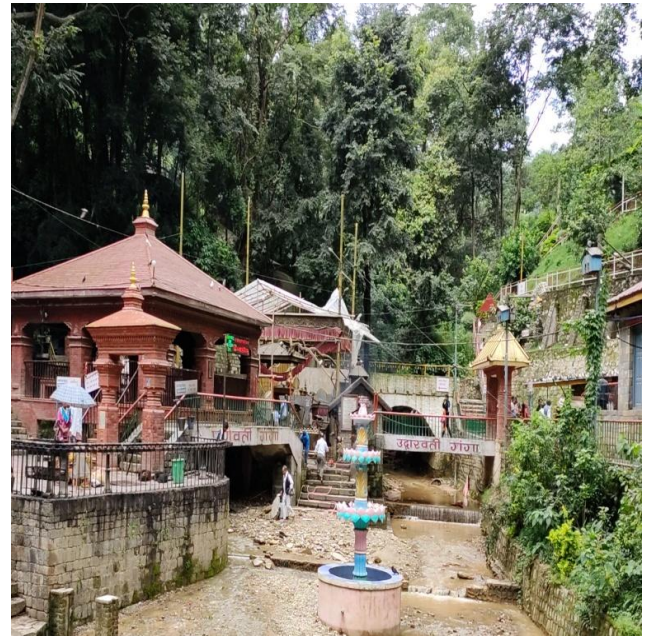
<b>Correlations</b>						
		Log tree carbon stock (t/ha)	Log tree diversity	Square root tree species richness	Log basal area (m <sup>2</sup> /ha)	Log DBH (cm)
Log tree carbon stock (t/ha)	Pearson Correlation	1	-.201	-.077	.925	.919
	Sig. (2-tailed)		.177	.607	.000	.000
	N	47	47	47	47	47
Log tree diversity	Pearson Correlation	-.201	1	.761	-.289	-.307
	Sig. (2-tailed)	.177		.000	.049	.036
	N	47	47	47	47	47
Square root tree species richness	Pearson Correlation	-.077	.761	1	-.197	-.243
	Sig. (2-tailed)	.607	.000		.185	.100
	N	47	47	47	47	47
Log basal area (m <sup>2</sup> /ha)	Pearson Correlation	.925	-.289	-.197	1	.976
	Sig. (2-tailed)	.000	.049	.185		.000
	N	47	47	47	47	47
Log DBH (cm)	Pearson Correlation	.919	-.307	-.243	.976	1
	Sig. (2-tailed)	.000	.036	.100	.000	
	N	47	47	47	47	47

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

**Annex 8  
Photoplates**



**Photo no.1** Swayambhu Sacred Grove



**Photo no.2** Dakshinkali Sacred Grove



**Photo no.3** Plot laying out process



**Photo no.4** Measuring DBH of tree



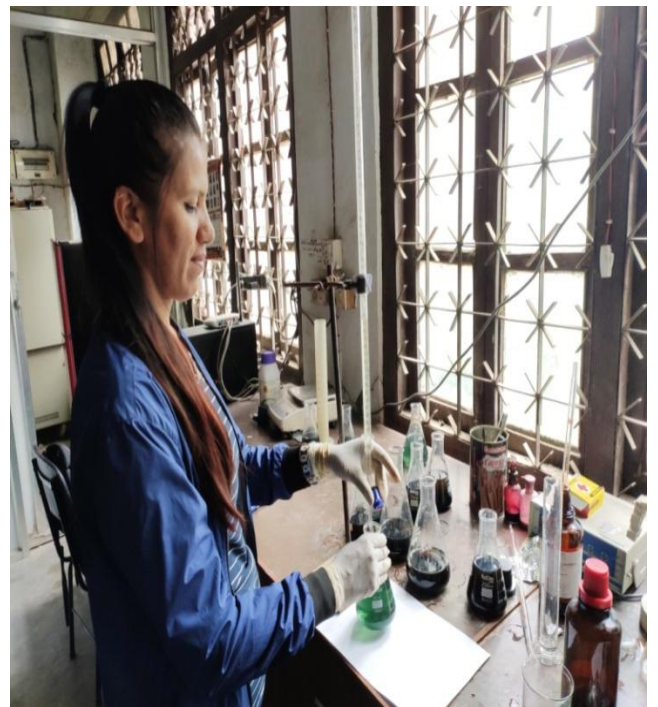
**Photo no.5** Collecting plant specimen



**Photo no.6** Seedling of *Pinus roxburghii*



**Photo no.7** Soil sampling for bulk density



**Photo no.8** Lab work