PHYTOSOCIOLOGICAL ANALYSIS AND SPECIES DIVERSITY IN AKKANATTUKARA SACRED GROVE, MAVELIKKARA, ALAPPUZHA

A project work submitted to the University of Kerala in partial fulfilment of the requirements for the B.Sc. Degree of Science in Botany

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May, 2022

DECLARATION

We do hereby declare that the Project entitled ‘Phytosociological analysis and species diversity in Akkanattukara Sacred Grove, Mavelikkara, Alappuzha’ during the year 2019-2022, under the supervision and guidance of Dr. Anto Mathew, Bishop Moore College Mavelikara in partial fulfilment of requirements for the award of the Bachelors of Science in Botany submitted to the University of Kerala. We also declare that it is an independent work and it has not been submitted anywhere else for any other degree, diploma or title.

Anjana Shibu
Ashiya C Benjamin
Aswathi P
Mohith M Das

Mavelikara
May, 2022

CERTIFICATE

This is to certify that this project report entitled 'Phytosociological analysis and species diversity in Akkanattukara Sacred Grove, Mavelikkara, Alappuzha', submitted to the University of Kerala in partial fulfilment of the requirements for the award of the Degree of Bachelor of Science in Botany carried out by Anjana Shibu (Register No. 24519101002), Ashiya C Benjamin (Register No. 24519101003), Aswathi P (Register No. 24519101004) and Mohith M Das (Register No. 24519101005). Certify that this is a bonafide work carried out under my supervision and guidance.

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Submitted for viva-voice examination held on ……

Examiners

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ABSTRACT

The sacred groves are the representatives of climax vegetation and exhibit the diversity of species such as trees, climbers, epiphytes and other shade loving herbs. Well-preserved sacred groves are storehouses of valuable medicinal and other plants having high economic value and serve as a refuge to threatened species. Every sacred grove carries its own legends, lore, and myths which form the integral part of the sacred grove. Therefore, the biodiversity-rich sacred groves are of immense ecological significance. The present study was conducted by quadrat method. A total of six random sampled quadrats (10 m × 10 m) were laid in the area. The study deals with floristic diversity, phytosociological analysis and conservational importance of valuable resources in Akkanattukara sacred grove (09°14′27.46″N and 76°33′48.78″ E) of Mavelikkara, Alappuzha district Kerala, India. Different population parameters were analysed *viz.* abundance, density, frequency, relative frequency, relative density, relative dominance, important value index, whiteford index, species richness index and spatial distribution.

A total of 11 tree species with 117 accessions falling under 11 families were documented. Out of which, the family Clusiaceae was dominate. Other dominant species were *Caryota urens* L. and *Xanthophyllum flavescens* Roxb. The members of *Garcinia xanthochymus*, *Bombax ceiba*, *Caryota urens* and *Schleichera oleosa* are under IUCN Red Listed, Least Concern (LC) species of Threatened Category. A total of 600 m^2 area was assessed and the results indicate the basal area of the trees was varied from 511.031 to 71955.4m^2/ha for *Salacia fruticosa* and *C. urens* respectively. The most frequently occurring species are *G. xanthochymus*, *X. flavescens* and *C. urens*. Species like *C. urens, G. xanthochymus, X. flavescens, B. ceiba* and *Cinnamomum malabatrum* were registered highest relative phytosociological values compared to other species. It is found that the threatened species likes *G. xanthochymus* and *C. urens* were the most significant species in this population. Whiteford index showed that all the species in the study sites are distributed in contiguous, however species richness and diverse was comparatively less.

The present study results indicated that habitat destruction and less species distribution and richness may severely influence the future existence of sacred species and many suitable habitats may disappear after years due to varied climatic conditions. Consequently the present study could lead to a better understanding of the sacred species with their traditional medicinal value and may shed some light for *in situ* conservation of each and every sacred grove.

INTRODUCTION

1. INTRODUCTION

Tropics are the richest biological units among all the bio-geographical regions of the world holding bewildering diverse flora and fauna. Tropical forests covering about 900 million hectares though constitute only 7% of the Earth's land, contain up to 60-70% of all living species (Myers, 1980; Wilson, 1988). Rain forests in the tropics are characterised by the presence of various synusiae, *viz.*, trees, shrubs, herbs, lianas, strangles and epiphytes in multi-storeyed structure (Richards, 1952; Whitmore, 1989). Species conservation is one of the most important applications in ecology. According to Hamilton (1999), conservation of tropical tree species is particularly significant as they give habitats and ecological niches for many species. As an eco-component of evergreen forests, a study on the survival strategies including adaptive traits may throw light into their population aspects. An understanding of biology as well as specific interactive ecology may help to standardize species recovery and ecorestoration programmes.

The degradation of tropical forests and destruction of habitat due to anthropogenic activities are the major causes of the decline in global biodiversity (Sukumaran *et al*. 2008, Rabha 2014). Therefore, in many areas conservation of biodiversity and maintaining landscape productivity are being taken up on a priority basis, for the restoration of degraded lands by planting fast-growing indigenous and native plant species (Solbrig 1991). One of the important challenging tasks before the ecologists is to understand the relationship between biodiversity and functioning of ecosystems (Younes 1992, Davis & Richardson 1995). The high rate of extinction of tropical species is aggravated by the clearing of forestland and conversion into agricultural cropland. Harvesting non-timber forest products, selective extraction of plants and animals, biological invasion and monocultural practices are serious threat to biodiversity (Myers 1993, Phillips 1995, Phillips 1997, Sundarapandian & Swamy 1997, Sundarapandian & Swamy 2000, Swamy *et al.* 2000, Mishra *et al.* 2004, Sundarapandian *et al.* 2005, Mehra *et al*. 2014, Rastogi *et al*. 2015, Sarkar & Devi 2017). Reorientation of the psyche of people towards maintaining biodiversity is of utmost importance (Ramakrishnan *et al.* 1998).

Sacred groves are tracts of virgin forest with rich diversity, which have been protected by the local people for centuries for their cultural and religious beliefs and taboos that the

deities reside in them and protect the villagers from different calamities. Every sacred grove carries its own legends, lore, and myths which form the integral part of the sacred grove. An inextricable link between present society and past in terms of biodiversity, culture, religious and ethnic heritage exists in sacred groves. Sacred groves are distributed across the globe, and diverse cultures recognize them in different ways encoding various rules for their protection. Sacred groves occur in many parts of India viz., Western Ghats, Central India, northeast India, etc. particularly where the indigenous communities live. India has well over 13,000 documented Sacred Groves. These are known by different names given to them by the ethnic people.

Sacred groves act as an ideal centre for biodiversity conservation. Several plants and animals that are threatened in the forest are still well conserved in some of the sacred groves. It has been observed that several medicinal plants that are not to be found in the forest are abundant in the sacred groves. Further, rare, endangered, threatened and endemic species are often concentrated in sacred groves. The sacredness, religious beliefs and taboos play a significant role in promoting sustainable utilization and conservation of flora and fauna of the region. However, with the passage of time, considerable changes have taken place in the extent of the sacred groves, in their vegetation structure, peoples' perception towards them and the religious beliefs and taboos. Therefore, a holistic understanding of the current status, structure and function of sacred grove is essential for assessing their ecological role and formulating strategies for their conservation.

Despite the vast and varied flora in Western Ghats, information on the biodiversity of the sacred groves is not explored to a desired level. The past workers such as Jeeva *et al.* (2005), Jeeva *et al.* (2006), Prakash *et al*. (2006) have studied phyto diversity of the region. Nayar (1959), Sundarapandian & Swamy (1997), Swamy *et al*. (2000) have paid much attention on forests other than sacred groves of Kanyakumari district. Due to religious beliefs, patches of vegetation are left untouched known as sacred groves. The importance and its conservation status have recently gained more importance; hence several studies have been carried out to evaluate the biodiversity of sacred groves throughout the country (Gadgil & Vartak 1976, Burman 1992, Rodgers 1994, Balasubramanian & Induchoodan 1996, Tripathi 2001, Khumbongmayum *et al*. 2005, Deepa *et al*. 2017). The plant wealth and conservation potential have acknowledged sacred groves as mini biosphere reserves (Gadgil & Vartak 1975).

Joshi and Gadgil (1991) reported that sacred grove might serve important refuge for threatened and rare species. Besides, they preserve genetic diversity of even the common trees (Nair *et al*., 1997). Byers *et al*. (2001) show that sacred forests have persisted longer than non-sacred forests in Zimbabwe. Biodiversity keeps the ecological processes in a balanced state, which is necessary for human survival. Therefore, the biodiversity-rich sacred groves are of immense ecological significance. They also play an important role in the conservation of flora and fauna.

OBJECTIVES

2. OBJECTIVES

The present study was carried out in Akkanattukara Sacred Grove, Mavelikkara, Alappuzha with the following objectives.

1. To study the floristic diversity of the Sacred Grove.
2. To find out the IUCN-RED listed plants of the Sacred Grove.
3. To analyses the phytosociological importance of the Sacred Grove for augmenting species conservation.

REVIEW OF LITERATURE

3. REVIEW OF LITERATURE

From the time immemorial nature has been worshipped in different cultures all around the world. One such religiously important factor is the sacred groves. It is of great importance in the cultural, religious and social norms of a society. As the name suggests, the abundance of precious medicinal plants in these groves make them sacred. The need for the conservation of these groves are gaining much attention now a days as studies are being conducted on why and how to preserve these rare, endangered and endemic species of plants. Many studies have been conducted all across the world so far on the religious, cultural and scientific norms for the protection of these groves. Such studies, to an extent, try to contribute to conserving biodiversity worldwide.

Mgumia and Oba studied 8 sacred groves of the Uganda chieftaincy of the Wanyamsuezi in central Tanzania representing burial sites existed from 6 – 300 years old, in order to compare woody species richness, and taxonomic diversity with other forest plots. From the data of species similarity index of 45% of forest plots and the groves were calculated. However, the higher values of the Shannon-Wiener species diversity index and evenness for the Forest Reserve plots over those of the sacred groves might reflect differences in spatial arrangements of species in the two systems (Mgumia and Oba, 2003). In India, 13720 sacred groves have been identified from 19 states and are named differently. Junsongduang did a study on the sacred forest used for traditional practices by the ethnic minorities in northern Thailand. They also compared the importance of swidden fallow fields and sacred forest as providers of medicinal plants among the Karen and lawa ethnic minorities in the Northern Thailand. They registered a total of 365 species in 244 genera and 82 families. The overall proportion of medicinal plants and non-medicinal plants in each habitat in the two villages were completely different ($\chi 2 = 19.30$, $df = 3$, $p = 0.00$) also when the village were tested separately. The most recently abandoned field, *i.e.,* the swidden fallows that are 1–2 years old, have the highest proportion of their species being used medicinally (Junsongduang *et al.* 2013).

In the study of Basu, Purulia district in West Bengal, contain about 18 sacred groves spread over 72681 m^2 area. Contain 106 species, of which tree species are 55. The ethnic groups, Bhumijis, Kurmis, Loharas, Mahalis, Sabars, Santhals *etc* offer goat, sheep, calf to

their deity on religious occasions (Basu, 2000). According to Mukundan Ramanujam, the surveys conducted in India were largely limited to enumeration of plants only, neglecting quantitative analyses which are essential for evolving strategies for their conservation. In this work, they studied the patterns of belief system and stand structure in four groves – one memorial grove, two anthropogenic stands and a formal grove. Their objective was to understand the linkage between culture and conservation. A total of 111 species belonging to 103 genera in 53 families were recorded in 15.6 ha. *Polyalthia suberosa* is a rare taxa found only in the grove, others are *Secamone emetica, Cretaeva magna, Syzizium cumini* and *Tamarindus indica* (Mukundan Ramanujam, 2003). Alemmeren S and Jamir studied diversity of vascular plants in 3 sacred groves of the Jaintia Hills in north east India. The recorded 345 species, 250 genera and 108 families under Pteridophyte, Gymnosperms and angiosperms. They noted that Orchidaerae, Rubiaceac, Asteraceac and Lauracean were the dominant families. They identified that Ficus was the largest genus with nine species (Alemmeren S and Jamir, 2003).

Many studies reported the medicinal importance of plants in the sacred groves (Kumar and Alagumanian, 2016, Anderson *et al.*, 2005, Manoj *et al.*, 2016, Sukumaran and Raj, 2010, Udayan *et al.*, 2005, Bhakat and Pandit, 2004, Dharmapal *et al.*, 2016, Kala, 2005, and Mantosh Kumar Sinha., 2013). Khumbongmayum and others, in their work identified 166 sacred groves in Manipur valley. They concluded that proceeding viable option to the local people is the only option for conservation. Groves that exist in the suburban, village or remote areas are in a better condition compared to those located in the urban areas. The sacred groves that exist in the inaccessible areas are well protected but the groves in poorly accessible areas are mildly disturbed (Khumbongmayum *et al.* 2005). The study of Bhagwat, was conducted in 58 sites of sacred forest in Kodagu district in the Western Ghats of India, 10 of them are present in formal protected area, a total of 215 trees, 86 birds and 163 fungi species were recorded. Endemic trees were more abundant in the forest reserve than in sacred groves but threatened trees were present more in sacred groves than in the forest reserve. The macro fungal assemblages in forest reserves and coffee plantations shows similarity, and those of sacred groves and coffee plantations shows dissimilar nature, suggesting the possibility that sacred groves shelter a distinctive assemblage. They found that sacred groves in Kodagu protect threatened trees, birds, and a distinctive macro fungal flora (Bhagwat *et al*, 2005).

Chandra Parakash Kala studied the wealth of medicinal plants used by the Apatani tribe of Arunachal Pradesh. The documented 158 medicinal plant species from 13 families and 124 genera. Asteraceae was the most dominant family followed by Zingiberaceae, Solanaceae and Araceae. Over 52 types of ailments were cured using these 158 medicinal plants. The medicinal plants used by the Apatani now open new avenues to scrutinize such a rich natural resource for further analysis in order to develop the potential of herbal medicine (Kala, 2005). Sukumaran and Raj studied rare, endemic threatened species in the sacred grove of Kanyakumari district. They reached in a conclusion that the similarity between the tropical forest of Western Ghats and sacred grove indicate that the vegetation stand as fragments of the evergreen tropical rain forest. They listed 36 species (RET) from 21 families belong to 29 genera, out of 36, 23 are endemic to western Ghats, 3 to peninsular India and rest of them are endangered in southern Western Ghats and Tamil Nadu at present. Out of the 285 species, collected 33 taxa were under RET category. Conservation of this habitat will help to preserve these endangered species facing threats of extinction due to lack of habitats (Sukumaran and Raj, 2007). The study of Prasanta Kumar Pandit deals with 20 sacred groves of Midnapur district of West Bengal. From total 108 plant species, 82 are medicinal, 10 to 24 plants with sacred value were recorded, from 88 mega fauna, 2 species belong to schedules of the wild life (protection) Act, 1972 and 11 are rare. It has been revealed that 93 plant species have ethno medicinal importance which represents 32.3 percent of total medicinal plant species (288) found in Midnapur district. Occurrence of ethno medicinal plants in respect of total plant resources is very high which is almost two third (Prasanta Kumar Pandit, 2007).

In Meghalaya, the tribal communities like Khasis, Garos and Jaintias, conserve environment traditionally by various beliefs and was passed from one generation to another. 79 sacred groves were located in Meghalaya and Tiwari and Barik studied their biodiversity value. It contains about 514 species representing 340 genera and 131 families based on floristic survey. Out of this 1.3% of sacred groves are undisturbed, 42.1% had relatively dense forest, 26.3% had sparse canopy cover and 30.3% had open forest compared the species diversity of disturbed forest and this undisturbed forest. There is difference in species diversity between these forests (Tiwari *et al.*, 2008). Jaryan *et al.* conducted study in Shivbari sacred grove of Himachal Pradesh. They documented floral wealth of shivbari and promoting plantation of indigenous species in participation with local people. A total of 69 flowering plant species were identified inside the grove, which include 14 trees, 9 shrubs and 3 lianas and 43 herbs. Inside the Shivbari, good population of *Putranjiva roxburghii, Syzygium*

cuminii and *Grewia optiva* is present, which are rare in nature (Jaryan *et al.*, 2010). Navendu V. studied the effect of fragmentation and surrounding matrix on trees, shrubs, lianas and epiphytes in tropical forest fragments of Kodagu, Western Ghats, India. Plants were identified at 2 sites, in continuous forests and 11 forest fragments. A total of 122 species of trees, 29 species of lianas, 60 species of shrubs and 66 species of epiphytes were recorded.

Large contiguous forests maintain a much larger proportion of regional species on account of their larger area, they do not adequately represent the landscape and habitat heterogeneity within the region (Navendu *et al.*, 2010). In the study of Manikandan *et al.*, they discussed about threats to sacred groves that need to be addressed through management approaches and they also dealt with the status and floristic richness of these groves in Theni district, Tamil Nadu. These sacred grove contain about 98 species of plants belong to 38 plant families with 76 genera. 112 types of plants were recorded. 50 medicinal plants were identified, 14 have timber value out of 32 sacred grove and 11 were sthalavirksha. Drafting clear policy on sacred groves, sacred forests may be taken over by the Department of Environment, forming self-help group in the villages are some suggestion by the authors (Manikandan, *et al.* 2011).

Chandrashekara conducted a study on 28 sacred groves of Kerala and documented socio-cultural and ecological value. Out of 670 angiosperm species recorded, 76 species are endemic to the southern Western Ghats, 37 of Western Ghats and 21 to the peninsular India. Among 12 major threats faced by sacred groves, dumping of solid wastes, trespassing, illegal collection and removal of fallen timbers and other forest products were prominent. Physical barrier such as fencing and compound wall are needed to protect sacred groves. The essentiality of SGBN (Sacred Grove Biodiversity Network) is also highlighted (Chandrashekara, 2011). Deepa and Sheema Dharmapal, did exploratory survey in some selected sacred groves of Chavakkad taluk namely Cherayi Padinjakkara Sarpakavu, Kanjiramthara kavu, Nariyampully Kavu, Ullanattraman Moothapanicker vaka Sarpakavu *etc.* There are 74 species of flowering plants in 42 families. 46.84% trees, 15.19% shrubs, 11.39% herbs and 26.58% climbers. 7 plants were endemic, 7 vulnerable, 3 plants coming under lower riks near threatened in Kerala (Deepa *et al.*, 2012). Kannan Warrier *et al.* did work on sacred groves of Alappuzha. Alappuzha is the only district in Kerala state without natural forests. So sacred groves of this region is the only natural forest once present. From their survey about 1128 sacred groves were identified. About 687 plant species were

recorded. They belonged to 493 genera and 127 families. 27 species were found endemic to Western Ghats. Break up of ancestral joint family system to nuclear families is the major reason for deterioration of these valuable resources. Exotic weeds also have role in degradation. Overexploitation of the resources leads to its retrogression to a great extent. Removal of litter along with the seeds from the floor resulted in retrogression by hindering the natural regeneration process. Exotic weeds like *Mikania micrantha, Lantana camera* and *Chromolaena odorata* overgrow the native species and play a major role in degradation (Kannan Warrier *et al.* 2015).

Study of Haritha and Nandu was conducted at 3 regions of Kannur district of Kerala. 20x20m size quadrat was used. Randomly placed vegetation structure and floral composition were assessed. Total 107 species were identified in Poongotta Kavu. from Thaaya Kavu, 43 from Chekkicheri Kavu. Ferms, Non-vascular plants, Gymnosperms and Lianas were present. Endemism is present in Poongotta Kavu and most of them are under threatened category. Plants include 17 endemic, 11 threatened, 1 critically endangered plant *Vateria indica* in Poongottu Kavu (Haritha and Nandu, 2016). Sreeja *et al.* did a floristic survey of Vallikkattu kaavu, with botanical features, conservation status, endemic status and habit in detail. She has recorded 245 flowering plants belonging to 209 genera and 77 families. Endemic plants like *Sonerila rheedei, Litsea ghatica, Lagenandra meeboldii* and *Ischaemum tumidum*, threatened and endemic plants like Anaphyllum Wightii, Kunstleria keralensis and Acorus calamus with endangered status were recorded (Sreeja and Unni, 2016). Deepa *et al.* did an exploratory survey of different sacred groves of Thrissur District namely Adipparambukavu, Daivathinkavu, Kanisherikavu, Kottaichalippattukavu, Kottarthukav etc. They collected about 119 species coming under 104 genera and 51 families. Maximum diversity is present in Kanisherykavu and minimum in Adiparambukavu. Out of 119 species, 17.64% herbs, 19.33% shrubs, 41.18% trees and 21.85% climbers were observed. This study shows that natural vegetation that are protected inside the sacred grove and all species are medicinal. Soil erosion is common and therefore fertilized upper soil lost, these adversely affected the plant growth. Invasive weeds like *Chromolaena odorata* (L.) and *Mikania micrantha* Kunth adversely affect the growth of other plants inside (Deepa *et al.*, 2016).

Taxonomical and phytosociological studies were conducted in sacred groves of Perumudiyoor region of Pattambi, Kerala by Nishitha Parappurath and Paul. 165 Angiosperms, 1 Gymnosperm and 2 Pteridophyte belongs to 62 families were identified. The

dominant families are Amaranthaceae and Asteraceae. The Shannon Weiner Diversity Index (H1) is 1.80695667 which indicates that the species are uniformly distributed and shows high diversity. Land reclamation for buildings in the agricultural field, surface sand mining for roads, buildings, unethical use of agrochemicals and weed infestation are found to be serious threat to the natural flora in the sacred grooves in Perumudiyoor region (Nishitha Parappurath and Paul, 2016). M. R. Deepa conducted study at Chittalikavu sacred grove of Thrissur district. They explored plant diversity and structural parameters. They identified 57 species of angiosperm belongs to 54 genera and 35 families. Among them 29.82% were trees, 24.56% were shrubs, 15.79% herbs and 29.83% climbers. *Strychnos nux-vomica* was recorded as the most dominant species in the community by IVI value. Besides *Strychnos nux-vomica* (IVI = 1.085), *Ficus benghalensis* L. (0.634), *Terminalia paniculata* (0.338) and *Schleichera oleosa* (0.309) 50 were the other important tree species from Chithalikavu (Deepa *et al*., 2017).

MATERIALS AND METHODS

4. MATERIALS AND METHODS

The present study was conducted in Akkanattukara Sacred Grove (09°14′27.46″N and 76°33′48.78″ E; 600 m^2 area) of Mavelikkara, Alappuzha district Kerala, India **(Figure 1 and 2)**. The soil of this area is sandy and climate is warm and humid. The area is separated by temple, human settlements, plantations, roads and paddy fields. The present grove is governed by Chendhamvettathu Sree Bhuvaneswary Kudumba Shekthra Trust Akkanattukara Reg. No. 73/IV/2020.

Figure 1. *a.* Chendhamvettathu Sree Bhuvaneswary Kudumba Shekthra Trust Akkanattukara *b.* The Sacred Grove (Study site)

Figure 2. Vegetational map showing different study plots (courtesy Google maps)

4.1. Climatological factors

The climatological factors (2021-2022) of the grove (interior) and outside (exterior) were documented in two major seasons such as winter (November to January) and summer (February to April). The parameters recorded for the present study were atmospheric temperature (°C), canopy temperature (°C), Atmospheric humidity (RH, %) Canopy humidity (RH, %) and sunlight intensity (Lux). The canopy temperature was taken from very close to their canopy area. Those parameters were directly measured by thermometer (Barigo), Moisture meter (Barigo) and light meter (lutron LX – 1102) respectively. The data collected during the field trips were averaged to get mean value.

4.2. Edaphological factors

Abiotic parameters: Soil temperature (°C) and moisture (%) was recorded both inside (interior) and outside (exterior) using digital soil thermometer (Dimples model) and moisture meter (Lutron PMS - 713) respectively.

4.3. Population structure analysis

Phytosociological studies were carried out in the present Sacred Grove by quadrat sampling method **(Figure 3)** followed by various workers in respect of phytosociological studies (Cottam and Curtis 1956; Mishra 1968; Saxena and Singh 1982; Gupta and Yadav, 2005; Nautiyal 2008). In study area, 6 quadrates were laid down with the size of each quadrat being 10 × 10 m. All species (≥ 10 cm DBH) were recorded and various characteristics such as number of species and accessions, DBH (diameter at breast height), individual height, crown projection and plants under IUCN-RED list were noted and recorded. To check the average breast height (DBH), wrap a fabric measuring tape around the stem at the height of 4.5 feet from ground level and measured the tree's perimeter or girth (cm). All floral samples were captured under Canon DS126251 (EOS7D) camera and recorded details.

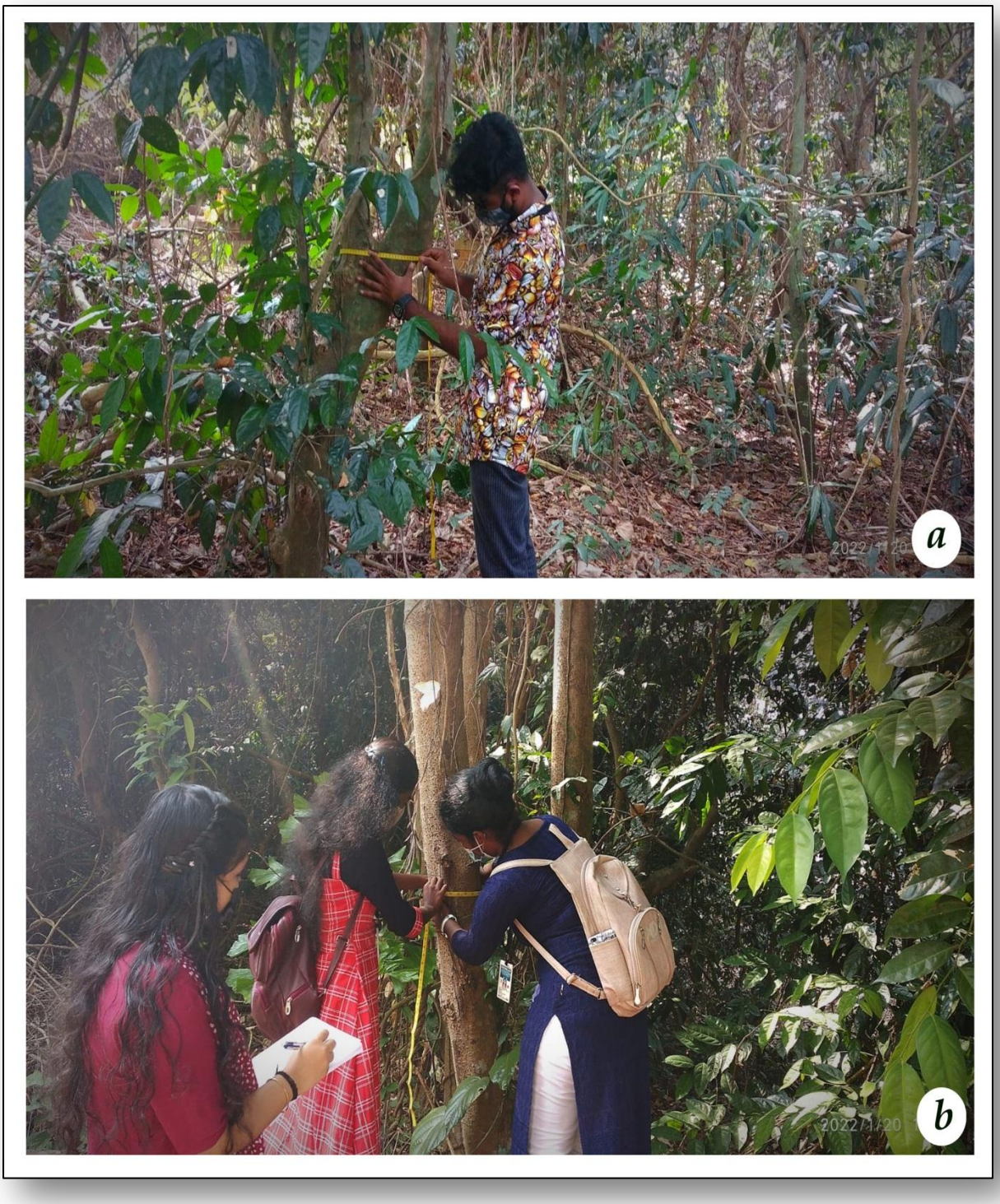

Figure 3. *a* and *b.* Population analysis

Different population parameters were analysed as follows:

$$\textbf{Abundance (Abu)} = \frac{\text{Total number of individuals}}{\text{Number of quadrats of occurrence}}$$

$$\textbf{Density (Den)} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats studied}}$$

$$\textbf{Frequency (\%) (Fre)} = \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of quadrats studied}} \times 100$$

$$\textbf{Relative frequency (\%) (Rfr)} = \frac{\text{Individual frequency of a species}}{\text{Total frequency of all species encountered}} \times 100$$

$$\textbf{Relative density (\%) (Rde)} = \frac{\text{Individual density of a species}}{\text{Total density of all species encountered}} \times 100$$

$$\textbf{Relative dominance (\%) (Rdo)} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

The basal area is the coverage or spatial occupancy of individuals in a given species and find out using the equation πr^2, where r is the radius of the individuals at breast height.

Important Value Index (IVI): The IVI is used to analyse the overall importance of each species in the community structure. The values of Rfr, Rde and Rdo (or relative basal area) added together to give the IVI (Curtis, 1959).

$$\textbf{Important Value Index (IVI)} = \text{Rfr} + \text{Rde} + \text{Rdo}$$

Whiteford index (WFi): Population dispersion pattern was determined following Whiteford index (Whiteford, 1949).

$$\textbf{Whiteford index} = \frac{\text{Abundance}}{\text{Frequency}}$$

The ranges of Whiteford index values determining the population dispersion pattern, and the values less than 0.025 indicated the regular dispersion pattern, the values between 0.025 -

0.05 indicated the random dispersion pattern and greater than 0.05 represent the contiguous dispersion pattern.

Species Richness Index

$$\textbf{Margalef Richness Index} = \frac{(S - 1)}{\text{Log}\,(n)}$$

Where, S = Total Number of Species; n = Total Number of Individuals in the sample

4.4. Spatial distribution

Spatial distribution of each individual in their respective quadrat was mapped using Garmin e-Trex GPS and modelled using DIVA-GIS software (version 7.5).

RESULTS

5. RESULTS

5. 1. Climatological factors

The present study was conducted in Akkanattukara Sacred Grove (600 m^2 area) with an altitudinal range of 11-13 m asl and geographic coordinates are 09°14′27.46″N and 76°33′48.78″ E; Mavelikkara, Alappuzha district Kerala, India **(Figure. 4).**

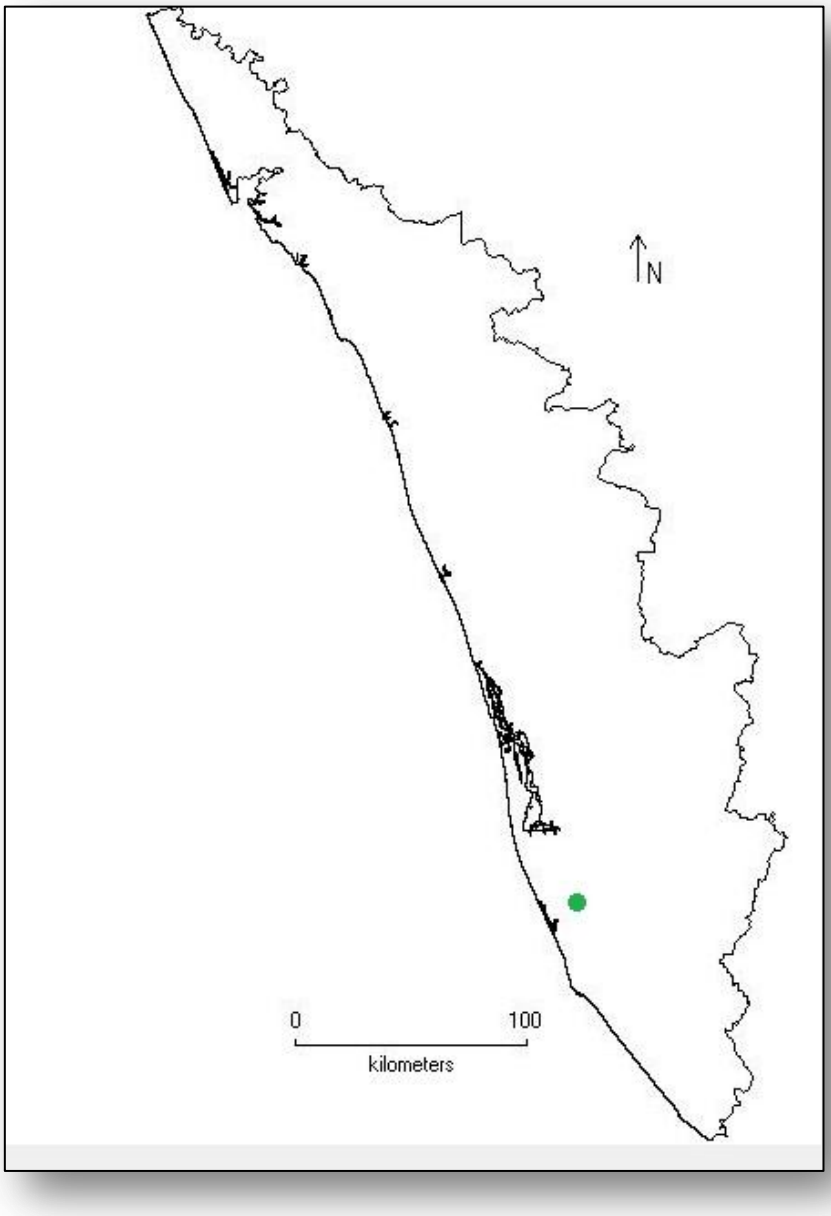

Figure 4. Map showing the study area (Green colour dot represented as study area)

The climatological factors of the population (interior) varied significantly compared to outside of the population (exterior). The day time atmospheric, canopy and soil temperatures was noted less in interior *i.e.,* 25.3 ± 2.2, 21.5 ± 2.6 and 22.3 ± 2.4 °C compared to exterior 26.3 ± 3.1, NA and 23.1 ± 2.1 °C. However, the day time atmospheric and canopy relative humidity was noted higher in study area *i.e.,* 71.1 ± 7.4 and 73.5 ± 6.3 % compared to exterior 70.3 ± 6. 3% and NA. Soil moisture content was also higher in interior *i.e.,* 52.3 ± 7.6. The ground day light intensity in the interior was less (1038 ± 120 lux) compared to exterior (1989 ± 213 lux) **(Table 1).**

Table 1. Climatological factors of the study area

Parameters (Day time)	Interior	Exterior
Geographical altitude (m asl)	11-13	11-14
Atmospheric temperature (°C)	25.3 ± 2.2	26.3 ± 3.1
Canopy temperature (°C)	21.5 ± 2.6	NA
Soil temperature (°C)	22.3 ± 2.4	23.1 ± 2.1
Atmospheric humidity (%)	71.1 ± 7.4	70.3 ± 6. 3
Canopy humidity (%)	73.5 ± 6.3	NA
Soil moisture (%)	52.3 ± 7.6	46.7 ± 5.4
Light intensity (Lux)	1038 ± 120	1989 ± 213

m asl- Meter above sea level; °C- Degree Celsius; %- Percentage; Lux- Light intensity; NA- Not Applicable

5.2. Floristic analysis

Spatial distribution of all the accessions of different species was documented and mapped **(Figure 6)**. A total of 11 tree species with 117 accessions falling under 11 families were documented. Out of which, the family Clusiaceae was dominate with 29 members of an IUCN Red Listed *Garcinia xanthochymus* are present in this Sacred Grove **(Figure 5)**. With respect to their girth, there are 12 seedlings, 09 saplings and 08 trees. The other dominant species were *Caryota urens* L. and *Xanthophyllum flavescens* Roxb. with 27 and 15 accessions respectively. Other members like *Bombax ceiba*, *Caryota urens* and *Schleichera oleosa* are also under IUCN Red Listed, Least Concern (LC) species of Threatened Category **(Table 2)**.

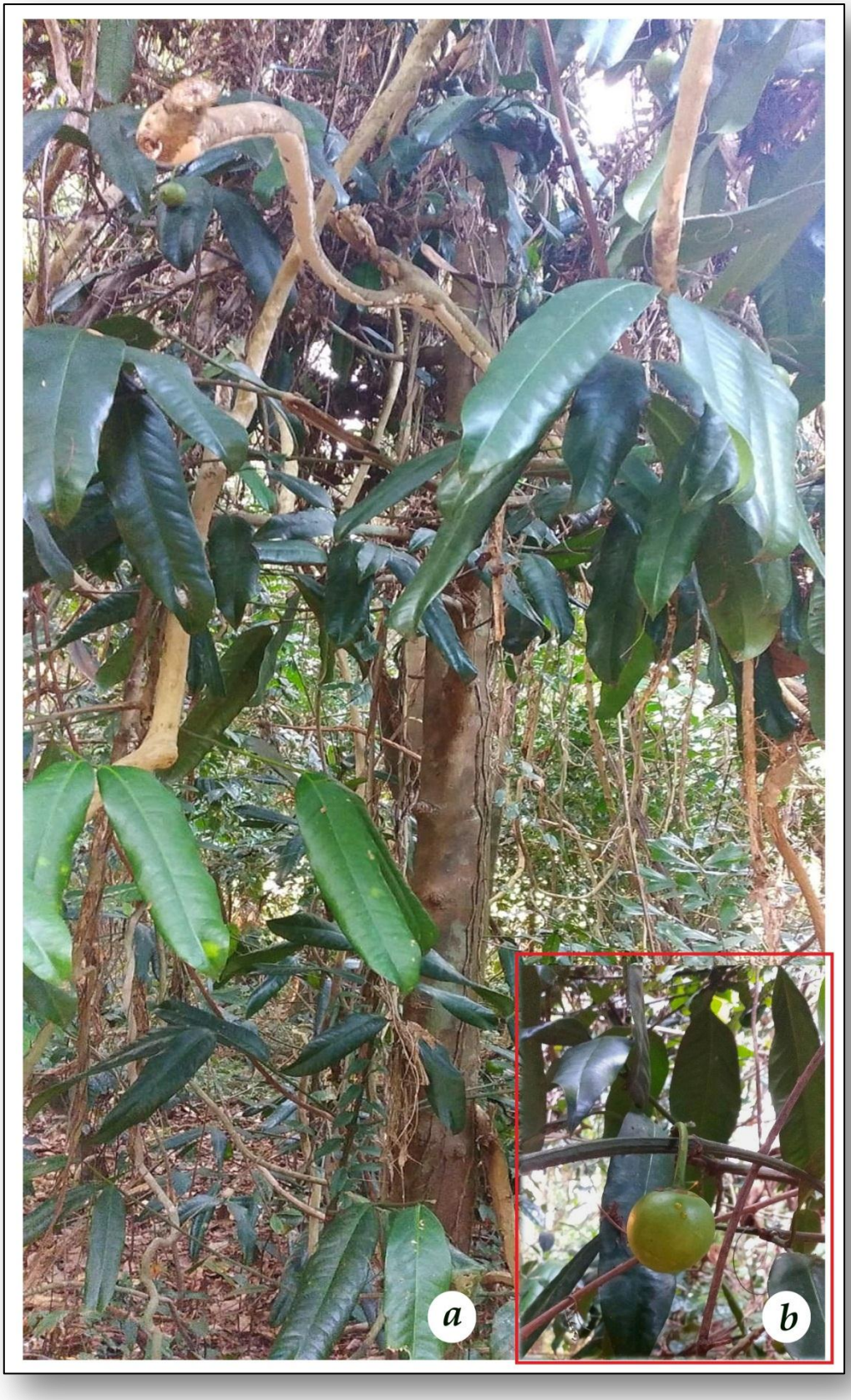

Figure 5. *Garcinia xanthochymus* an IUCN Red Listed, Least Concern (LC) species of Threatened Category. *a.* Habit; *b.* Fruit

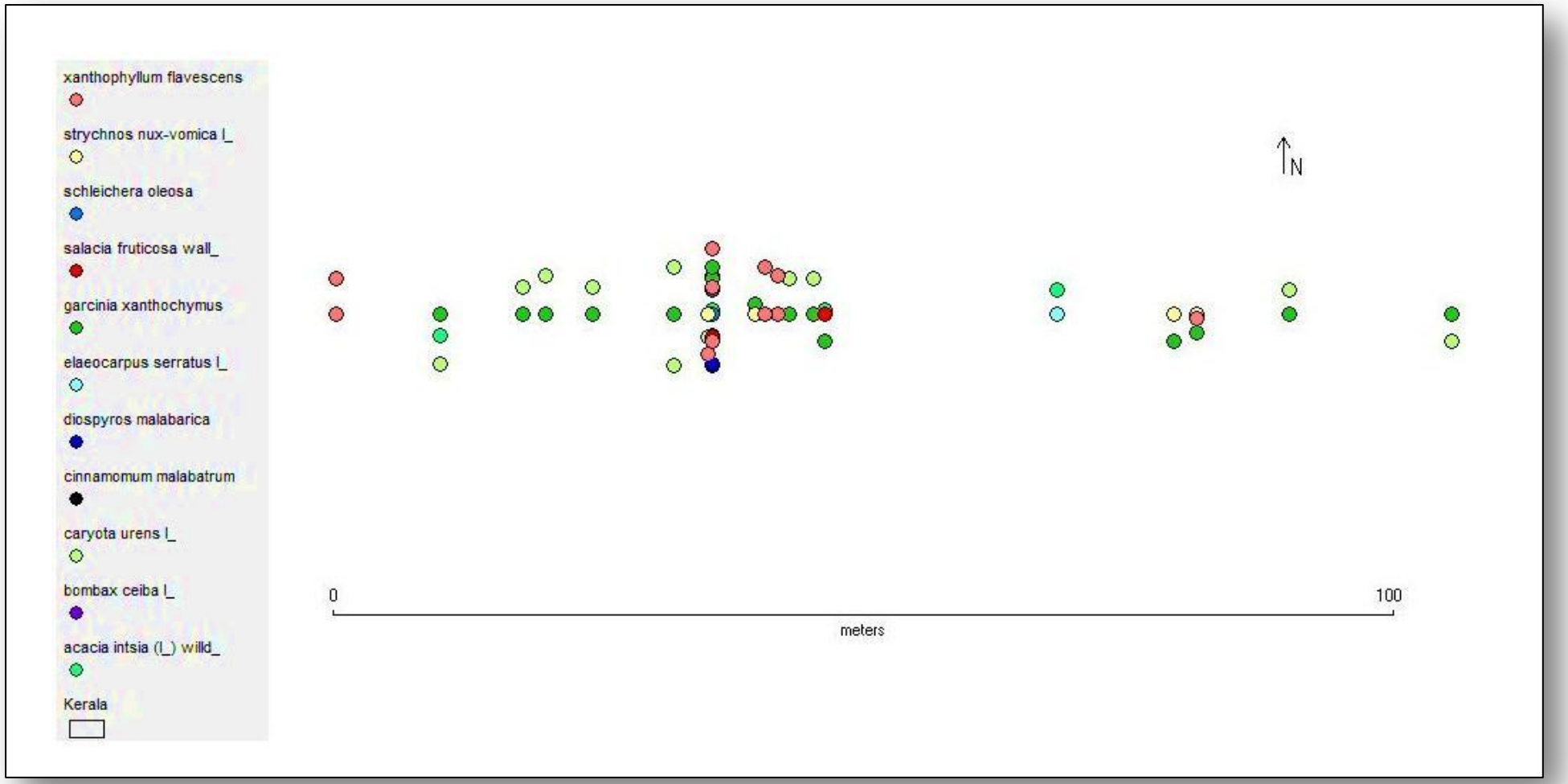

Figure 6. Geographic information system (GIS) mapping of different species in study area

5.3. Phytosociological studies

A total of 600 m^2 area was assessed and the results indicate the basal area of the trees was varied from 511.031 to 71955.4m^2/ha for *Salacia fruticosa* and *Caryota urens* respectively. *C. urens* is the most dense tree species followed by *Bombax ceiba* and *Garcinia xanthochymus* having basal area of 38163.5 and 34444.2 m^2/ha respectively. The highest value of abundance and density was found in *G. xanthochymus* (4.8- 4.83) followed by *C. urens* (4.5).

The most frequently occurring species are *G. xanthochymus, Xanthophyllum flavescens* and *C. urens*. Species like *C. urens, G. xanthochymus, X. flavescens, B. ceiba* and *Cinnamomum malabatrum* were registered highest Relative phytosociological values compared to other species **(Table 2)**. It is found that the species *C. urens* and *G. xanthochymus* are the most significant species in this population with important value index is 75.7 and 57.1 respectively. Of the various plant species available in the study area, the species of least significance (lowest IVI) were shown by the species like *Diospyros malabarica, C. malabatrum, Elaeocarpus serratus, Acacia intsia, Schleichera oleosa* and *Salacia fruticosa*. Based on IVI score made by this species it is understood that thus are poorly established species in the communities of the study sites of sacred grove **(Table 2)**.

Table 2. Phyto-sociological parameters in the sacred grove (600 m^2 area)

Species	IUCN	Family	Ab	De	Fr	Rde	Rfr	Ba	Rdo	IVI	Wfi
Acacia intsia (L.) Willd.	-	Leguminosae	03	1.5	50	7.69	6.81	785.122	0.42	14.9	1.17
Bombax ceiba L.	<LC>	Malvaceae	02	0.67	33.3	3.41	4.54	38163.5	20.7	28.6	1.17
Caryota urens L.	<LC>	Arecaceae	4.5	4.5	100	23.0	13.6	71955.4	39.0	75.7	0.87
Cinnamomum malabatrum (Burm.f.) J.Presl	-	Lauraceae	2.5	0.83	33.3	4.27	4.54	4308.01	2.33	11.1	1.46
Diospyros malabarica (Desr.) Kostel.	-	Ebenaceae	02	0.67	33.3	3.41	4.54	675.881	0.36	8.33	1.17
Elaeocarpus serratus L.	-	Elaeocarpaceae	01	0.5	50	2.56	6.81	4925.87	2.67	12.0	0.39
Garcinia xanthochymus Hook.f. ex T. Anderson	<LC>	Clusiaceae	4.8	4.83	100	13.6	24.7	34444.2	18.69	57.1	0.94
Salacia fruticosa Wall.	-	Celastraceae	01	0.83	83.3	11.3	4.27	511.031	0.27	15.9	0.23
Schleichera oleosa (Lour.) Merr.	<LC>	Sapindaceae	0.8	0.67	83.3	11.3	3.41	1857.31	1.00	15.7	0.18
Strychnos nux-vomica L.	-	Loganiaceae	03	2	66.6	9.09	10.25	1926.39	1.04	20.3	0.87
Xanthophyllum flavescens Roxb.	-	Polygalaceae	2.5	2.5	100	13.63	12.82	24725.9	13.4	39.8	0.48

Individuals with girth≥ 10 cm included, <LC>- Least Concern (IUCN); Ab- Abundance; De – Density; Fr- Frequency; Rde- Relative density; Rfr- Relative frequency; Ba- Basal area; Rdo- Relative dominance; IVI- Important value index and Wfi- Whiteford index.

The value of Whiteford index showed that all the species in the study sites are distributed in contiguous because the value higher than the value 0.05 **(Tables 2)**.

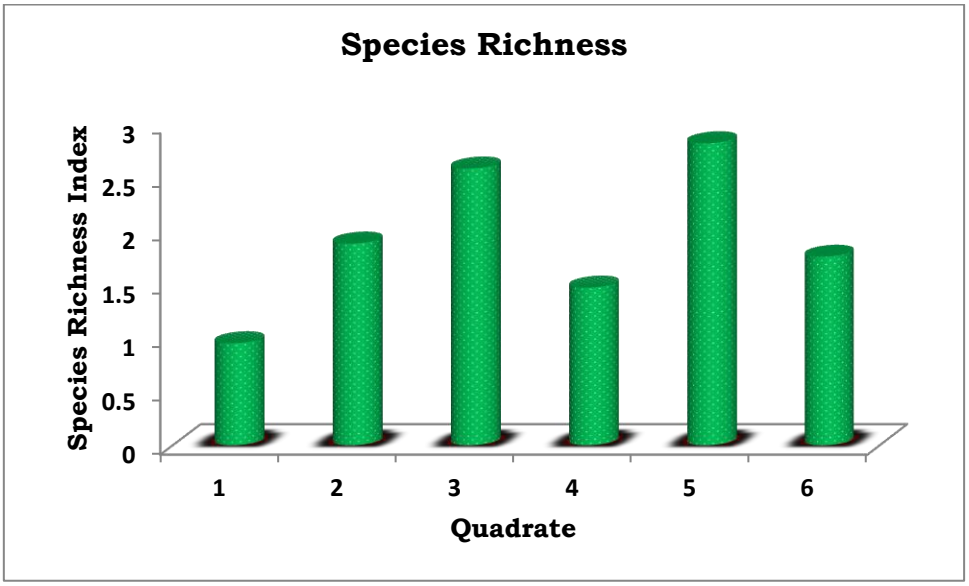

Figure 7. Species richness per quadrat (100 m^2)

Species richness (number of species per 100 m^2 area) clearly indicated that the community is comparatively less diverse area **(Figure 7).**

DISCUSSION

6. DISCUSSION

An understanding the present population structure, spatial distribution and associations with respect to biotic and abiotic factors may provide valuable insights in the conservation of bio resources. Environmental factors of a particular niche play a key role in growth, reproduction, seed germination and distribution of plants. According to Slade and Hutchings (1989), the population studies related to environmental factors may help in understanding the ways in which habitat conditions influence the species distribution. Study of eco-physiological factors of an area is inevitable to conserve the biological diversity (Gupta and Malik, 1996). The plant wealth and conservation potential have acknowledged sacred groves as 'Mini Biosphere Reserves' (Gadgil and Vartak 1975).

6.1. Ecophysiological factors

Climate is probably very important factor of vegetation patterns globally and has significant effect on the structure, distribution and ecology of forests. The global valuation has showed that future climate variations are likely to significantly influence the natural ecosystem (Ravindranath *et al.,* 2006). The studies on the climatic and edaphic factors of present study habitats are significant for understanding the species specific niche and specialities of the species which influence much for their existence and regeneration. Endemic species have comparatively less tolerance to environmental changes and can be dependent on certain edaphic and geologic features (Bárcenas-Argüello *et al.,* 2013).

The climatological factors between interior and exterior of the present study sites varied significantly. The day time atmospheric, canopy and soil temperatures and day light intensity was noted less in interior (study area) compared to outside the population (exterior). However, the day time atmospheric and canopy relative humidity and soil moisture content was noted higher in interior compared to exterior. The exact physiological implication behind this high humidity is not experimentally proved though it may be described to very high transpiration rate of leaves of these floral elements. These abiotic interactions influence the species distribution, growth and abundance of plant populations within time and space (Billington *et al*., 1990; Hobbs and Mooney, 1991 and Biondi *et al*., 2004). The temperature, humidity, sunlight, rainfall can regularly govern the seed germination and succeeding

establishment of plants in a habitat. Frankel and Galun (1977) reported that edaphic factors such as soil moisture, nutrients and climatic parameters like temperature, humidity, light intensity are the major factors which control the flowering in plants. Mineral nutrients and water availability also influence the distribution pattern of trees and these minerals are also often associated with topography (John *et al*., 2007).

Significant seasonal variables such as humidity and temperature also restrict the growth of plants in sacred groves. Undisturbed areas of this grove shows luxuriant vegetation comprising several storeys of trees mixed with shrubs, lianas and herbs. The ground layer is rich in litter and macro fungi and hence the soil is abundant in humus which favours the growth of seasonal members usually thick populated species preferring humus and love shade for growth.

6.2 Phytosociology

Phytosociology is the quantitative study of vegetation and it describes the vegetation pattern, population structure and dynamism of forests. Several workers have carried out phytosociological studies in different sacred groves in India such as Sukumaran *et al.,* (2018) and Reddy *et al.,* (2008).

Phytosociological analysis of a plant community is the first and foremost basis of the study of any piece of vegetation as it is a pre-requisite for the understanding of community structure and organization. For understanding the community structure and organization, species composition is foremost requisite. Species composition is one of the major characters of plant community (Dansereau, 1960). Bhagwat (2005) said that the sacred groves are the last home of some endangered species and also are known to represent the only existing climax vegetation communities. But the area under sacred groves is fast depleting due to the interplay of an array of factors. Sacred groves originally maintained in the form of untouched ecosystems dedicated to the deity are looked as a source of revenue. Role of sacred groves in maintenance of biodiversity is undoubtedly significant. It is very important therefore refresh this traditional establishment and its further conservation (Sujana and Sivaperuman, 2008).

The vegetation of the sacred groves has certain distinctive ecological characteristics. The sacred groves of Kerala (Rajendraprasad 1995) have distinct tiers of trees, shrubs and herbs,

climbers and stranglers, epi-phytes, parasites, and many wild relatives of cultivated plants. The concept of importance value index is the expression of the ecological success and dominance of any species with a single number (Misra, 1968). The IVI of each species in the population showed that the species like *C. urens* and *Garcinia xanthochymus* are the most significant species in this population. *G. xanthochymus* is also an IUCN Red Listed, Least Concern (LC) of Threatened Species (IUCN 2020).

The value of Whiteford index showed that all the species in the study sites are distributed in contiguous because the value higher than the value 0.05 (Whiteford, 1949). Predominance of contagious species distribution in an area indicates abiotic and biotic interactions acting together as described by Mishra and Jeeva (2012). However species richness (number of species) in this community is comparatively indicating less diverse area and under certain environmental stresses. This appears to be the result of combined effect of non-extreme stable environmental conditions and gap phase dynamics within the forest patches (Whittaker 1975). The study revealed that, main driving force behind the disturbance of the species occurs due to varied climatic conditions and it will adversely affects the functional pattern of the this small ecosystem.

SUMMARY AND CONCLUSION

7. SUMMARY AND CONCLUSION

Sacred Groves are relic forest patches traditionally protected by communities in reverence of a deity. Sacred groves form important repositories of forest biodiversity and provide refuge to many plant and animal species of conservation significance. They are the good source of a variety of medicinal plants, fruits, fodder, fuel, wood, spices, *etc.* The study of interrelationship between the human beings and plants and animals in their surrounding environment (ethno biology) is very revealing.

The present study results indicated that habitat destruction and less species distribution and richness may severely influence the sacred species future existence and many suitable habitats may disappear after years due to varied climatic conditions. So the present study area need urgent conservational importance and must be given conservation priority to protect valuable and threatened species like *G. xanthochymus*, *Bombax ceiba*, *Caryota urens* and *Schleichera oleosa*. The findings in the present study could lead to a better understanding of the sacred species with their traditional medicinal value and may shed some light for *in situ* conservation of each and every Sacred Grove. Such conservational methods may also be tried with other sacred groves for their conservation, particularly with those which share similar habitats.

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