

**VEGETATION DYNAMICS OF MADAYIPARA LATERITE
HILLOCK IN RELATION TO WEATHER**

By
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(2012 - 20 - 110)

THESIS

**Submitted in partial fulfilment of the
requirements for the degree of**

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2017

DECLARATION

I, Sarath B (2012 – 20 – 110) hereby declare that this thesis entitled “**Vegetation dynamics of Madayipara laterite hillock in relation to weather**” is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.



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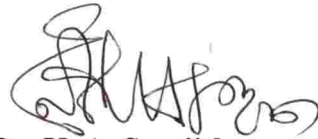
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Certified that this thesis entitled “**Vegetation dynamics of Madayipara laterite hillock in relation to weather**” is a record of research work done independently by Mr. Sarath B, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.



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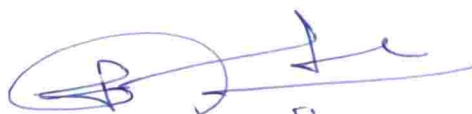
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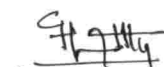
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SYMBOLS AND ABBREVIATIONS

c	Concentration of the element
C	Control
CEC	Crust Edges or Cliffs
CO ₂	Carbon dioxide
EP	Ephemeral pools
EC	Electrical Conductivity
EFV	Ephemeral Flush Vegetation
ERS	Exposed Rock Surfaces
I	Intensity of light
IMD	India Meteorological Department
k	Constant of proportionality
KCCPL	Kerala Clays and Ceramic Products Ltd.
KCL	Potassium chloride
KFRI	Kerala Forest Research Institute
N	Nitrogen
pH	Potential of Hydrogen
RB	Rock Boulders
RC	Rock Crevices/Fissures
RCF	Rock Crevices or fissures

SCA	Soil-covered Areas
SEA	Soil Enrich Area
SEP	Small Ephemeral Pools
SFD	Soil-filled Depressions
SP	Seasonal Ponds
SRA	Soil-rich Areas
T	Tree Cover and Tree Associated
θd	Moisture

CHAPTER 1

INTRODUCTION

Vegetation is an important part of the ecosystem that reflects the entire environmental effects (Billings, 1952). Vegetation means plant community collectively, especially those found in a particular area or habitat. Vegetation complex fluctuates from season to season based on successional stage. These fluctuations suggest a response by each species population to the prevailing heat, moisture and light as modified by the vegetation itself (Heady, 1958). The development and death or decay of plant species alters the pattern of species distribution in a community (Watt, 1964).

The environment of Northern Kerala is governed by its peculiar geographic features. A unique feature of this region is the presence of lateritic hillocks which give fascinating undulations for the midland terrain in particular. Such hillocks are present up to Malappuram district towards south and spread to South Karnataka in the North. The lateritic hills are the most imposing but extremely threatened topographical floristic and faunastic feature of Northern Kerala. The alteration of very wet and dry condition creates an unusual ecological condition and varying microhabitats that supports unique biota. Plants on the plateaus are adapted to various microhabitats and each of these microhabitats is unique in its edaphic properties and species composition.

Owing to the scarcity of woody species or forest cover, the plateaus appear devoid of vegetation in remote sensing images and are often considered as 'waste lands' but in reality they are landscape units having high biodiversity value and ecological significance (Sreejith *et al.*, 2016) In monsoon, the impermeable nature of the hard rock surface leads to water logging and creation of ephemeral wetlands (Watve, 2013). Plant species commonly seen in these areas are showing high specificity towards their microhabitat. Some species are restricted to specific microhabitats where as some are seen in different microhabitats. (Sreejith *et al.*, 2016)

Madayipara in Kannur district is a unique vegetation tract in Kerala. The Madayipara is well known for its rich biodiversity. The aquatic and semi-aquatic plants form extensive carpets of blue, pink, white and yellow during the monsoon season. It is typical of the Laterite foot hills of the Western Ghats. The area is notable for the presence of some rarest plants in the world such as *Euricaulon madayiparens*, *Rotala malabarica*, etc. The vegetation of the hillocks may be classified mainly into grasslands and scrub jungles. The grasslands can again be categorized into wet phase and dry phase based on the seasons. The grasslands on the laterite hills of North Malabar are low elevation dry grasslands, characterized by remarkable flora and fauna. This type of natural grassland is the characteristic feature of the laterite hills of Kozhikode, Kannur and Kasaragod districts and the lower parts of Wayanad district. These grasslands are highly seasonal and interspersed with other herbaceous plants and scrub jungle. Grasses control erosion, and several species are well known for their rich fodder value.

Regional floristic studies have reported the occurrence of many narrow-niched endemic and habitat specialist angiosperms from lateritic plateaus (Bachulkar, 1983; Deshpande *et al.*, 1993; Sardesai and Yadav, 2002) throughout the Western Ghats. The lateritic hills of Northern Kerala is also not an exception as indicated by 7 new angiosperm species reported in recent past by Ansari and Balakrishnan (2009), Swapna *et al.* (2012), Sunil *et al.* (2012), Narayanan *et al.* (2012), Sunil *et al.* (2013) and Pradeep *et al.* (2013). Still, the 'wasteland' status supports the over exploitation or conversion of these important habitats for mining, monoculture plantation, industries and infrastructure development. The management of pressures due to human impact is often misguided due to poor understanding about the special ecological features of the habitat (Watve, 2013).

The lateritic hillocks in Northern Kerala are highly neglected areas from conservation point of view since they appear with less number of species. It has been noted that these hillocks differ completely from their surrounding vegetation in both physiognomy and floristic aspects. In spite of harsh environment, these

hillocks are unique in having various micro habitat conditions and species which are habitat specific (Sreejith *et al.*, 2016).

Hence, baseline scientific information regarding ecological significance of lateritic hills is needed to evolve strategies for conservation and management of this landscape especially when habitat destruction is at its peak. This study is a part of collating baseline information to highlight the ecological significance of the lateritic hills of Northern Kerala, Western Ghats and the impacts of weather changes on different microhabitats in the laterite hillock.

Plants growing together have a mutual relationship among themselves and with the environment (Mishra *et al.*, 1997). The relationship between vegetation, climate and weather is absolute. Each is entirely dependent on the other. The moisture released into the atmosphere by plants contributes to the climate, while the moisture level in the climate in turn contributes back to the Earth's ability to foster the growth of vegetation. Since the geographical distribution of natural plants is controlled by climate, to a large extent, spatial distribution of vegetation types will be modified in response to climatic changes (Woodward and Beerling, 1997).

Basic concepts of soil and vegetation development indicates that vegetation and soils are mutually associated with each other, both being the product of the same environmental variables. Soil is the substratum in which, the geotropic half of the vegetation is embedded and which yields necessary macro- and micro-nutrients. More than the nutrients, soil also provides the para-gravitational orientation to plants. Most of the moisture required for the build-up and per endurance of biological matter is also obtained from the soil. The present study aims to understand the relation of soil and weather parameters with the vegetation of specific microhabitats in a laterite hillock.

CHAPTER 2

REVIEW OF LITERATURE

2.1 VEGETATION DYNAMICS

The wet/dry phase grasslands and scrub jungles mainly constitutes the vegetation on the Madayipara laterite plateau. Most of the plants flourish in the rainy season that commences normally in the month of June and lasts up to November. These plateaus provide extremely diverse physical environments and thereby microhabitats leading to the development of specialized life forms. Madayipara is a flat-topped plateau with scrub vegetation on the slopes. The upper part is having an undulating terrain without tree cover and appears barren in summer months. Different micro habitats like exposed rock surfaces, rock crevices, soil covered areas, perennial ponds and seasonal pools are noticed on the terrain, supporting large number of endemic and preferential species.

During rainy seasons, small and shallow temporary pools are formed which support a large number of hydrophytes including endemic species showing various degrees of rarity. Lateritic plateaus provide extremely harsh physical environment for life forms. These conditions play a decisive role in the development of strongly seasonal vegetation, where more than 95% of the plant species complete their life cycle during monsoon period. Extreme environments of the plateau have led to the development of specialized plant communities, with large number of endemic and habitat specific species (Pramod *et al.*, 2013).

Wet phase that starts with the first fall of southwest monsoon, during late May or early June stimulates the germination of seeds and the growth of annual plants. The first group of plants seen are *Neanotis spp.*, *Eriocaulon spp.* and grasses, followed by insectivorous plants such as *Utricularia spp.* and *Drosera indica* that dominate the land. The deep blue flowers of *Utricularia* and white flower heads of *Eriocaulon* and *Rhamphicarpa* literally paint the whole plateau in shades of blue, violet and white, amidst herbaceous plants such as *Sopubia trifida*, *Lindernia*, *Polygala elongata*, *Justicia japonica*, *Leucas sp.* and several others.

The shallow depressions filled with water accommodate plants such as *Marsilea minuta*, *Cryptocoryne spiralis*, *Rotala malampuzhensis*, *Rotala malabarica* and *Isoetes coromandelina*. The sparsely distributed south Indian endemic *Chamaesyce katrajensis* (syn. *Euphorbia katrajensis*) can also be observed during this phase on the laterite rocks. Following the retreat of south west monsoon, during September, most of the early appearing plants give way to others such as *Celosia argentea*, *Sesamum radiatum* and grasses such as *Arundinella spp.*, *Ischaemum indicum* etc., which dominate subsequently. The abundance of grasses can be noticed during this period. The wet phase lasts up to the end of November (Balakrishnan, et. al., 2010).

In the dry phase, stronger winds during the month of January and the direct incidence of sunlight enhance the drying up process of the flora of Madayippara. The majority of the herbaceous plants dry up except for some grass species and the thorny *Lepidagathis keralensis*, which may remain spread all over the rocky regions of the hill. The silver coloured, *Polycarpaea corymbosa* can also be seen against the black surfaces of the rocks. The scrub jungles form the protective cover of the slopes of the hills. The thick grove adjacent to the clay mining site is one of the major vegetation patches of this hillock. The evergreen forest species like *Hydnocarpus pentandra*, *Holigarna arnottiana* and *Cinnamomum sp.* are seen in this area except for geological, geochemical and mineral exploration studies, there is very little information available on the ecology and biodiversity of laterite hills. The Flora of Calicut by Manilal and Sivarajan (1982) is the first detailed attempt to explore the laterite hillocks of Calicut district. The flora of similar habitats of Kasaragod area has been explored by Ansari (1985). However, the flora of Madayippara was not dealt with in detail in the Flora of Cannanore District by Ramachandran and Nair (1988) or any other subsequent works. The study of Babu (1990) also was mainly confined to the flora of laterite hillocks of the Malappuram district. During their studies on the bladderworts (*Utricularia*) Janarthanam and Henry (1992) explored the laterite hillocks of northern Kerala also. Similarly during their study, Ansari and Balakrishnan (2009) also explored the diversity of *Eriocaulon* species of the laterite hillocks of northern Kerala.

It is the explorations by some botanists such as Joseph and Sivarajan (1988), Pradeep *et al.* (1990, 1991) and Madhusoodhanan and Singh (1992) that yielded many interesting finds from the laterite hills of Madayipara and its adjacent areas. Sreekumar and Nair (1991) made an extensive survey of the grasses in the grasslands of north Malabar including Madayipara. Unnikrishnan (1995) described the ecology of sacred groves of north Malabar with a note on the laterite hills. In 2000, Palot and Khaleel made some observations on the butterfly predation by *Drosera indica*. Padmanabhan (2002) presented a comprehensive account of the laterite hillocks of northern Kerala. It highlighted the socio-ecological significance of the laterite ecosystem in depth. Palot (2002) and Radhakrishnan (2005) documented the faunal diversity of Madayipara. The checklist of plant diversity of Madayipara and comprehensive ecological and faunal studies of the ecosystem was done by Balakrishnan, *et al.* (2010).

2.2 RARE AND ENDANGERED PLANTS

The geographic and climatic peculiarities made Madayipara and the adjacent laterite hillock system capable of supporting a unique assemblage of species. It is the home of some unique and sparsely distributed endemic plants such as *Nymphoides krishnakesara* (Joseph and Sivarajan, 1990), *Rotala malabarica* (Pradeep *et al.*, 1990), *Justicia ekakusuma* (Pradeep *et al.*, 1991) and *Lepidagathis keralensis* (Madhusoodanan and Singh, 1992). *Nymphoides krishnakesara* is a small water lilly that appear during the wet phase in the small pools and ponds of the plateau. *Rotala malabarica* is a semi-aquatic plant seen largely in the temporary pools. *Justicia ekakusuma* (Pradeep *et al.*, 1991), aptly named because of the nature of its flower, is rare and seen in the rocky edges of the plateau. *Lepidagathis keralensis* (Madhusoodanan and Singh, 1992) was described for the first time from this locality and it flowers during the dry phase. It is observed that the number of *Justicia ekakusuma* has been declining drastically over the years, while other newly described species remain uniformly distributed.

Out of 512 species known from the Madayippara, 59 are Peninsular Indian endemics; of which 14 are narrow endemics of Kerala, confined to the laterite

hillocks. Seven species are Indian endemics and 28 species are confined to Peninsular India and Sri Lanka and 13 species to Indian region and Sri Lanka. The presence of endemic species belonging to various threat categories such as *Hoepa ponga*, *Capparis rheedii*, *Eriocaulon cuspidatum* and *Neanotis rheedii* are also indicate the conservation significance of the area.

The wet phase of the Laterite hillocks is the more active in terms of the appearance of plant and animals (Palot and Radhakrishnan, 2005). An analysis of the biological spectrum reveals the fact that, majority of the herbaceous members appear along with the first showers, flourish during the monsoon season, complete their life cycle towards the end of the rainy season and enter into the dormant phase by shedding their fruits/seeds or in the form of rhizomes. The dry phase is characterized by the presence of highly adapted, xerophytic plants such as *Lepidagathis*, *Chamaesyce*, etc. They may remain fresh to some extent of the summer season, and may dry up leaving the perennial rootstock.

2.3 GRASSLANDS

Grasslands occupy about 30–40 % of the earth's land surface. They cover more terrestrial area than any other single biome type. The extent and diversity of grasslands and related habitats is reflected in their ecological and economic importance at local, regional, and global scales. Grasslands provide critical habitat for a diverse array of plants and animals. Grassland soils store tremendous quantities of carbon and other key nutrients and play a major role in global biogeochemical cycles.

2.3.1 Grassland in Madayipara hills

Grasslands of Kerala have been classified into two types i.e., Low elevation grasslands and high elevation grasslands. The grasslands on the laterite hills of north Malabar are classified under low elevation dry grasslands, characterised by remarkable diversity. This type of natural grassland is the characteristic feature of the laterite hills of Kozhikode, Kannur and Kasaragod districts and the lower parts

of Wayanad district. These grasslands are highly seasonal and interspersed with other herbaceous plants and scrub jungles.

A total of 55 species of grasses are recorded from Madayipara hills, many more remaining to be fully identified. The common grass species are *Eragrostis uniloides*, *Ischaemum indicum*, *Heteropogon contortus*, *Pennisetum polystachyon*, *Cynodon dactylon* and species belonging to the genera *Arundinella*, *Dimeria*, *Panicum*, *Themeda*, etc. Species of *Arundinella* form the commonest grasses during the months of October and November. The pinkish inflorescence of these grasses makes the area appear as if burnt mixed here and there with green shades. *Arundinella* form a higher stage in the succession. So it can be safely stated that *Arundinella* grasses represent a higher stage in grassland development in the areas where they occur.

Recent plant explorations revealed some more new species of grasses from the laterite hills of north Malabar (Sreekumar and Nair, 1991), 11 out of 37 endemic grasses of Kerala are reported from this kind of locality. Thus, these hillocks are isolated ecological niches of conservation importance. However, a detailed account of the species association is lacking.

Grasslands have also played an important role in the development and testing of ecological theory, such as assessing relationships between species richness and ecosystem function and as model systems for assessing the impacts of global changes, including responses to chronic Nitrogen (N₂) deposition, elevated Carbon dioxide (CO₂) concentrations, and climate change. This is due, in part, to the relative ease of performing manipulative experiments in grasslands, the sensitivity of grasslands to perturbations, and the relatively rapid responses they often exhibit to these manipulations. In fact, one of the longest running field experiments in the world is the Park Grass Experiment at the Rothamsted Experimental Station in England. This experiment was established in 1856 with the original goal of assessing the effects of various nutrient amendments on grass yields. The experiment has since been used to address a broad range of

fundamental questions in ecology and evolutionary biology (Silvertown *et al.* 2006).

Grasslands also include some of the most endangered ecosystems on the planet, such as the tallgrass prairies of North America and other temperate grasslands (Hoekstra *et al.* 2005). In addition to the historical loss of grasslands to agricultural expansion, grasslands today are threatened by a broad array of environmental changes, including climate change, elevated atmospheric CO₂ concentrations, increased nitrogen deposition, invasive species, habitat fragmentation, degradation due to overgrazing, change in natural disturbance regimes (e.g. fire suppression), and woody plant expansion. Conserving, and in some cases restoring, these ecosystems will require a solid foundation of ecological knowledge.

2.4 ROCK OUTCROPS

Rock outcrops are well known throughout the world but less studied. Most of the studies are from African, American and Australian outcrops (Porembski *et al.*, 1994, 2000; Burke, 2005 a,b; Jacobi *et al.*, 2007) describing the habitat types and associated vegetation composition. In India, relatively very few reports exist about vegetation on these special habitats (Porembski and Watve, 2005; Watve, 2008, 2013; Lekhak and Yadav, 2012; Bhattarai *et al.*, 2012).

2.4.1 Lateritic rocks and basaltic rocks

The Western Ghats mountain range stretches from Navapur on the Gujarat-Maharashtra border to Kerala and is almost continuous with the exception of a gap near Palakkad. High altitude rock outcrops are found throughout the Western Ghats in India. Rock outcrops are naturally occurring landforms where open rock surface is visible over a large area that has very little soil or only pockets of deep soil. The rock outcrops in the Western Ghats are of two types based on the rock formation and soil type developed from it: (i) Lateritic—lateritic rock cover is well preserved over the parent basalt rock and soil rich in iron e.g., Kas Plateau and other low altitude plateaus in the Konkan region and (ii) Basaltic—having black

hard rock and soil, e.g. plateaus with forts, such as Naneghat Plateau. (Rahangdale and Rahangdale, 2014).

Ecological studies and floristic and faunal observations on basalt and laterite outcrops have been published by Watve (2003a,b, 2006, 2007, 2008), and Watve and Thakur (2006). A review paper on the biodiversity and ecology of rocky plateaus (Watve 2010) has been included as part of the Western Ghats Ecology Expert Panel (WGEEP) report on ecologically sensitive areas of the Western Ghats. Measures used for protection of forest or grassland habitats are not appropriate, as the ecological processes on rocky plateaus are different in nature. The lack of baseline information regarding rocky plateau ecology has severely hampered efforts of management and conservation. Thus, this is an effort to collate baseline information with a view to highlight conservation and management priorities.

2.5 LATERITES IN KERALA

Laterite occurs principally as a cap over the summits of Basaltic hills and plateaus and is the characteristic feature of tropical monsoon regions. It is best developed in the Western Ghats and its foothills. Vast stretches of laterite-capped hillocks are characteristic features of Kannur-Kasaragod districts of Kerala. Laterite stone was used as building material in Kerala for centuries. Ancient buildings like temples are examples. Its geological nature was described only later by Francis Hamilton Buchanan, a medical officer of East India Company. From Angadipuram in Malappuram District of Kerala, he discovered a type of weathered material which was indurated clay, full of cavities and pores, containing large quantity of iron in the form of red and yellow ochre. It was soft when fresh and could be cut easily and when exposed, it became hard and resisted air and water much better than bricks (Buchanan, 1807). He used the term laterite to designate this material (laterite in Latin means 'brick stone'). He defined it as "a residual product of weathering, rich in secondary oxides of iron and aluminium or both-nearly devoid of bases and primary silicates and commonly found with quartz and kaolin and developed in tropical or warm temperate climatic regions". In the areas

of extensive laterite formations, its mining has emerged as a major economic activity of the local people. Now mining is more mechanized and intensive mining of bricks, its transportation and marketing brought tremendous changes in the physical as well as socio-economic set up of the region. This chapter examines the properties of laterites and their mining from a geographical point of view.

2.5.1 Physical properties of laterite

Laterites are residual sedimentary rocks, reddish or brownish coloured, comparatively soft rocks, with high degree of porosity and are carrying vermiform structure. The porosity is due to the *in situ* weathering of parent rocks. The laterite profiles show that its exposed layers are much harder than the sub surface layers. Two or three layers differing in their texture, physical properties and associations are usually found below the hard, indurated cap (Prasad, 2014).

2.5.2 Hydrological properties

Laterite, apart from its use as a promising natural building material, is also regarded to act as ground water recharging source because of its physical properties particularly porosity. Laterite constitutes one of the important hydrological provinces in Kerala, as it holds roughly 55% of the total dynamic ground water storage. The laterite terrain receives heavy rainfall during every monsoon season and is getting recharged year after year. The high porosity of it enhances quick infiltration of rain water. The peculiar vesicular structure is a favourable factor in the vertical infiltration of rain water to join ground water reserve. But the lithomarge clay occurring in between lateritic cap and underlying weathered bedrocks has a low permeability and prevents easy downward movement. This may facilitate retention of water in the pores of laterite for a long period. The ground water condition of laterite is always in a dynamic state due to fluctuations of water table (Prasad, 2014).

2.5.3 Laterite hills in Kannur district

Two types of laterite hills are seen in Kannur region. Laterite rock hills and laterite soil hills. The rock hills are covered by laterite rocks. The exposed laterite

in contact with air is converted into hard black coloured rocks having an uneven surface. According to Buchanan's description 'it looks like the skin of a person suffering from skin disease'. Beneath this surface, up to a certain depth the laterite stone continues. As it goes deeper, the laterite becomes soft. Beneath it is clay. Such laterite rock hills generally have flat top surface. Madayipara, Moorkhanparamba and Kalliattuparamba are examples. Plant growth is possible only in spaces among the laterites where a little soil remains. Usually the top surface is covered with grass, herbs, shrubs and some smaller trees. Madayipara is endowed with most rare species of flora and fauna. Rock pools and lakes are present on some of these hills. (Eg: Madayi, Meenkulam, Peringome, Eramam, Oorathur, Peruvalathuparamba, etc.)

2.6 MINING IN KANNUR DISTRICT

The Kannur district is endowed with rich deposits of clay. Various types are mined at many places for pottery, tile and ceramic industries. China clay is found in abundance in Thaliparamba and Kannur Taluks. This resource is not fully utilized in the district. China clay is mined from Pazhayangadi and nearby areas of Kannur district. Kannapuram, Cheruthazham, Ramapuram, Pattuvam and Madayipara are having mining of china clay. It is estimated that a total reserve of 172 million tonnes of china clay is available in the State. Even though the Department of Mining and Geology has all legal regulations to direct the mining scenario into the right dimension, it is real irony that most of the entrepreneurs are not following any of these regulations. Due to such activities, the impact of laterite mining has brought many environmental changes to the mining area.

Geologically, the land had emerged from the sea and the plateau is rich in deposits of China clay, lignite and probably other minerals. A mining site of Kerala Clays and Ceramic Products Ltd. (KCCPL) is situated on the southwestern side of the plateau, which had extended up to the vicinity of the Shiva temple and its pond, posing serious threat to the entire ecosystem. The damage and the pollution due to mining during the past 25 years has heavily affected the adjoining areas of Madayi and Vengara.

2.7 MICROHABITATS CLASSIFICATION

Plants on the plateaus are adapted to various microhabitats and each of these microhabitats is unique in its edaphic properties, water availability and species composition (Lekhak and Yadav, 2012). The most common habitat types observed on plateaus are categorized by following a fairly established categorization for rock outcrops by Porembski and Barthlott (2000) and Jacobi *et al.* (2007) with some modifications (Lekhak and Yadav, 2012). According to Lekhak and Yadav (2012) microhabitats in the lateritic plateau ecosystems of Western Ghats, southwestern Maharashtra, are Boulders, Crust Edges or Cliffs (CEC), Ephemeral Flush Vegetation (EFV), Exposed Rock Surfaces (ERS), Rock Crevices/Fissures (RC), Seasonal Ponds (SP), Small Ephemeral Pools (SEP), Soil-covered Areas (SCA), Soil-filled Depressions (SFD), Soil enriched Areas (SEA), Tree Cover and Tree Associated (T).

According to Rahangdale and Rahangdale (2014), total of 11 types of microhabitats are identified in the rock outcrop area junnar, Maharashtra, following the microhabitat classification in the Western Ghats by Watve (2008) and Lekhak and Yadav (2012) with some modifications. Each microhabitat has characteristic features with respect to soil, water and species composition.

2.8 TEMPERATURE VARIABILITY OVER KERALA

A clear upward trend in surface air temperature across the West coast between 1961 and 2003 by 0.8°C in maximum and 0.2°C in minimum temperature, with an increase in average surface air temperature of 0.6°C was noticed. According to the India Meteorological Department (IMD) the maximum, minimum temperature and mean temperature over the State has increased by 0.8°C, 0.2°C and 0.5°C respectively during the last 43 years from 1961-2003. Rao *et al.* (2009) reported that there was an increase in maximum temperature over the State by 0.64°C during the period of 49 years, commencing from 1956 to 2004

while the increase in minimum temperature was 0.23°C. Overall increase in annual average temperature was 0.44°C (Gopakumar, 2011).

2.9 RAINFALL VARIABILITY OVER KERALA

Krishnakumar *et al.* (2009) studied the temporal variation in monthly, seasonal and annual rainfall over Kerala, India, during the period from 1871 to 2005. The analysis revealed significant decrease in southwest monsoon rainfall while increase in post-monsoon season over the State of Kerala which is popularly known as the “Gateway of summer monsoon”. Rainfall during winter and summer seasons showed insignificant increasing trend. Rainfall during June and July showed significant decreasing trend while increasing trend in January, February and April. The decreasing trend in southwest monsoon rainfall over Kerala is supported by other researchers (Kumar *et al.*, 1992; Guhathakurta and Rajeevan, 2007). Joseph *et al.* (2004) reported that the period of Intra Seasonal Oscillation of South Kerala rainfall during summer monsoon has large inter-annual variability in the range of 23–64 days. Joseph *et al.* (2004) analysed time series of daily rainfall of south Kerala using data from a network of 39 to 44 rain gauge stations for the summer monsoon season of 95 year (1901-1995) to study the inter-annual variation of the period of the intra-seasonal oscillation (ISO). They found that the period of intra-seasonal oscillation does not vary during a monsoon season in most of 22 the years, but it has large inter-annual variability in the range of 23 to 46 days. They also found that of the 95 years, 11 years had no significant ISO. Krishnakumar *et al.*, (2007 and 2009) have observed that monthly rainfall in Kerala during June and July was decreasing while increasing in August and September, indicating that there was a shift in monthly rainfall as August and September rainfall was increasing. Nayagam *et al.* (2008) have attempted to develop a linear multiple regression model for the long range forecasting of monsoonal rainfall of Kerala using ocean and atmospheric parameters as input. Simon and Mohankumar (2004) studied the variation in the occurrence of rainfall using factor analysis and found it was significantly influenced by the general physiographic of the State. They also reported that the altitude and rainfall in

Kerala are not correlated. Soman *et al.* (1988) reported a fall in the annual rainfall in the southern part of Kerala. However, they could not find similar decrement in the northern part of the State. Singh *et al.* (1989) studied the inter-annual and long term fluctuations of various rainfall events and reported that for most of the rainfall periods, the time series of starting and ending dates and length are homogeneous and random, and tend to observe the normal probability distribution (Gopakumar, 2011).

CHAPTER 3

MATERIALS AND METHODS

The main objective of the study was to understand the floral diversity of a lateritic hillock and to understand the influence of weather and edaphic parameters on vegetation dynamics.

3.1 DATA AND TOOLS USED

Data and tools used for the current study are described in the following sections.

3.1.1 Area of Study

The present study was carried out in the lateritic hill of Madayipara (Fig.1) which is a flat topped hillock overlooking Payangadi town on the northern bank of Kuppam river. It is located in the Madayi village, at latitude 12°2' N and longitude 75°16'E, about 21 km north of Kannur town. As the name suggests, the top of this hillock is a laterite plain more than 365 ha in area. The river Kuppam flows through the south eastern edge of Madayipara, then meet the larger Valapattanam River at Matakara, and finally discharging into the Arabian Sea at Azhikkal.

Total of 52 plots were taken each with (5x5m) from 5 regions of Madayipara.

3.1.2 Floral inventory

A check-list of angiosperms in the study site has been prepared by visiting sites along with locality details including microhabitat. At least two field visits were made during every month for a period of one year from December 2016-September 2017. Also soil samples were collected from 9 different microhabitats in the study site for the soil analysis. Daily weather parameters like temperature and humidity were collected using hygrometer whereas rainfall data was obtained from Rain gauge installed at the site. Each location was marked with GPS. Plant

specimens were collected, identified with the help of local and regional floras and deposited in KFRI herbarium

3.1.3 Climate

The rainfall in this region is mainly from Southwest monsoon which commences during early June and normally ends by the middle of September. The average annual rainfall recorded here lies in the range of 1500-1800mm. The average annual minimum temperature is 31.5°C. Geologically, the land had emerged from the sea and the plateau is rich in deposits of China clay, lignite and probably other minerals. A mining site of Kerala Clays and Ceramic Products Ltd. (KCCPL) is situated on the southwestern side of the plateau, which had extended up to the vicinity of the Shiva temple and its pond, posing serious threat to the entire ecosystem. The damage and the pollution due to mining during the past 25 years had been heavily affecting the adjoining areas of Madayi and Vengara quarters of Kannur district in Kerala.



Figure 1. Instruments used for measuring weather parameters
a) Temperature, Humidity sensor b) Rain gauge for measuring rain

LATERITE PLOTS FOR VEGETATION DYNAMICS STUDIES
STUDY AREA IN MADAYIPARA, KANNUR

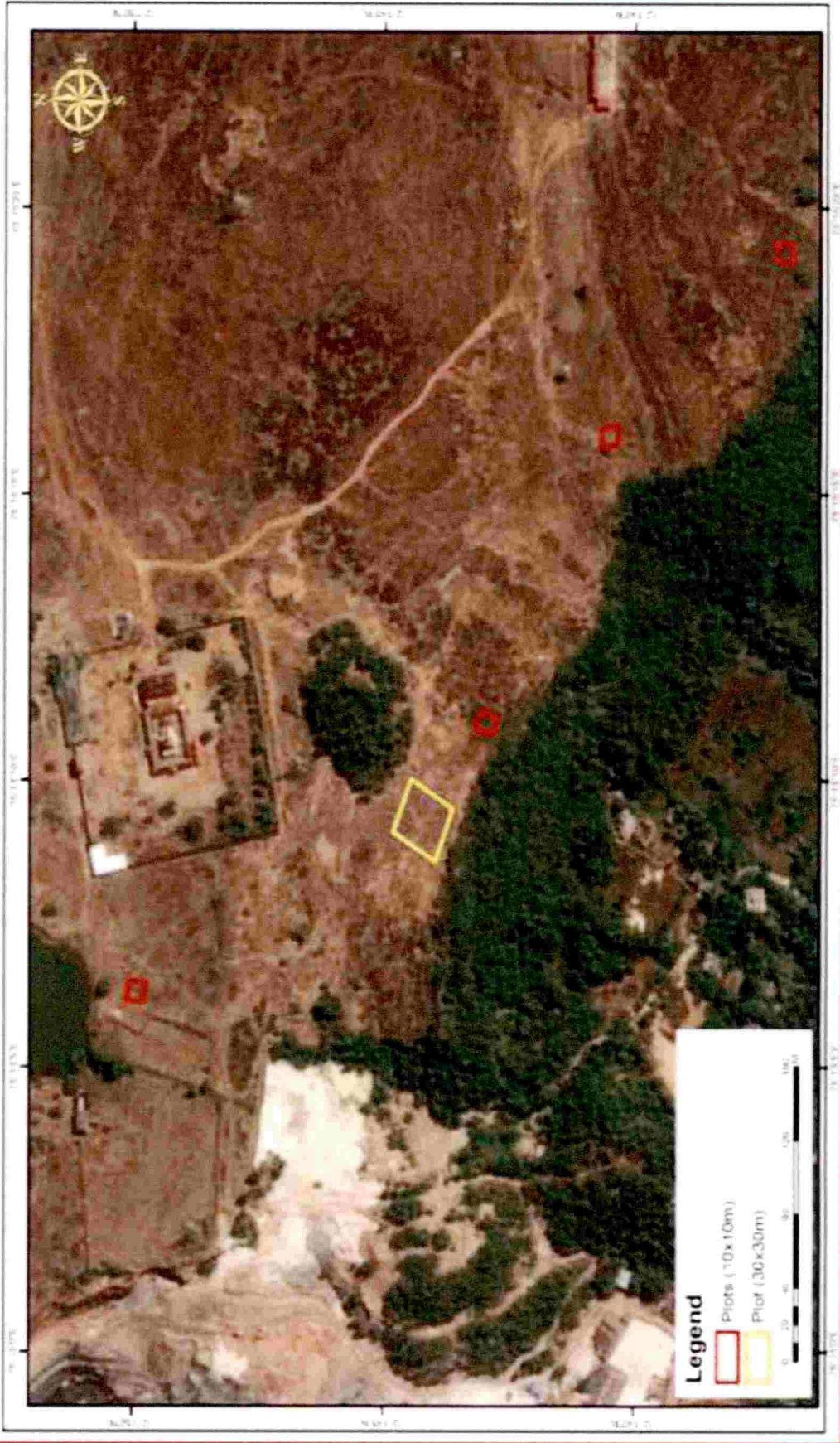


Figure 2. Study area

3.1.4 Sorensen's Similarity index

The microhabitats classified were further analysed for their similarity in species composition by Sorensen's Similarity index. In order to compare two communities we calculated the Sorensen's Similarity index is suggested by Sorensen (1948)

$$\text{Sorensen's Similarity index } S = \frac{2C}{A+B}$$

Where S= Similarity index; A= number of species in sample; B= number of species in sample; C=number of species in sample common to A and B both.

3.2 PHYSICO CHEMICAL PARAMETERS OF SOIL

3.2.1 Soil pH

The pH of 1:2.5 soil: water suspension was estimated using a pH meter. It is a measure of hydrogen ion activity of the soil - water system and indicates whether the soil is acidic, neutral or alkaline in reaction. The pH meter consists of a glass electrode and a reference electrode. It allows the pH value of the sample to be obtained by measuring the potential difference between the two electrodes with a potential difference meter. When two solutions with different pH exist inside and outside a glass membrane, electromotive force occurs in that membrane (electrode membrane) in proportion to the difference between the two pH values. Since the solution typically used inside the glass membrane has a pH value of 7, the pH value of the solution outside the membrane can be obtained by measuring the electromotive force generated in the membrane.

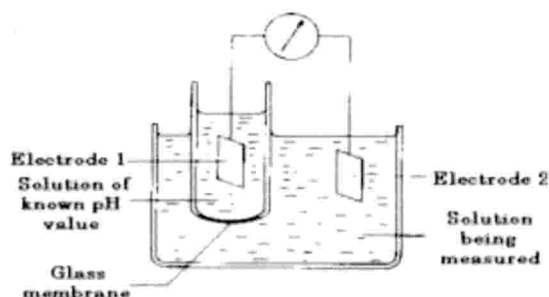


Figure 3. Schematic diagram of pH meter

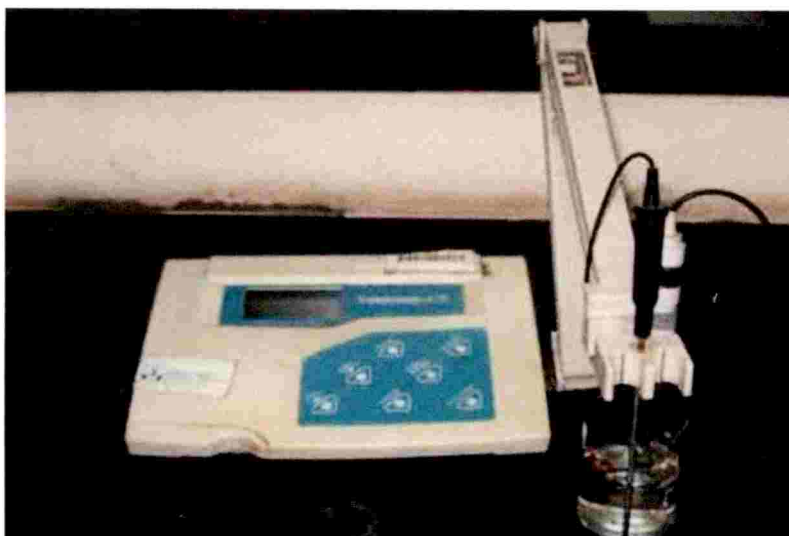


Figure 4: pH meter

10g soil was weighed and transferred to a 100ml beaker. To this 25ml water was added. It was then stirred thoroughly with a glass rod and suspension was allowed to settle for 30 minutes. pH meter was then standardized with the buffer and the pH reading of the sample was recorded.

3.2.2 Electrical Conductivity

Electrical conductivity in soil water system is a measure of soluble salts and extent of salinity in the soil and is measured using a conductivity meter.

The clear supernatant of 1:2.5 soil:water suspension prepared for pH measurement was used for estimating EC. The conductivity meter was calibrated using 0.01N KCl solution and the cell constant was determined. Then conductivity of the soil– water suspension was determined using the instrument.

3.2.3 Soil Moisture

The soil moisture content may be expressed by weight as the ratio of the mass of water present to the dry weight of the sample, or by volume as the ratio of volume of water to the total volume of the soil sample. To determine any of these ratios for a particular soil sample, the water mass must be determined by drying the soil to constant weight and measuring the soil sample mass after and before drying. The water mass (or weight) is the difference between the weights of the

wet and oven dry samples. The criterion for a dry soil sample is the soil sample that has been dried to constant weight in oven at temperature between 100-110°C. It seems that this temperature range has been based on water boiling temperature and does not consider the soil physical and chemical characteristics

Weigh an aluminium tin, and record its weight. Place a soil sample of about 10g in the tin and record the weight. Place the sample in the oven at 105°C and dry for 24hours or overnight. Weigh the sample, and record the weight. Return the sample to the oven and dry for several hours, and determine the weight of dry soil. Repeat step 5 until there is no difference between any two consecutive measurements of the weight of dry soil.

3.2.3.1 Calculations

The moisture content on dry weight basis may be calculated using the formula

$$d = \frac{(\text{wt of wet soil} + \text{tare}) - (\text{wt of dry soil} + \text{tare})}{(\text{wt of dry soil} + \text{tare}) - (\text{tare})}$$

3.2.4 Water Holding Capacity

For the estimation of water holding capacity, 25g soil was put in a wet Whatmann’s filter paper cone fitted on funnel placed on a conical flask. Water was poured to the soil uniformly drop by drop till few drops of the water spill out to the conical flask. The quantity of water poured to the soil and excess water collected in the flask were noted and thus water retained by the soil was calculated (Rajeshwar, 2015).

3.2.4.1 Calculations

Volume of water retained in the soil = Volume of water poured- Volume of water collected

$$\text{Water Holding Capacity} = \frac{\text{Volume of water retained in the soil} \times 100}{\text{Weight of the soil taken}}$$

3.2.5 Soil texture

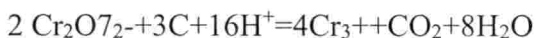
Texture, or size distribution of mineral particles (or its associated pore volume), is one of the most important measures of a soil because finely divided soil particles have much greater surface area per unit mass or volume than do coarse particles. Thus, a small amount of fine clay and silt will be much more important in chemical reactions, release of nutrient elements, retention of soil moisture, etc., than a large volume of coarse gravel or sand. The most common method for determining soil texture is the hydrometer method.

In this method the soil particles are dispersed with a sodium metaphosphate (calgon) and then agitated. After dispersion, the amount of each particle group (sand, silt, clay) are determined by using a hydrometer. The hydrometer measures the amount of particles in suspension. The principle of Stokes law, which states that particles will fall out of suspension at different rates over time, based on particle size, is used to determine the amount of each particle size present in a soil. The amount of each particle fraction, sand, silt and clay, determines the soil texture.

3.2.6 Organic Carbon

Soil organic matter has been defined as the organic fraction of soil, including plant, animal and microbial residues and at all stages of decomposition and the relatively resistant soil humus (SSSA, 1979). Carbon is the chief element present in soil organic matter, comprising 48-58% of the total weight. Therefore organic carbon determinations are often used as a basis for organic matter estimates through multiplying the organic carbon value by a factor. For many years the Van Bemmelen factor of 1.724 was used based on the assumption that the organic matter contains 58% organic carbon.

Schollenberger (1927) first proposed that the organic matter in soil may be oxidized by treatment with a hot mixture of $K_2Cr_2O_7$ and H_2SO_4 according to the equation



After the reaction, the unreacted $\text{Cr}_2\text{O}_7^{2-}$ is titrated with standard Fe $(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$ and the $\text{Cr}_2\text{O}_7^{2-}$ reduced during the reaction with soil is assumed to be equivalent to the organic carbon present in the sample. Jackson (1958) recommended that o-phenanthroline can be used as an indicator in the $\text{Cr}_2\text{O}_7^{2-}$ titrations because the color changes (formation of complex with Fe^{2+}) occur at higher oxidation reduction potential. Dichromate methods that use heat of dilution or minimal heating do not give complete oxidation of organic compounds in soil although the most active forms of organic carbon are converted to CO_2 . Walkey and Black (1934) found that on an average about 76% of the organic carbon was recovered by the heat of dilution procedure and they proposed that a correction factor of 1.32 be used to account for unrecovered organic carbon.

3.2.6.1 Walkey – Black Wet Digestion Method (Walkey, 1947)

Grind the soil to pass through a 0.5 mm sieve avoiding iron or steel mortars. Transferred a weighed sample, containing 10-25mg of organic carbon (approximately 0.5 to 1g soil), but not in excess of 10g of soil, into a 500 ml wide mouth conical flask. Add 10 ml of 1N $\text{K}_2\text{Cr}_2\text{O}_7$ to it and swirl the flask gently to disperse the soil in the solution. Then rapidly add 20 ml of concentrated H_2SO_4 . Immediately swirl the flask gently until the soil and the reagents are mixed, then more vigorously for a total of one minute. Allow the flask to stand on sheet of asbestos for about 30 minutes. Then add 200 ml of water to the flask. Add 3-4 drops indicator and titrate the solution with 0.5N ferrous ammonium sulphate. As the end point approaches, the solution takes on a greenish cast and then changes to a dark green. At this point add the ferrous ammonium sulphate drop by drop until the colour changes sharply from blue to red. Make a blank determination in the same manner, but without soil, to standardize the $\text{K}_2\text{Cr}_2\text{O}_7^{2-}$.

Organic carbon content was calculated using the equation.

$$\text{OC (\%)} = [(\text{blank} - \text{titer value of sample}) * 0.5 * 0.003 * 100] / \text{sample weight.}$$

3.2.7 Nitrogen

The nitrogen in the samples was estimated using Kjeldahl method. This method consists of two phases.

3.2.7.1 Distillation

The separation and isolation of the nitrogen from the digestion tube by raising the pH with NaOH and by doing this the ammonium radical is converted to ammonia. On heating, the ammonia is distilled out and collected in 4% boric acid as a trapping Medium.

3.2.7.2 Titration

The determination of the amount of Nitrogen in the condensate flask is done by titrating with a Standard solution of 0.02 N H₂SO₄ in the presence of mixed indicator.

% Nitrogen = $(\text{reading-blank}) \times 0.02 \times 0.014 \times 10000$ Weight of the sample

3.2.8 Potassium and Sodium

Content of Potassium and Sodium in the soil samples were determined using flame photometer (Elico-CL378). The principle of operation of flame photometer is based upon the quantitative measurement of the characteristic light emitted when a solution of the element being determined is atomized as a mist into gas flame. When a metallic salt is introduced into a non-luminous flame, the salt is separated into its component atoms because of high temperature. The energy provided by the flame excites the atoms to higher energy levels and when the atoms return to the ground or unexcited state, they emit these characteristic radiations. Since the excitation can be to different levels, light of several wavelengths can be emitted. The intensity of light emitted could be described by the Scheibe-Lomakin equation; $I = kcn$.

c = concentration of the element

k = constant of proportionality

$n \sim 1$ (at the linear part of the calibration curve), therefore the intensity of the emitted light is directly proportional to the concentration of the sample. Each individual atom emits one quantum of radiation. Therefore the intensity of radiation emitting from the flame will be proportional to the number of atoms in the flame that is the concentration of the element in the flame. Because of the very narrow and characteristic emission lines from the gas-phase atoms in the flame plasma, the method is relatively free of interferences from other elements. Therefore, the flame photometry is very sensitive; measuring concentrations of ppm magnitude usually does not cause any problem. The energy needed for excitation is provided by the temperature of the flame (2000-3000⁰C), provided by the burning of acetylene or natural gas (or propane-butane gas) in the presence of air or oxygen. The most sensitive parts of the instrument are the aspirator and the burner. The air sucks up the sample (according to Bernoulli's principle) and passes it into the aspirator, where the bigger drops condense and could be eliminated.



Figure 5. Flame photometer

5g of soil was taken in a 100ml conical flask and added 25ml neutral ammonium acetate solution and shake for 5 minutes. Filtered immediately through a dry Whatman No.42 filter paper. Potassium concentration in the extract is determined using flame photometer after necessary setting and calibration of the instrument. The extract prepared for potassium was used for estimating Na also.

3.2.9 Phosphorus, Sulphur and Boron

Phosphorus, Boron and Sulphur in the sample were determined by using spectrophotometer (Xplorer, Xp2001). Spectrophotometry based on Beer-Lambert's Law. This Law may be expressed mathematically as $I_t = I_0 K c$

I_t = Intensity of transmitted light

I_0 = Intensity of incident light

K = constant for a given cell

c = concentration

The value of K depends on the size of the cell and the solution under test.

Thus $I_t/I_0 = Kc$ or

$E = \log I_t / \log I_0 = Kc$

E = Extinction coefficient



Figure 6. Spectrophotometer

3.2.9.1 Phosphorus

Phosphorus in the samples were estimated by Brays method. To 5g of soil added 50ml of Brays reagent and shaken in 250ml conical flask for exactly 5 minutes and filtered through No.42 filter paper. 5ml of aliquot of the extract is pipetted into a 25ml volumetric flask and added 4ml colouring reagent and the solution is made up to the mark. Shaked well and allowed the colour to develop for 10 minutes and noted the intensity of blue colour in spectrophotometer at 660nm. Concentration of P was determined by comparing with standard solutions.

3.2.9.2 Boron

Although there are a variety of chemical tests for predicting crop response to boron the hot water extraction procedure developed by Gupta (1967) is the easiest method. Weighed 20g of air – dried processed soil in a 250ml quartz or other boron free conical flask and 50ml distilled water. Added 0.5g activated charcoal and boil for five minutes on a hot plate, filtered immediately through Whatman No.42 filter paper. Allowed to cool the contents to room temperature and transferred 1 ml aliquot of blank, diluted boron standard or sample solution in a 10ml polypropylene tubes. Added 2ml of buffer and mixed well. Then added 2ml of Azomethine-H reagents mix and after 30 minutes noted the absorbance at 420nm on spectrophotometer. Prepared a standard curve plotting boron concentration on X axis and absorbance on Y axis.

3.2.9.3 Sulphur

Shaked 10g soil with 50ml 0.15% CaCl_2 solution in a 250ml conical flask for 30 minutes. Filtered extract through Whatman No.42 filter paper. 10 ml of extract was pipetted into a 25ml volumetric flask. Added 1g BaCl_2 crystals to each flask and swirled to dissolve. Added 1ml of 0.25% gum acacia solution, made up the volume with distilled water and shaken well. Within 5-30 minutes of development of turbidity, noted the absorbance at 440nm on a spectrophotometer.

CHAPTER 4

RESULTS AND DISCUSSION

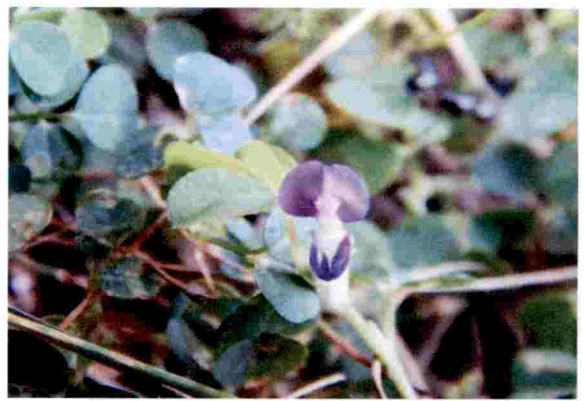
The objectives of the study were to understand the role of edaphic parameters (physical and chemical) and weather parameters (temperature, humidity and rainfall) on vegetation dynamics. The soil analysis was carried out for 9 different microhabitats and one control (Normal soil collected from laterite rock) during January to August.

4.1 FLORAL INVENTORY

A total of 100 angiosperm species were recorded during this study from the plots established in different microhabitats. It is interesting and noteworthy that these species were distributed in 9 microhabitats and majority of them shows very narrow ecological niche (Plate 1). Four species (*Desmodium triflorum*, *Eragrostis unioloides*, *Eriocaulon heterolepis*, *Eriocaulon madayiparense*) were found to be distributed in 5 microhabitats with a wide ecological niche as indicated by its presence in different microhabitats (Plate 4.1).



Centranthera indica



Desmodium triflora



Drosera indica



Geissaspis tenella



Hygonia mystax



Justicia japonica



Lindernia cileata



Lindernia hyssopioides

Plate 1. Flora of Madayipara



Neonotis hohenackeri



Rhamphicarpa longiflora



Rotala malabarica



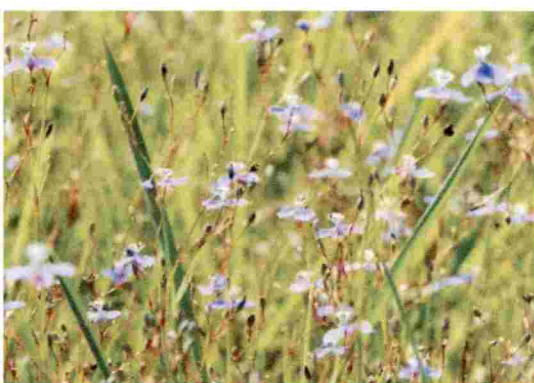
Salamonia ciliata



Xyris indica



Utricularia reticulata



Murdannia semiteres



Alysicarpus bupleurifolius

Plate 2. Flora of Madayipara

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4.2 CLASSIFICATION OF MICROHABITATS

Plants on the plateaus are adapted to various microhabitats and each of these microhabitat is unique in its edaphic properties, water availability and species composition. The most common microhabitats types on the lateritic hillock plateaus have been described along with characteristic species assemblages (Plate 4.2).

4.2.1 Ephemeral flush vegetation (EFV)

It occurs on rocks where water seeps continuously through the rainy season and soil deposition is negligible. It occupies a large area on plateaus, colonized predominantly by *Eriocaulon heterolepis*, *Leucus aspera*, *Eragrostis uniolooides*, *Arundinella leptochloa*, *Utricularia reticulata*, *Utricularia cecili*, *Desmodium heterophyllum*, etc. Recorded 36 species in this particular microhabitat, of which 2 species (*Cyanotis cristata*, *Mimosa pudica*) are specifically confined to this microhabitat.

4.2.2 Exposed rock surfaces (ERS)

They are flat or uneven rock surfaces, exposed to direct sunlight. They may gradually get covered by grasses during monsoon. Some common plants of the habitat are *Drosera indica*, *Eriocaulon madayiparens*, *Lepidagathis keralensis*, *Utricularia cecili*, *Arundinella metzii*, *Eragrostis uniolooides*, *Eragrostis tenuifolia* etc. We could record 24 species in this particular microhabitat of which 5 species (*Belosynapsis vivipara*, *Centotheca lappacea*, *Ischaemum hirtum*, *Ischaemum timorense*, *Murdannia lanuginose*) were specifically confined to this microhabitat.

4.2.3 Rock crevices/fissures (RCF)

They are frequently found on lateritic plateaus providing a unique ecological niche specific to small number of species. Many species such as *Eriocaulon heterolepis*, *Impatiens diversifolia*, *Utricularia cecili*, *Impatiens minor*, *Oldenlandia corymbosa* and *Polycarpaea corymbosa* were present in this microhabitat. Recorded 11 species in this particular microhabitat, of which two

species (*Eriocaulon quinquangulare*, *Oldenlandia corymbosa*) were specifically confined to this microhabitat.

4.2.4 Small Ephemeral Pools (SEP)

They are shallow depressions which remain filled with water during monsoon. Since there is hardly any soil deposition, plateau crust can be seen easily. The dominant species in this microhabitat includes *Eriocaulon madayiparense*, *Utricularia reticulata*, *Rotala malampuzhensis* and *Rotala malabarica*. We could record 27 species in this particular microhabitat of which four species (*Cryptocoryne spiralis*, *Spermacoce latifolia*, *Marsilea minuta*, *Isoetes coromandelina*) were specifically confined to this microhabitat.

4.2.5 Soil-Filled Depressions (SFD)

It is a specific microhabitat with depressions that accumulate soil and water. *Cleome viscosa*, *Eriocaulon heterolepis*, *Eriocaulon parviflorum*, *Commelina diffusa*, *Arundinella leptochloa* and *Brachiaria reptans* are the most common species found here. We could record 21 species of this particular microhabitat of which 2 species (*Dimeria thwaitesi*, *Xyris indica*) were specifically confined to this microhabitat.

4.2.6 Soil-Rich Areas (SEA)

These are soil-rich microhabitats with more than 20 cm soil-thickness. The gaps left between mats are mainly occupied by species *Commelina diffusa*, *Commelina erecta*, *Heliotropium marifolium*, etc. We could record 29 species in this particular microhabitat of which 2 species (*Chamecrista mimosoides*, *Phyllanthus emblica*) were specifically confined to this microhabitat.

4.2.7 Tree Cover and Tree Associated (T)

This microhabitat is entirely different from the rest simply because of the dominance of tree species. These are soil-rich areas of plateaus where trees could grow and survive. The covered shady areas provide a habitat which is entirely different from the harsh extreme environmental conditions prevailing on the

exposed surfaces of plateaus. *Bredilia retusa*, *Chromolaena odorata*, *Cissus repans*, *Sida acuta*, *Impatiens minora*, *Passiflora foetida*, *Salamonia ciliate*, *Spermacoce pusilla*, etc. are commonly found in this area. Recorded 20 species in this particular microhabitat of which 15 species were specifically confined to this microhabitat.

4.2.8 Boulders (B)

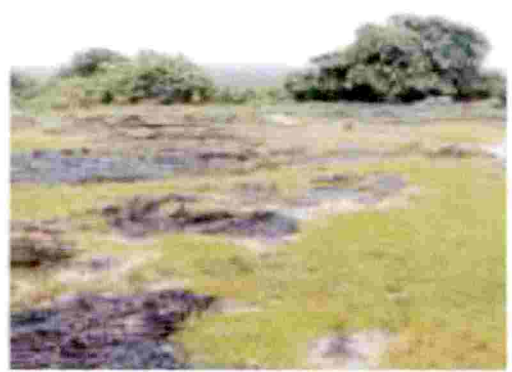
They are large rocks either isolated or in groups. They are usually covered by lichens and bryophytes. Some typical angiosperm species were also found to be associated with the system which include *Utricularia cecilia*, *Ariopsis peltata*, *Impatiens diversifolia*, *Impatiens minor* and *Eragrostis nigra*. We could record 8 species in this particular microhabitat of which 6 species specifically confined to this microhabitat.

4.2.9 Crust Edges or Cliffs (CEC)

They are edges of the plateaus inhabited by species such as *Lepidagathis keralensis*, *Murdannia crocea*, *Neanotis hohenackeri*, *Polycarpaea corymbosa*, *Neanotis rheedei* etc. We could record 10 species in this particular microhabitat.



SEA



ERS



EFV



TC



REC



RCF

Handwritten signature or mark in the bottom right corner.



RB



EP



SFD

Plate 3. Nine microhabitats observed in Madayipara

4.3 PHYSICAL PARAMETERS OF SOIL

4.3.1 Soil texture

According to the soil texture analysis, soils in the Exposed Rock Surfaces (ERS), Rock Boulders (RB), Soil Filled Depressions (SFD), Crust edges or Cliffs (CEC) were sandy loam in nature. Whereas that of Soil Enriched Area (SEA) and Rock Crevices or Fissures (RCF) were Loamy Fine Sand. In the case of Tree Cover and Tree Associated (T) and Ephemeral Flush Vegetation (EFV), the soils were sandy clay loam and soil in the control(C) and Small Ephemeral Pools (SEP) were sandy clay (Table 4.1)

4.3.2 Moisture content

Moisture content is lower in the month of March due to high temperature and higher in the month of June due to high precipitation and low temperature. Due to the presence of vegetation, even in January and February some moisture could retain especially in Rock Boulders which was about 46.43%. But during the same period soil moisture content of Ephemeral Flush Vegetation (EFV) and Small Ephemeral Pools (SEP) were very low due to the absence of vegetation, it was about 6.67 and 9.30 percent (Table 4.2) respectively.

Table 4.1. Soil Texture of different microhabitats in lateritic hillock of Madayipara

MICROHABITAT	SILT	CLAY	SAND	TEXTURE
Exposed rock surfaces (ERS)	0.09	18.16	81.75	Sandy Loam
Rock Boulders (RB)	0.01	16.16	83.83	Sandy Loam
Soil enriched area (SEA)	0.05	12.16	87.79	Loamy Fine Sand
Rock crevices or fissures (RCF)	0.01	10.16	89.83	Loamy Fine Sand
Soil filled depression (SFD)	0.08	18.16	81.76	Sandy Loam
Tree cover and tree associated (T)	0.14	26.16	73.7	Sandy Clay Loam
Crust edges or cliffs (CEC)	0.02	18.16	81.82	Sandy Loam
Soil ephemeral pools (SEP)	0.1	40.16	59.74	Sandy Clay
Ephemeral flush vegetation (EFV)	0.34	28.16	71.5	Sandy Clay Loam
Control (C)	0.08	52.16	47.76	Sandy Clay

Table 4.2. Soil Moisture (%) of different microhabitats in lateritic hillock of Madayipara

MICRO-HABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
ERS	17.84	16.79	13.79	6.45	2.35	94.19	45.32	7.64
RB	46.43	41.01	1.4	18.74	3.69	142.65	33.27	4.02
SEA	21.38	20.34	3.34	30.33	6.91	38	60.74	37.47
RCF	17.69	12.32	3.38	39.57	4.6	46.13	65.41	3.67
SFD	18.74	11.01	1.87	8.79	4.45	60.35	154.54	5.73
T	19.08	14.03	3.15	23.13	11.9	43.67	42.14	37.69
CEC	18.64	10.12	1.42	8	4.94	39.6	35	3.73
SEP	9.3	4.97	0.3	25.72	13.7	72.07	50.75	57.89
EFV	6.67	7.09	2.12	35.95	9.67	179.19	81.75	49.56
C	-	-	1.77	-	-	-	-	-

4.3.3 Water holding capacity (WHC)

Generally water holding capacity is higher in laterite soil. The soils with high sand content retained least amount of moisture at both tensions than soils with high clay content. This might be due to the red soils and red laterite soils being dominated by kaolinite clay with small surface area, retained appreciable amount of water at different soil water suctions. T, SEP were having high water holding capacity because their textures are Sandy Clay Loam and Sandy Clay. Clay soils are having finer pores capable of holding water due to capillary forces. At the same time CEC have less water holding capacities because it is Sandy Loam in texture with more macropores (Table 4.3)

Table 4.3 Water Holding Capacity of different microhabitats in lateritic hillock of Madayipara

MICROHABITAT	Water Holding Capacity
ERS	89
RB	40
SEA	88
RCF	76
SFD	64
T	96
CEC	52
SEP	96
EFV	88
C	80

4.4 CHEMICAL PARAMETERS OF SOIL

4.4.1 Soil conductivity

Conductivity increases in the soil as monsoon proceeds. That is in the month of June, July, August conductivity increases. Electrical current in soils mainly depends on the amount of water remained in the pores. The electrical conductivity and resistivity of laterite soils are significantly influenced by water content, but it decreases after the water content is above 23.4%, which is close to the optimum water content. In July SFD got higher value of conductivity (about 5.04) while in August higher conductivity was in the microhabitat EFV (about 4.72) (Table 4.4).

4.4.2 Organic carbon content

Organic carbon content in February was least in all microhabitats because of burning on land. Burning causes conversion of biomass into light, heat, gases, ash and char. This leads to increase in inert carbon content and decrease in Organic

carbon content. From May onwards the organic carbon content level become higher. Microhabitats associated with rocks such as CEC, RB and RCF shows higher organic carbon content in May, June and August respectively. This is because these microhabitats were almost filled with grasses (Table 4.5).

4.4.3 Soil pH

Soil pH ranges between 3.77 and 6.5. But in the month of February, pH is much higher in Ephemeral Flush Vegetation (EFV) which is about 8.97. During February some area is affected by fire so burning causes addition of basic materials like Potassium, Nitrogen and Phosphorus etc. It leads to dilution and results in higher pH (Table 4.6)

Table 4.4. Soil Conductivity ($\mu\text{s}/\text{cm}$) of different microhabitats in lateritic hillock of Madayipara

MICROHABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
ERS	0.09	0.18	0.30	0.11	0.04	0.29	0.14	0.06
RB	0.13	0.14	0.18	0.13	0.10	3.08	0.96	0.12
SEA	0.08	0.03	0.06	0.24	0.12	0.61	0.20	0.24
RCF	0.08	0.10	0.11	0.12	0.08	0.68	0.33	0.19
SFD	0.08	0.13	0.22	0.07	0.07	0.37	5.04	0.32
T	0.07	0.07	0.09	0.10	0.14	1.27	0.37	0.19
CEC	0.16	0.25	0.05	0.10	0.06	4.23	0.44	0.21
SEP	0.04	0.21	0.38	0.19	0.37	1.21	0.44	1.01
EFV	0.05	0.20	0.24	0.37	0.22	0.16	1.25	4.72
C			0.81					

Table 4.5. Organic Carbon content in different microhabitats in lateritic hillock of Madayipara

MICRO HABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
ERS	2.37	0.87	1.26	4.35	0.75	3.9	3.2	1.5
RB	4.44	0.75	1.29	7.95	9.6	8.5	3.2	4.85
SEA	3.93	1.08	1.35	7.05	4.95	4.5	5.6	9
RCF	4.74	2.07	1.68	8.1	7.2	5.55	7.6	8.65
SFD	4.08	1.08	2.28	4.35	3.9	6.75	8.2	8.4
T	4.62	1.38	1.2	4.65	4.8	5.25	4.8	7.5
CEC	5.13	2.43	1.08	5.25	8.95	7.35	3.6	4.95
SEP	0.99	1.11	1.26	7.5	5.85	3	3.2	8.5
EFV	2.22	0.81	1.05	4.5	4.8	6.6	4.1	2.85

Table 4.6. Soil pH of different microhabitats in lateritic hillock of Madayipara

MICROHABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
ERS	4.16	5.34	5.01	4.61	4.89	5.7	5.4	5.5
RB	4.62	5.53	4.81	4.53	4.61	5.6	5.8	5.6
SEA	4.27	4.74	4.83	4.63	4.5	5.8	5.6	6.2
RCF	4.76	5.12	4.65	4.74	4.74	5.7	5.4	5.7
SFD	4.78	5.16	5.56	4.72	4.69	5.9	6	5.2
T	4.74	5.2	6.36	4.91	4.83	5.5	6	5.9
CEC	4.77	5.41	4.99	4.71	4.69	6.5	5.8	5.4
SEP	4.88	4.8	5.39	4.28	3.89	5.5	5.2	5
EFV	5.14	8.97	4.92	3.77	4.22	5.1	4.5	5.2
C			4.61					

4.4.4 Macro nutrients

The major macro nutrients analysed were Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulphur.

4.4.4.1 Available Nitrogen

Available Nitrogen was low during August. Crust edges or Cliffs show low Nitrogen content during august (44.78ppm) because of decrease in the amount of rain and vegetation. Nitrogen content is highest during February followed by June. Highest nitrogen content was recorded in Rock boulders, soil enrich area and rock crevices. Soils in the RB and CEC microhabitats were formed by the accumulation of burned soils leached out from different places hence the nitrogen content in the microhabitats associated with rocks showing higher value in February. Addition of vegetation increases the nitrogen content of the soil. Burning of land consumes

the vegetation in the soil and added ash and char rather than organic matter. Ash gives minerals while char resist decomposition. Organic matter decomposition yields nitrogen. Hence nitrogen obtained during February. RCF show a very high nitrogen content during February (231.16ppm). Higher Nitrogen content in the month of June is due to the availability of rain and new individuals and species emerged during the month. In August Nitrogen content of all microhabitats were least (Table 4.7).

4.4.4.2 Available Phosphorus

Phosphorus content is lowest in the month of January and July. Tree cover and tree associated microhabitats have low Phosphorus content 1.16ppm content during February. Soil filled depressions (SFD) have the highest P content among all other microhabitats. P content in SFD during February is 12.12ppm (Table 4.8).

Table 4.7. Available nitrogen content in the microhabitats (in ppm) in lateritic hillock of Madayipara

MICRO HABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
ERS	218.39	190.13	198.63	201.56	100.76	190.13	156.79	138.84
RB	195.64	162.37	55.98	191.22	192.96	205.51	207.64	78.39
SEA	187.05	210.00	192.96	192.02	189.25	212.77	184.23	201.56
RCF	200.11	231.16	191.22	173.57	201.56	145.58	194.29	167.99
SFD	167.99	185.37	184.23	111.96	162.37	201.04	196.83	179.20
T	190.13	195.98	123.17	123.17	183.19	185.42	117.59	201.56
CEC	186.45	145.58	162.37	140.00	134.38	203.22	61.56	44.78
SEP	195.98	194.29	192.96	201.56	191.22	187.55	131.34	167.99
EFV	134.38	185.89	185.89	162.37	184.23	189.09	145.58	89.60
C			188.13					

Table 4.8. Available Phosphorous content in the microhabitats (in ppm) in lateritic hillock of Madayipara

MICRO HABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
ERS	9.14	12.64	7.13	5.36	4.54	3.89	2.78	2.23
RB	5.72	7.08	6.34	4.21	6.42	7.00	5.17	4.07
SEA	2.71	7.99	11.99	6.97	6.63	2.78	2.25	9.75
RCF	4.79	7.81	8.26	8.26	9.05	10.41	10.39	6.50
SFD	1.52	12.12	7.38	6.79	6.25	9.05	8.33	6.39
T	1.16	11.58	4.41	3.98	5.52	10.68	0.75	1.82
CEC	6.17	12.72	8.60	7.34	6.06	8.00	3.64	5.45
SEP	4.49	5.75	12.54	3.25	7.24	3.17	2.99	2.97
EFV	4.30	7.44	8.84	5.05	7.20	9.05	1.50	3.78
C			4.64					

4.4.4.3 Available Potassium

Potassium content was lowest during August due to decrease in rainfall and vegetation. Comparing to August, in all other months the microhabitats have higher K content. And it is highest in the month February. This is due to burning of biomass which increases K content in the soil. Among the microhabitats, soil enrich area has the least K content and rock crevices have the highest K content. Rock crevices have a K content of 145.14 ppm during February (Table 4.9).

4.4.4.4 Available Calcium

Calcium content was highest during June. Soil filled depressions (SFD) have a high Calcium content during June (754.00ppm). Calcium content was high during February and then it gradually decreases over the months March, April and May then becomes highest during June (Table 4.10).

4.4.4.5 Available Magnesium (ppm)

Magnesium content highest during June due to good rainfall and good vegetation in the microhabitats. It decreases and become lowest in the month August due to decreasing vegetation. It is low during January because of less vegetation. Small ephemeral pools (SEP) had very low Mg content 14.03 during January and 17.73ppm during August (Table 4.11).

4.4.4.6 Available Sulphur (ppm)

Sulphur content was lowest during June. Tree cover and tree associated areas have lower S content compared to other microhabitats. Sulphur content was highest during January (Table 4.12).

Table 4.9. Available Potassium content in the microhabitats (in ppm) of lateritic hillock, Madayipara

MICRO-HABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
ERS	45.00	116.50	14.50	93.00	35.50	135.00	46.00	48.50
RB	105.00	69.50	52.93	41.50	92.50	138.04	61.50	11.00
SEA	27.50	24.21	52.00	52.00	61.50	106.50	57.50	27.50
RCF	91.00	145.14	135.82	81.50	68.50	65.00	134.50	45.19
SFD	31.50	109.00	36.50	114.50	53.00	143.00	92.50	30.50
T	79.00	139.53	86.50	142.38	68.00	56.00	46.50	25.00
CEC	137.61	123.00	65.50	57.79	51.00	120.50	38.50	10.50
SEP	10.00	110.00	88.50	112.01	140.02	37.00	22.00	62.50
EFV	16.00	117.00	90.50	118.00	139.62	78.50	34.50	33.50
C			27.50					

Table 4.10. Available Calcium content in the microhabitats (in ppm) in lateritic hillock of Madayipara

MICRO HABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
ERS	96.75	402.25	409.50	161.50	161.50	151.84	138.50	204.75
RB	267.25	185.25	144.29	113.75	113.75	637.75	184.07	55.00
SEA	45.75	107.25	98.56	89.25	157.50	452.00	150.75	134.50
RCF	290.25	313.59	348.00	291.21	266.50	468.25	519.73	71.25
SFD	76.25	423.50	444.00	119.25	233.75	754.00	259.50	10.88
T	135.25	386.25	202.73	99.03	106.50	468.50	52.00	45.74
CEC	618.00	400.75	200.00	97.08	95.50	314.25	13.25	99.00
SEP	30.00	251.25	94.79	50.12	41.75	86.50	8.50	11.19
EFV	53.00	94.82	117.50	47.75	84.00	102.00	86.50	59.88
C			76.00					

Table 4.11. Available Magnesium content in the microhabitats (in ppm) in lateritic hillock of Madayipara

MICRO-HABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
ERS	17.25	119.97	115.00	41.73	38.15	71.48	32.58	33.60
RB	88.55	51.25	51.25	31.18	159.66	191.08	59.13	14.50
SEA	33.63	35.40	42.84	65.28	26.03	129.73	54.92	34.20
RCF	33.63	81.28	34.35	108.64	91.10	105.03	152.28	38.63
SFD	23.38	76.88	28.33	34.76	41.45	76.28	65.03	19.50
T	52.50	193.95	69.90	129.56	64.17	156.60	47.67	47.25
CEC	66.80	115.17	54.05	84.58	72.28	77.88	16.63	22.93
SEP	14.03	43.60	26.50	37.62	48.09	32.05	15.55	17.73
EFV	9.98	68.90	47.05	21.50	77.22	32.05	19.08	22.00
C			25.06					

Table 4.12. Available Sulphur content in the microhabitats (in ppm) in lateritic hillock of Madayipara

MICRO HABITAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
ERS	10.72	3.89	18.40	8.39	6.78	1.12	2.79	3.21
RB	7.21	3.66	10.88	25.68	3.76	6.34	4.06	19.01
SEA	61.88	9.53	7.89	15.97	16.38	1.02	16.83	6.59
RCF	23.42	4.47	8.01	6.95	6.66	5.35	13.42	3.08
SFD	12.61	1.10	19.13	12.90	8.39	0.83	20.36	4.34
T	9.12	1.45	4.62	7.35	14.35	1.12	2.03	2.37
CEC	15.46	18.48	4.04	6.27	9.84	2.00	12.50	7.15
SEP	23.42	10.46	28.59	22.21	39.32	1.86	17.53	17.75
EFV	6.80	2.09	17.07	10.78	34.30	2.41	12.85	7.24
C			20.52					

4.5 MONTHLY AND SEASONAL CHANGES IN VEGETATION

Each microhabitat has its own peculiarities and uniqueness. Some of them are only seen with the onset of south west monsoon. The vegetation between microhabitats may vary and each microhabitat may vary in vegetation structure and composition based on seasonal changes driven by weather parameters. Some species were seen only in particular type of microhabitat for a particular period. Water availability, soil characteristics and nature of the particular type of substratum allows some plants to flourish, grow and survive in its unique microhabitats. Five sites studied were extremely different in different months (Plate 4.3 to Plate 4.7).

From December onwards drying up of the flora of Madayipara was started due to the strong winds and direct incidence of sunlight. The vegetation in December was dominated by grasses like *Arundinella leptochloa*, *Arundinella metzii* and *Ischaemum Indicum*. Other species associated were *Lepidagathis*

keralensis, *Polycarpha corymbosa* etc. Microhabitats like small ephemeral pools and ephemeral flush vegetation were absent in this dry phase. But some grasses like *Eragrostis uniolooides*, *Cyperus iria*, *Arundinella leptochloa* and *Arundinella metzii* can be seen in the place of the microhabitat ephemeral flush vegetation. Fire occurred in the month of February in the study area. Most of the place was affected by fire and the vegetation was completely burned in some microhabitats. The cause of the fire is unknown. It may be due to the increase in temperature because the temperature in the February month (28.79°C) is higher than that of January (26.86°C) (Table 22.) or it may be human induced by burning of debris, negligently discarded cigarettes and intentional acts of arson. Fire changed the soil properties, its chemical and mineralogical component and altered the amount of micro and macro nutrients. When fire is reintroduced, plants sometimes reappear where they have not been recorded. Fire may lead to loss of species and a change or reduction in biodiversity. Highest temperature (31.27 °C) recorded in the month of April in Madayipara. From May onwards some grass species (*Murdannia loriformis*, *Desmodium triflora*), began to flourish and the temperature was slightly lower than March (30.50°C).

After the dry phase, wet phase starts from June with the onset of Southwest monsoon. The highest amount of rainfall was recorded in the month of June (1120.86mm) Ephemeral flush vegetation and small ephemeral pools were visible in the monsoon season with high species richness. Ephemeral flush vegetation flourished with *Mimosa pudica*, *Murdannia loriformis*, *Utricularia reticulate*, *Utricularia cecili* etc. and small ephemeral pools is dominated by *Parasopubia hofmannii* var. *albiflora*, *Rotala malampuzhensis*, *Rotala malabarica* and *Utricularia reticulate*. At the same time, *Heliotropium marifolium*, *Parasopubia hofmannii* var. *albiflora*, *Phyllanthus emblica*, *Polygala elongata*, *Rhamphicarpa longiflora* etc. were seen in the microhabitat Soil Enriched Area. The land were covered with. *Utricularia* species from middle of June.

Neonotis hohenackiri, *Rotala malabarica* and *Utricularia malabarica* were flourished from July onwards followed by *Eriocaulon cuspidatum* and

Eriocaulon madayiparens. They covered most of the area dominating over *Utricularia* species and then the *Utricularia* amount decreased gradually. In August, most of the microhabitats were occupied by *Eriocaulon* species and in soil filled depression *Xyris indica* and *Rhingospora wightiana* were dominated. During September the vegetation in soil enriched area and small ephemeral pools were dominated by *Murdania semeteres*, *Alysicarpus bupleurifolius*, *Centranthera indica* and *Geisaspis cristata*.



JANUARY



FEBRUARY



MARCH



APRIL



MAY



JUNE



JULY



AUGUST



SEPTEMBER

Plate 4. 1st plot, Vegetation dynamics in EFV and SEP microhabitat (January to September)

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JANUARY



FEBRUARY



MARCH



APRIL



MAY



JUNE



JULY



AUGUST



SEPTEMBER

Plate 5. 2nd plot, Vegetation dynamics in SEA microhabitat (January to September)



JANUARY



FEBRUARY



MARCH



APRIL



MAY



JUNE



JULY



AUGUST



SEPTEMBER

Plate 6. 3rd plot, Vegetation dynamics in ERS microhabitat (January to September)



JANUARY



FEBRUARY



MARCH



APRIL



MAY



JUNE



JULY



AUGUST



SEPTEMBER

Plate 7. 4th plot, Vegetation dynamics in T microhabitat (January to September)



JANUARY



FEBRUARY



MARCH



APRIL



MAY



JUNE



JULY



AUGUST



SEPTEMBER

Plate 8. 5th plot, Vegetation dynamics in CEC, RB, RC and SFD microhabitat (January to September)

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Plate 9. Madayipara in Monsoon



A. Summer period (Dry phase)



B. Monsoon period (Wet phase)



C. Post monsoon period

Plate 10. Madayipara Laterite Hillock in different season

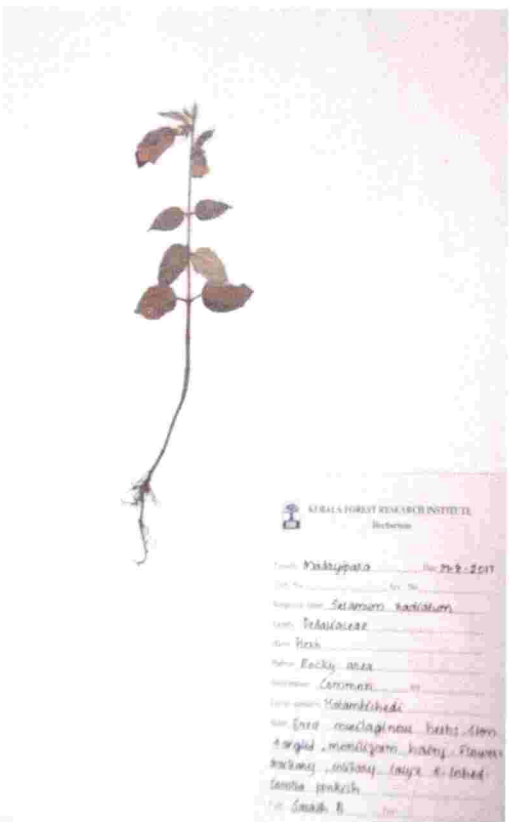
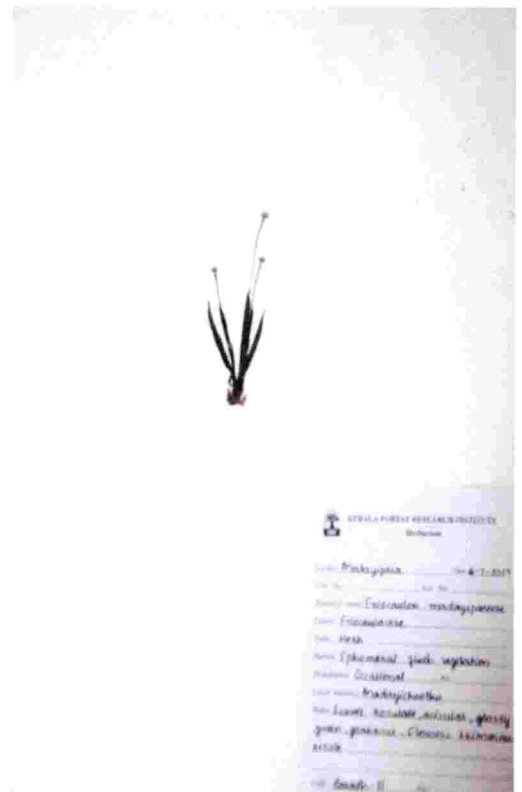
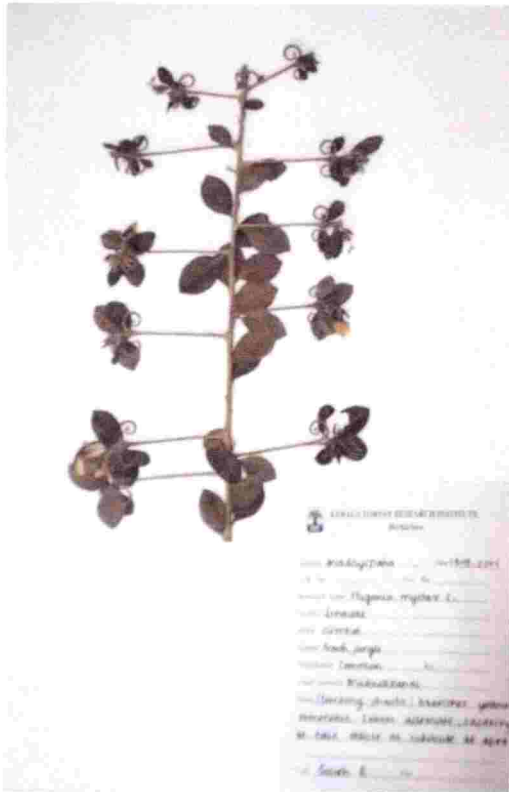


Plate 11. Herbarium collected from Madayipara



A. China clay Mining



B. Forest fire



C. Grazing

Plate 12. Threats to Madayipara

Table 4.13. Number of individuals of selected dominant Species in Each Microhabitat

Sl. No.	MICRO-HABITAT	SPECIES	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17
1	EFV	<i>Eriocaulon heterolepis</i>	0	0	0	0	0	0	0	22	19	7
		<i>Leucus aspera</i>	0	0	0	0	0	0	5	30	27	0
		<i>Eragrostis unioides</i>	59	54	0	0	0	10	14	20	12	31
		<i>Arundinella leptochloa</i>	106	110	0	0	0	0	0	0	0	0
		<i>Utricularia reticulata</i>	0	0	0	0	0	0	15	55	21	0
		<i>Utricularia cecii</i>	0	0	0	0	0	0	19	55	18	0
2	SFD	<i>Cleome viscosa</i>	0	0	0	0	0	0	33	23	22	28
		<i>Eriocaulon heterolepis</i>	0	0	0	0	0	0	6	35	56	2
		<i>Eriocaulon parviflorum</i>	0	0	0	0	0	0	4	23	23	12
		<i>Commelina diffusa</i>	0	0	0	0	0	0	47	29	37	22
		<i>Arundinella leptochloa</i>	75	76	34	0	0	0	0	0	0	0
		<i>Centotheca lappacea</i>	18	10	0	0	0	0	9	3	4	8
		<i>Brachiaria reptans</i>	82	90	0	0	0	0	4	9	11	16
3	ERS	<i>Drosera indica</i>	0	0	0	0	0	0	7	36	19	23
		<i>Eriocaulon madayiparens</i>	0	0	0	0	0	0	0	53	39	0
		<i>Lepidagathis keralensis</i>	15	21	100	100	100	0	0	0	0	0
		<i>Utricularia cecii</i>	0	0	0	0	0	0	20	52	15	0

		<i>Arundinella metzii</i>	62	62	62	0	0	0	0	0	0	0
		<i>Eragrostis unioloides</i>	143	137	119	0	0	171	133	61	74	117
		<i>Eragrostis tenuifolia</i>	64	58	59	0	0	0	0	0	0	0
4	T	<i>Bredilia retusa</i>	30	28	28	27	28	31	29	22	27	38
		<i>Chromolaena odorata</i>	44	44	44	43	46	43	46	51	48	48
		<i>Cissus repans</i>	57	53	56	53	52	48	48	21	45	43
		<i>Sida acuta</i>	34	38	34	36	34	35	34	21	13	22
		<i>Impatiens minor</i>	26	28	22	25	26	26	30	26	32	37
		<i>Passiflora foetida</i>	28	26	29	28	27	25	27	14	13	18
		<i>Polycarpha corymbosa</i>	0	0	0	0	0	0	0	22	19	0
		<i>Salmonia ciliata</i>	0	0	0	0	0	0	0	23	13	0
		<i>Spermacoce pusilla</i>	0	0	0	0	0	0	0	12	14	0
5	CEC	<i>Lepidagathis keralensis</i>	90	95	101	99	90	97	36	36	10	47
		<i>Murdannia crocea</i>	0	0	0	0	0	0	25	24	28	46
		<i>Neanotis hohenackeri</i>	0	0	0	0	0	0	43	28	37	50
		<i>Polycarpha corymbosa</i>	110	105	99	101	110	103	25	0	0	0
		<i>Neanotis rheedei</i>	0	0	0	0	0	0	30	16	23	31
6	RCF	<i>Eriocaulon heterolepis</i> Steud	0	0	0	0	0	0	0	70	78	0
		<i>Impatiens diversifolia</i>	0	0	0	0	0	0	0	13	8	103
		<i>Utricularia cecilia</i>	0	0	0	0	0	0	80	23	4	0

		<i>Impatiens minor</i>	0	0	0	0	0	0	0	2	13	97
		<i>Oldenlandia corymbosa</i> L.	0	0	0	52	54	48	0	0	0	0
		<i>Polycarpaea corymbosa</i> (L.) Lam.	0	0	0	48	46	52	0	0	0	0
7	SEP	<i>Eriocaulon madayiparense.</i>	0	0	0	0	0	0	0	27	40	0
		<i>Utricularia reticulata</i>	0	0	0	0	0	0	29	33	4	0
		<i>Rotala malampuzhensis</i>	0	0	0	0	0	0	41	58	6	0
		<i>Rotala malabarica</i>	0	0	0	0	0	0	30	54	6	0
8	B	<i>Utricularia cecilii</i>	0	0	0	0	0	0	47	44	19	0
		<i>Ariopsis peltata</i>	0	0	0	0	0	0	22	36	34	37
		<i>Impatiens diversifolia</i>	0	0	0	0	0	0	88	77	63	91
		<i>Impatiens minor</i>	0	0	0	0	0	0	43	43	62	38
		<i>Eragrostis nigra</i> Nees ex Steud.	35	40	47	35	34	0	0	0	4	7
		<i>Eragrostis unioloides</i> (Retz.) Nees ex Steud.	65	60	53	65	66	0	0	0	3	6
9	SEA	<i>Murdannia semiteres</i>	0	0	0	0	0	0	0	0	1 3	61
		<i>Parasopubia hofmannii</i> var. <i>albiflora</i>	0	0	0	0	0	0	5	26	80	13
		<i>Alysicarpus bupleurifolius</i>	0	0	0	0	0	0	0	0	5	62
		<i>Leucus aspera</i>	0	0	0	0	0	0	8	25	34	19

	<i>Heliotropium marifolium</i>	0	0	0	0	0	0	62	6	0	0
	<i>Eragrostis unioides</i>	74	72	0	0	0	24	114	69	57	38
	<i>Cyperus Iria</i>	123	123	0	0	0	51	42	30	27	16

4.6 DOMINANT SPECIES IN EACH MICROHABITAT

Species composition and their contribution varied with season. Each microhabitat was dominated by some species in a particular time period. After that, another species would replace the earlier ones. Dominant species in each microhabitat are tabulated in Table (4.13). In ephemeral flush vegetation (EFV) grass species such as *Arundinella leptochloa* and *Eragrostis unioides* were dominant in January and got drastically reduced in February due to fire occurred on the land. Then *Eragrostis unioides* got re-established on May. In June *Leucus aspera*, *Utricularia cecili* and *Utricularia reticulata*, took over and peak was observed in July. *Eriocaulon heterolepis* was observed only in July. (Fig 4.1)

In soil filled depressions (SFD) grass species were dominant in January and February months. From June onwards *Commelina diffusa*, *Cleome viscosa*, *Centotheca lappacea* started dominating. From July Eriocaulon species came up and all these ephemeral plants faded quickly by August. In exposed rock surfaces (ERS) *Drosera indica* which is an insectivorous plant was dominant in June, July and August along with *Utricularia reticulata* and *Eriocaulon madayiparens* Fig (10). In tree cover and tree associated (T) microhabitat most of the tree species were already present. But in June, July some species were added (*Impatiens minor*, *Salamonia ciliate*, *Spermacoce pusilla*). From September onwards the newly added species disappeared and this microhabitat continuous the old pattern of vegetation, it can be understood from the figure (12). In crust edges and cliffs (CEC) in dry vegetation the dominant species were *Lepidagathis keralansis* and *Polycarpaea corymbosa*. From the onset of southwest monsoon *Neanotis*

hohenackeri, *Murdannia crocea* and *Neanotis reedhei* sprouted and they gradually decreased by August-September.

In Rock crevices or fissures (RCF), *Oldenlandia corymbosa* and *Polycarpaea corymbosa* were dominant in March, April and May. Then *Utricularia cecili* was dominated in June followed by *Eriocaulon heterolepis*, *Impatiens diversifolia* and *Impatiens minor* in July. Ephemeral pools (E P) can only be seen after June. The main species that flourished in this microhabitat were *Utricularia reticulata*, *Rotala malampuzhensis* and *Rotala malabarica* followed by *Eriocaulon madayiparense*, *Eragrostis nigra* and *Eragrostis uniolooides* were the dominant species in the microhabitat Boulders (B) from December to April. *Utricularia cecili*, *Ariopsis peltata*, *Impatiens diversifolia* and *Impatiens minor* sprouted from June whereas *Eragrostis nigra* and *Eragrostis uniolooides* replaced them from the month of August. Soil enriched area is the microhabitat which had higher dominance next to Ephemeral flush vegetation (EFV). *Cyperus iria* and *Eragrostis uniolooides* were dominant in January and February. There is no vegetation from February to May due to fire and *Cyperus Iria* and *Eragrostis uniolooides* were seen to sprout from the month of May.

EPHEMERAL FLUSH VEGETATION

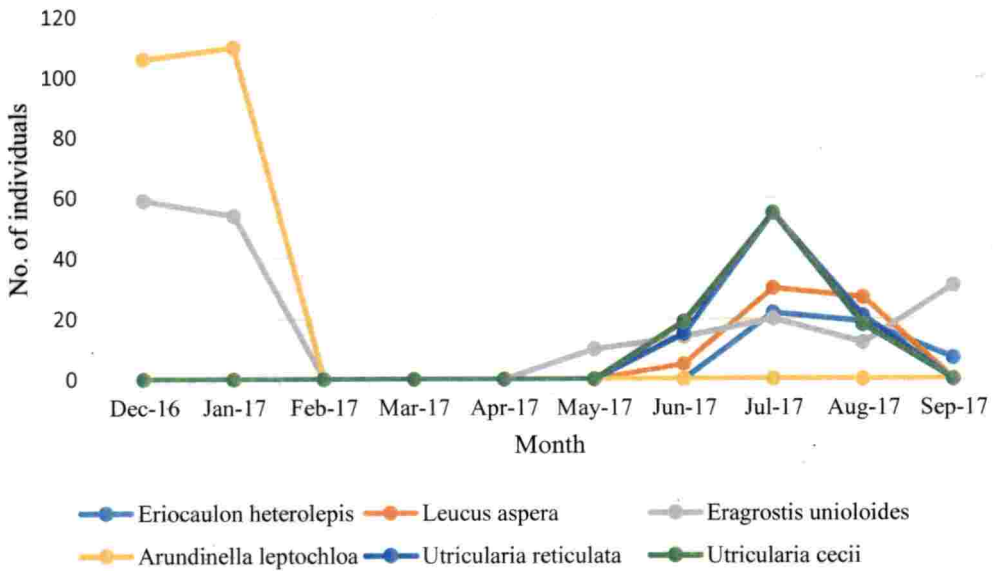


Figure 7. No. of individuals of selected dominant species on ephemeral flush vegetation at lateritic hillock of Madayipara

SOIL FILLED DEPRESSIONS

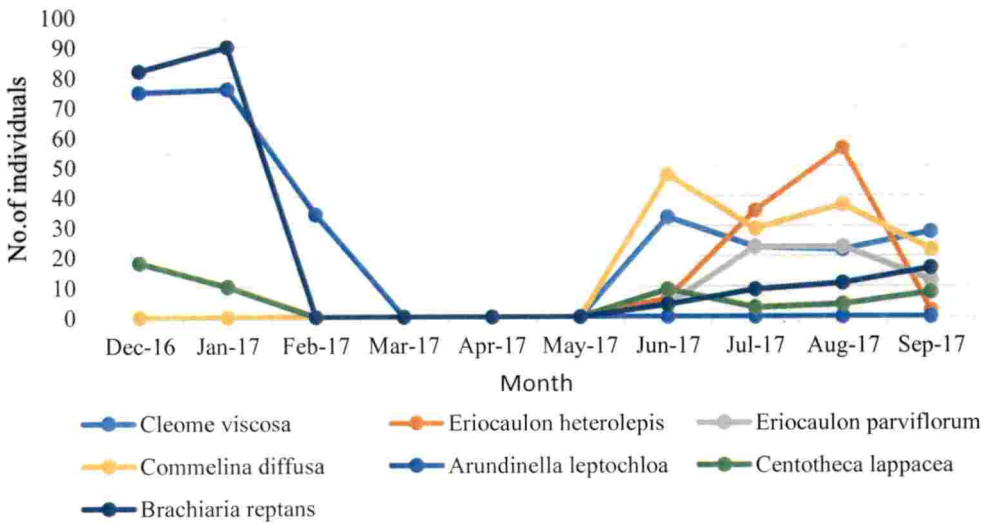


Figure 8. No. of individuals of selected dominant species on Soil filled depressions at Madayipara laterite hillock

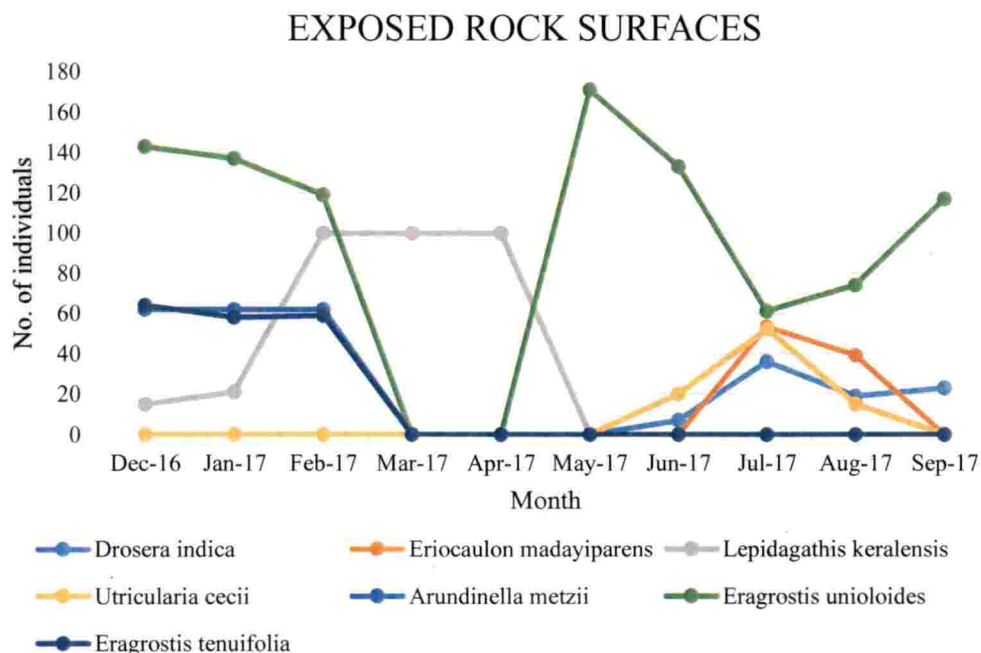


Figure 9. No. of individuals of selected dominant species on Exposed rock surfaces at lateritic hillock of Madayipara

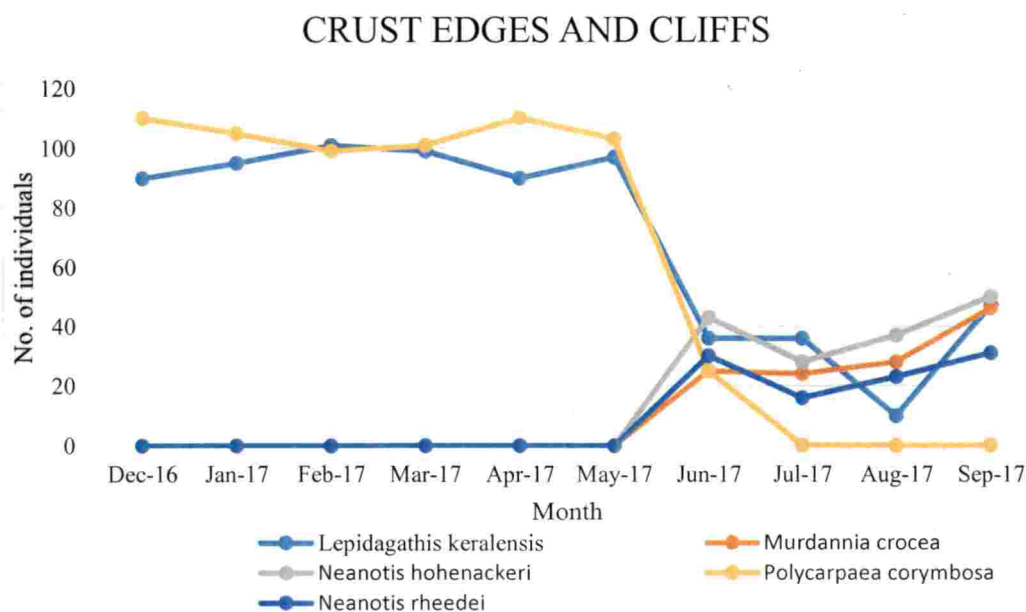


Figure 10. No. of individuals of selected dominant species on Crust edges and cliffs at laterite hillock of Madayipara

TREE COVER AND TREE ASSOCIATES

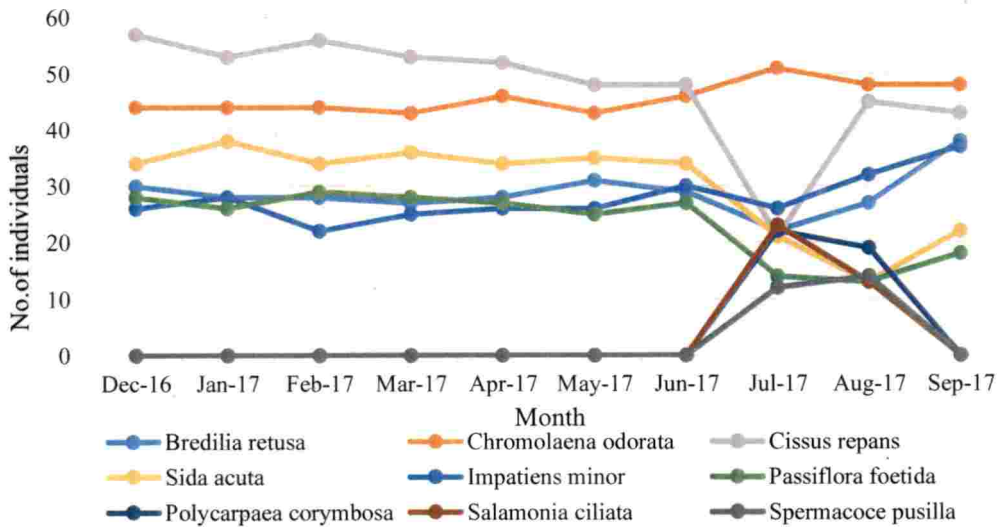


Figure 11. No. of individuals of selected dominant species on Tree cover and tree associates at lateritic hillock of Madayipara

ROCK CREVICES OR FISSURES

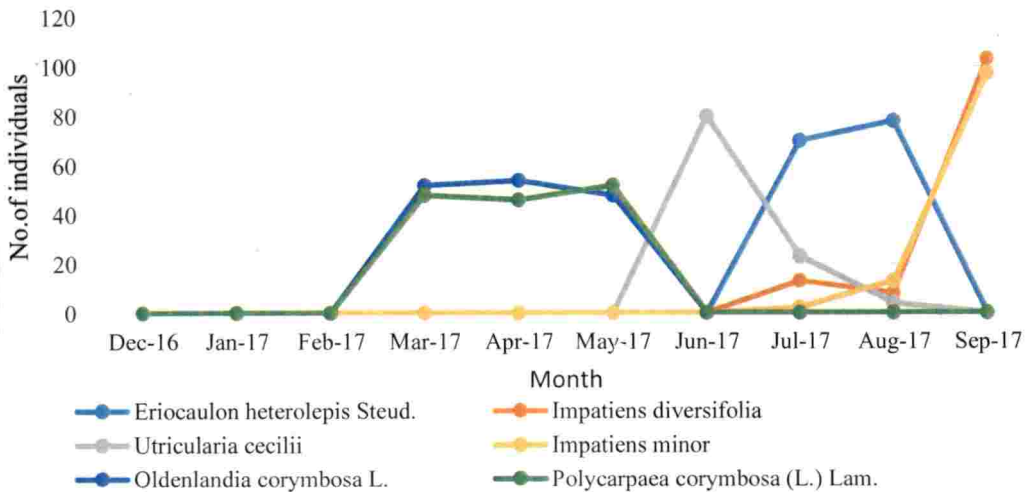


Figure 12. No. of individuals of selected dominant species on Rock crevices or fissures at lateritic hillock of Madayipara

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EPHEMERAL POOLS

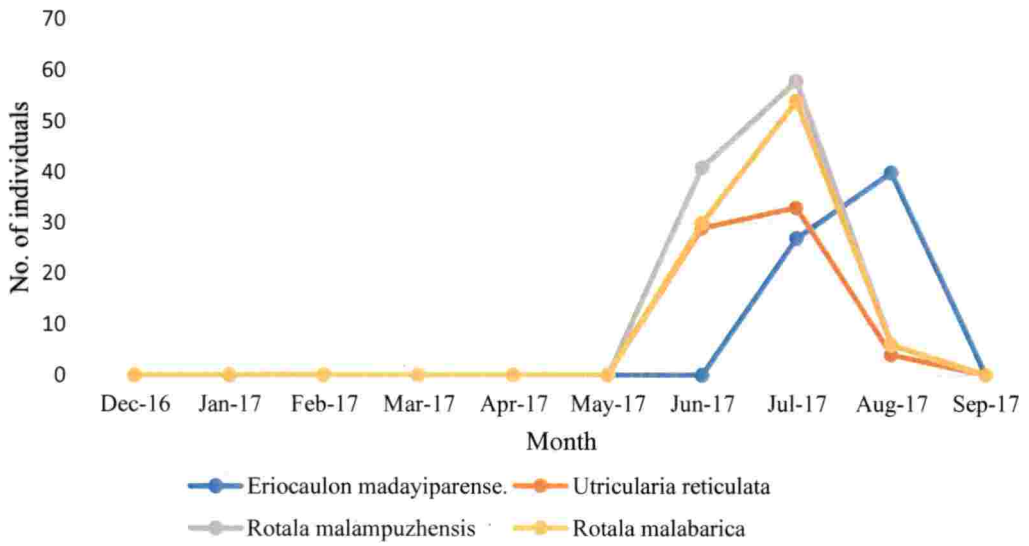


Figure 13. No. of individuals of selected dominant species on Ephemeral Pools at lateritic hillock of Madayipara

BOULDERS

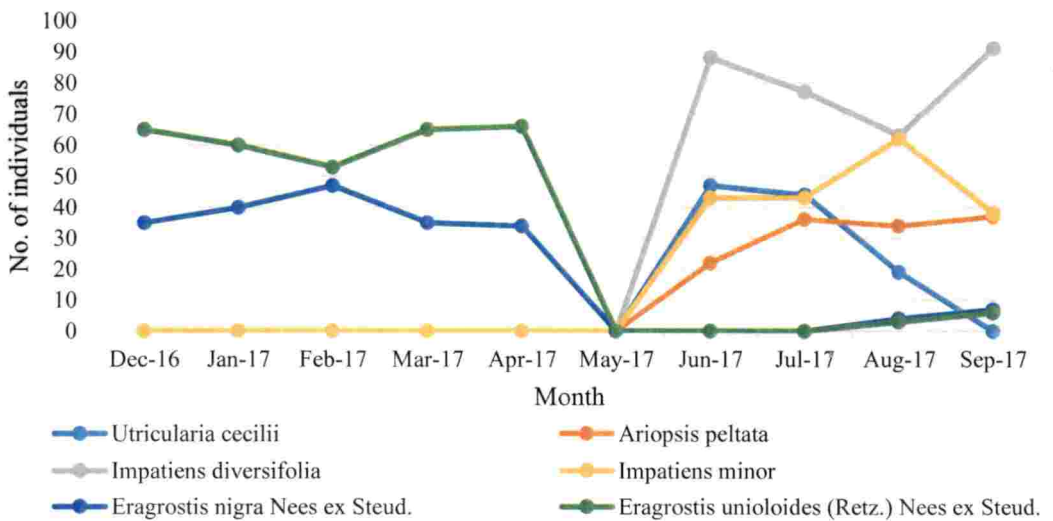


Figure 14. No. of individuals of selected dominant species on Boulders at lateritic hillock of Madayipara

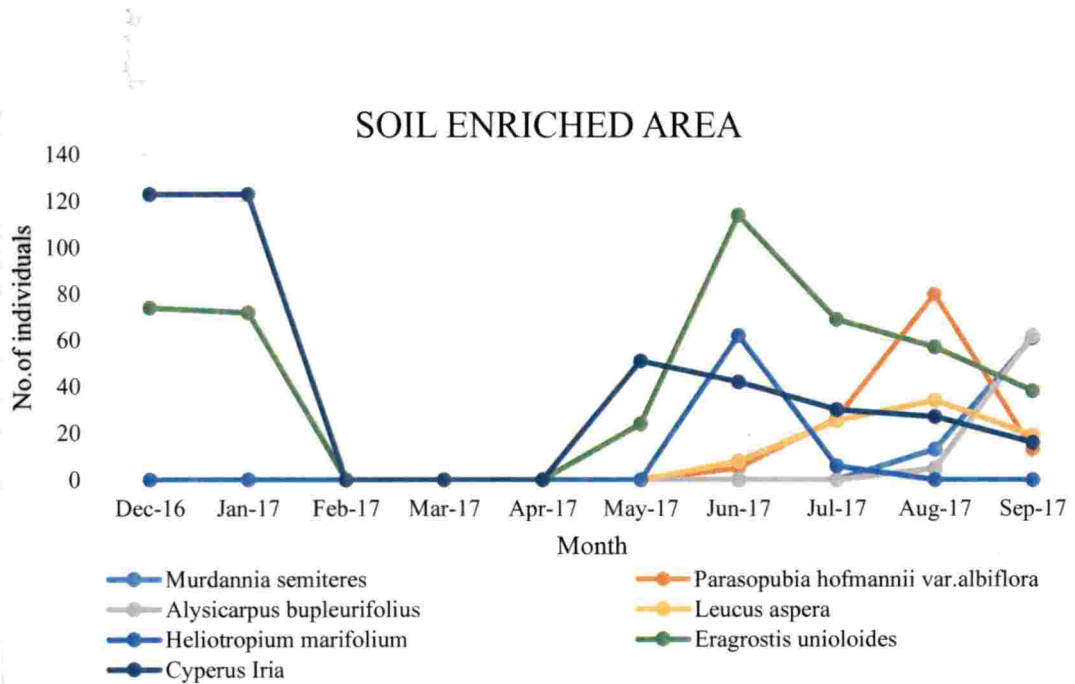


Figure 15. No. of individuals of selected dominant species on soil enriched area at lateritic hillock of Madayipara

4.7 SPECIES RICHNESS IN EACH MICROHABITAT

Among all microhabitats Ephemeral flush vegetation (EFV) had high species richness. About 37 species were present in EFV whereas only 8 species were found in Boulders (B) which had the lowest species richness (Table.4.14). Ephemeral flush vegetation adds more species in June, July and August and from September onwards the total number of species got reduced to 22 from 27 in August (Table 4.15). The least species diversity was observed in the microhabitats associated with the rock which includes CEC, RCF and RB that had only 10, 12, and 8 species respectively.

General vegetation showed a great variation especially during the monsoon months. Different plant communities successively dominated in the monsoon season. Next to EFV, microhabitats SEA, SEP, ERS, SFD and T have high species diversity of 31, 27, 24 and 21 respectively. Sixteen species were already present throughout the months in the Tree cover and tree associated

microhabitat. Addition to this five more species added in July and August whereas from September onwards the newly arrived species in monsoon started disappearing. Microhabitats EFV, SFD, SEA were affected by fire so there is no species from February to April. Maximum species diversity was seen in EFV (27 species) in August. Overall the month of August had high species diversity whereas March and April recorded the least diversity.

Table 4.14. Total species in different microhabitats at lateritic hillock of Madayipara

MICROHABITATS	EFV	SFD	ERS	T	CEC	RCF	SEP	B	SEA
NO. OF SPECIES	37	21	24	21	10	12	27	8	31

Table 4.15. Month wise Species richness in different microhabitats from December to September at lateritic hillock of Madayipara

Sl. No	MICRO-HABITAT	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17
1	EFV	6	6	0	0	0	8	17	24	27	22
2	SFD	5	5	0	0	0	0	14	18	18	11
3	ERS	9	9	6	1	1	5	14	15	17	9
4	T	16	16	16	16	16	16	16	21	21	16
5	CEC	2	2	2	2	2	2	7	9	8	6
6	RCF	0	0	0	2	2	2	3	9	8	2
7	SEP	0	0	0	0	0	4	18	23	20	8
8	RB	2	2	2	2	2	2	4	4	8	8
9	SEA	4	4	0	0	0	6	19	20	21	19
10	TOTAL	44	44	26	23	23	45	112	143	148	101

4.8 SPECIES DISTRIBUTION IN DIFFERENT MICROHABITATS

Some species were restricted to a particular habitat others were common to different microhabitats. *Desmodium triflorum*, *Eragrostis unioides* and *Eriocaulon madayiparense* were common to 4 different microhabitats. (EFV, ERS, SEP, SEA) (Table 4.16). Some conditions provided by these habitats are conducive to the growth and survival of these species. . In the microhabitat T have only 2 common species (*Rhynchospora wightiana*, *Sida acuta*). Among the four microhabitats EFV and SEA had high diversity of species indicating more favourable conditions to grow.

Table 4.16. Species distribution in different microhabitats at lateritic hillock of Madayipara

N O	SPECIES	EFV	SFD	ERS	T	CEC	RCF	SEP	B	SEA	TOTAL
1	<i>Alysicapus bupleurifolius</i>	✓						✓		✓	3
2	<i>Arundinella leptochloa</i>	✓	✓	✓							3
3	<i>Arundinella metzii</i>	✓	✓	✓							3
4	<i>Centotheca lappacea</i>		✓	✓							2
5	<i>Centranthera indica</i>	✓								✓	2
6	<i>Cleome viscosa</i>	✓	✓							✓	3
7	<i>Commelina diffusa</i>		✓			✓					2
8	<i>Cyperus Iria</i>	✓								✓	2
9	<i>Desmodium triflorum</i>	✓	✓	✓				✓		✓	5
10	<i>Digitalia sp.</i>	✓								✓	2
11	<i>Drosera indica</i>	✓		✓							2

12	<i>Eragrostis tenuifolia</i>	✓	✓	✓						3
13	<i>Eragrostis unioloides</i>	✓		✓			✓	✓	✓	5
14	<i>Eriocaulon cuspidatum</i>	✓	✓				✓			3
15	<i>Eriocaulon heterolepis</i>	✓	✓		✓	✓	✓			5
16	<i>Eriocaulon madayiparense</i>	✓		✓		✓	✓		✓	5
17	<i>Eriocaulon cuspidatum</i>	✓	✓		✓		✓			4
18	<i>Eriocaulon robustobrownianum</i>					✓	✓			2
19	<i>Geisaspis cristata</i>	✓					✓		✓	3
20	<i>Heliotropium marifolium</i>	✓	✓	✓					✓	4
21	<i>Impatiens diversifolia</i>					✓		✓		2
22	<i>Impatiens minor</i>			✓		✓		✓		3
23	<i>Ischaemum indicum</i>	✓		✓					✓	3
24	<i>Lepidagathis keralensis</i>			✓	✓					2
25	<i>Leucus aspera</i>	✓					✓		✓	3
26	<i>Lindernia hyssopioides</i>	✓					✓		✓	3
27	<i>Murdannia loriformis</i>	✓	✓				✓		✓	4
28	<i>Murdannia semiteres</i>	✓					✓		✓	3
29	<i>Neanotis hohenackeri</i>	✓			✓				✓	3
30	<i>Parasopubia hofmannii</i>						✓		✓	2

31	<i>Parasopubia hofmannii</i> <i>var. albiflora</i>	✓						✓		✓	2
32	<i>Polycarpaea corymbosa</i>					✓	✓				2
33	<i>Rhynchospora wightiana</i>	✓			✓						2
34	<i>Rotala malabarica</i>	✓						✓			2
35	<i>Sida acuta</i>	✓			✓			✓		✓	4
36	<i>Utricularia malabarica</i>	✓	✓								2
37	<i>Utricularia reticulata</i>	✓						✓		✓	3
38	<i>Utricularia ceciliae</i>					✓	✓		✓		3
39	<i>Utricularia graminifolia</i>		✓	✓			✓				3

4.9 SORENSEN'S SIMILARITY INDEX IN DIFFERENT MICROHABITATS OF MADAYIPARA LATERITIC HILLOCK

Table 4.17. Similarity index value between microhabitats in lateritic hillock of Madayipara

Sorensen's similarity index $S=2C/(A+B)$									
Microhabitats	EF V	SF D	ER S	T	CE C	RC F	EP	B	SR A
EFV		0.28	0.38	0.07	0.09	0.12	0.47	0.09	0.50 a
SFD			0.40	0.00 b	0.26	0.24	0.25	0.14	0.15
ERS				0.13	0.18	0.28	0.20	0.13	0.18
T					0.13	0.19	0.17	0.14	0.35
CEC						0.27	0.36	0.33	0.15
RCF							0.10	0.15	0.14
EP								0.17	0.63 a
B									0.04

Note: a- microhabitats which having more than 50% similarity; b- microhabitat which are 100% dissimilar

When we analysed these communities for their similarity in species composition, the index varied from 0-0.63. A total of 36 combinations were possible when 9 communities were compared between each other for their similarity in species composition, but interestingly only 2 (SRA and EFV, SRA

and EP) found to have more than 50% similarity (Table 2) which clearly indicates the diversity of habitats within the lateritic hillock. On the other hand, 1 microhabitat found 100% dissimilar (Table 22). This diversity in habitats and seasonality supports unique plant community in each habitat which further supports associated faunal elements and responsible for the high species diversity of the lateritic hills. Diversity is further supported by change in species composition and community within microhabitat due to seasonal fluctuations. Soil filled depression (SFD) and Tree cover and tree associates (T) were found to be the two communities which show more dissimilarity with other communities. This also indicates the succession pattern in the laterite hillock in which Soil filled depression (SFD) represents the pioneer community and Tree cover and tree associates (T) represent the climax community.

4.9 INFLUENCE OF WEATHER PARAMETERS ON SPECIES RICHNESS

Species richness of Madayipara was highly influenced by the weather parameters in 2013, 2015, 2017(Jan- Sept) (fig 16). Richness of species was highest during and following the monsoon season (June- December). When the weather is favourable for germination and growth of most of the species. Moisture, relative humidity and temperature were found to be optimum to sustain the species. Increase in temperature and decrease of moisture from January onwards results in the gradual disappearance of most of the susceptible species with consequent reduction in species diversity.

Drier the atmosphere, larger the driving force for water movement out of the plant, increasing rates of transpiration. A hydrated leaf would have a Relative Humidity (RH) near to saturation, just as the atmosphere on a rainy day would have. Any reduction in water in the atmosphere creates a gradient for water to move from the leaf to the atmosphere. The lower the RH, the lesser moist the atmosphere and thus, the greater the driving force for transpiration. When RH is

high, the atmosphere contains more moisture, reducing the driving force for transpiration. High humidity and rainfall with less temperature.

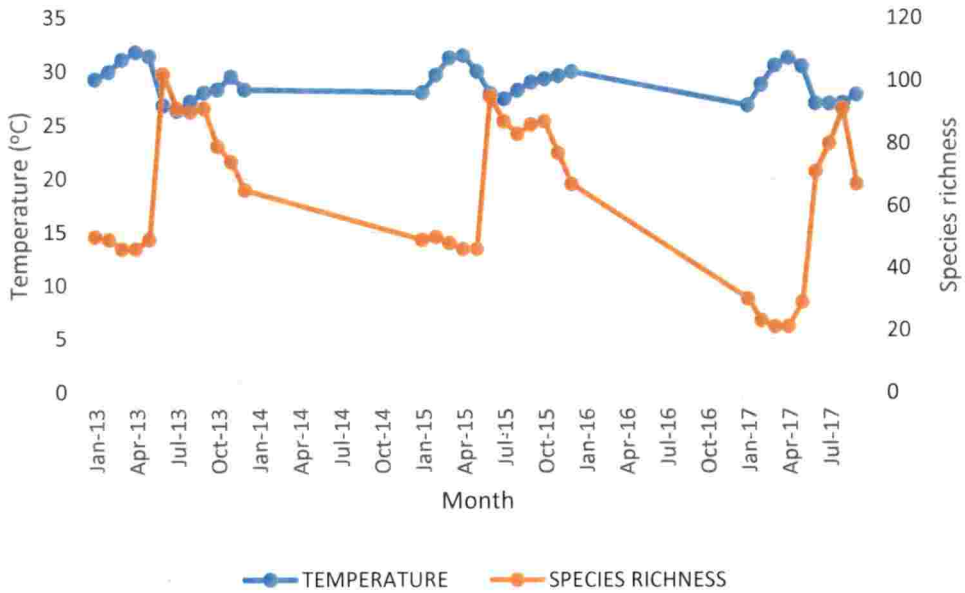


Figure 16. Temperature and species richness in 2013, 2015, 2017

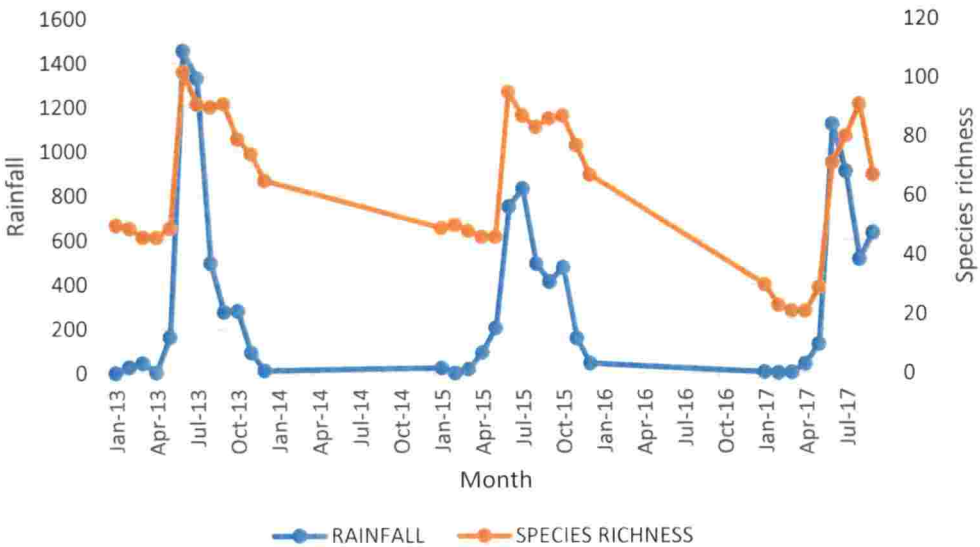


Figure 17. Rainfall and species richness in 2013, 2015, 2017

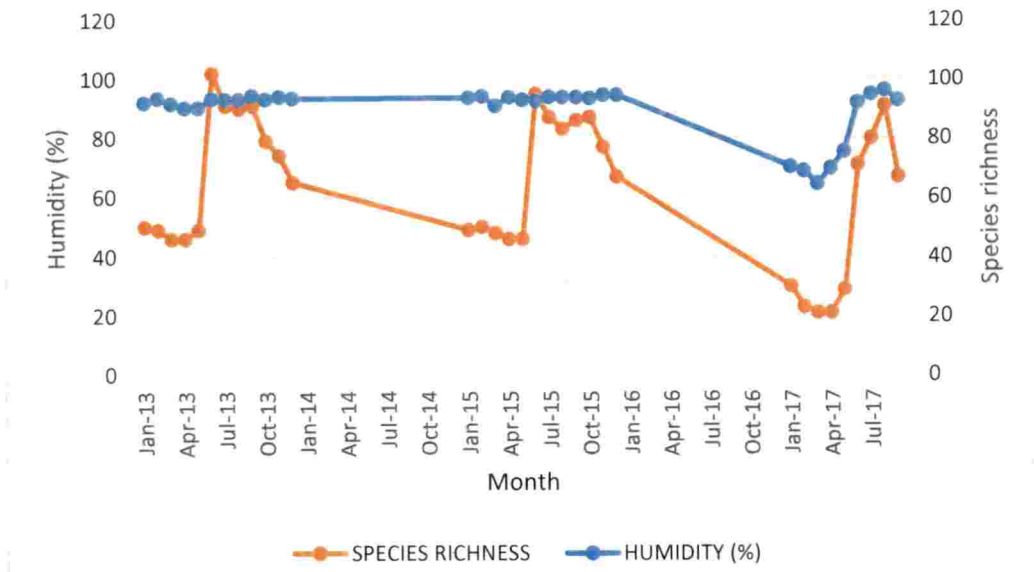


Figure 18. Humidity and species richness in 2013, 2015, 2017

Table 4.18. Monthly rainfall, temperature, humidity and species richness of Madayipara hillock in 2013, 2015, 2017

MONTH	RAINFALL	TEMPERATURE	HUMIDITY	SPECIES RICHNESS
Jan-13	0.00	29.23	92.03	50
Feb-13	27.00	29.93	93.53	49
Mar-13	46.10	31.06	91.70	46
Apr-13	3.40	31.80	90.30	46
May-13	162.70	31.40	90.30	49
Jun-13	1457.00	26.85	93.30	102

Jul-13	1332.00	26.35	93.09	91
Aug-13	496.30	27.20	93.10	90
Sep-13	277.60	28.05	94.47	91
Oct-13	281.50	28.31	93.29	79
Nov-13	93.80	29.50	94.10	74
Dec-13	11.60	28.32	93.55	65
Jan-15	23.80	28.03	93.71	49
Feb-15	0.00	29.67	94.18	50
Mar-15	17.60	31.28	90.97	48
Apr-15	94.00	31.50	93.87	46
May-15	205.70	30.03	92.97	46
Jun-15	749.30	27.94	92.67	95
Jul-15	830.40	27.47	93.97	87
Aug-15	493.70	28.24	93.87	83
Sep-15	412.00	29.01	93.87	86
Oct-15	477.10	29.31	93.61	87
Nov-15	158.00	29.61	94.67	77
Dec-15	44.80	29.99	94.68	67
Jan-17	4.50	26.86	70.35	30
Feb-17	0.00	28.79	68.95	23
Mar-17	3.20	30.55	64.53	21
Apr-17	41.50	31.27	69.75	21

May-17	131.50	30.50	75.48	29
Jun-17	1120.86	27.04	92.04	71
Jul-17	907.37	27.03	94.85	80
Aug-17	512.80	27.08	96.33	91
Sep-17	631.90	27.87	92.78	67

4.9 CORRELATION OF SPECIES RICHNESS WITH WEATHER PARAMETERS DURING 2013, 2015 AND 2017

Species diversity was correlated with rainfall, temperature and humidity parameters by pooling the data of 2013, 2015 and 2017. The correlation coefficients of species diversity with rainfall, temperature and humidity were high, indicating that species diversity had good positive correlation with rainfall and humidity. Temperature was negatively correlated with species richness because many species dry up as temperature increases during summer period.

Duan (2016), reported that the natural vegetation presents an increasing trend with the increase of rainfall. He has observed that the annual variation in vegetation coverage of the basin reached the peak in July of every year, whereas the peak in the desert was in May or June; ephemeral plants clearly flourished during this phase. The present study also is in agreement with the above observation in case of vegetation coverage.

According to Vidiella (1999), during the dry period the ephemeral species remain dormant in the soil as seeds and bulbs, respectively, and therefore are undetectable until their emergence after the rain. Since all species became established during the first month of sampling, the increase in plant cover observed in the first eight weeks of the study was a consequence of further growth and recruitment of species of annuals and geophytes already established, rather than the addition of new species to the plots.

It has been extensively reported that temperature, as an important metric of climate change, is significantly regulated by vegetation variations at the regional scale. The results demonstrate that vegetation growth in June across the Northeast China Plain may cool the daytime temperatures and warm the night time temperatures. On the other hand, the enhanced canopy transpiration may provide much more moisture to the atmosphere. The increased atmospheric vapour would intensify the atmospheric downward longwave radiation and retain more energy at low levels of the atmosphere. (Li, 2017)

Moreover, the results also indicate that both effects are likely related to the evapotranspiration due to vegetation growth. By enhancing the canopy transpiration rate, vegetation growth may intensify the latent heat and exhibit a cooling effect during the daytime, which is consistent with the findings of Zhang *et al.* (2013). In a recent comprehensive analysis of the depletion of rainfall in Western Australia, Andrich and Imberger (2013) state that the reduction of native vegetation from 60% to 30% of the land area in the wheat belt, between 1950 and 1970, coincided with an average 21% reduction in inland rainfall relative to coastal rainfall.

Water is required by all living organisms. Brown (1995) reported that the availability of water was the most important environmental factor limiting growth and survival of range plants. He observed that water deficit develops in plant tissue when rate of transpiration exceeded that of water absorption. As the result shows a strong negative correlation with temperature, it indicated that water deficit condition due to increase in temperature suppresses some plants and so the vegetation in the month of February, March, April were scarce. After the cessation of the rain, the short duration plants vanished due to the unavailability of water to survive. Seasonal vegetation is higher in this region. Short duration plants, ephemeral plants with shallow depth are seen since the onset of the southwest monsoon, since temperature is comparatively low and moisture content in the atmosphere is high. This favourable condition enhances the flourishing of short duration plants. Hence heavy rainfall coupled with high humidity results in high

moisture content in the atmosphere which enhances the vegetation and high temperature coupled with low humidity reduces the vegetation.

4.9.1 STATISTICAL ANALYSIS OF SPECIES RICHNESS WITH WEATHER PARAMETERS

The correlation study showed that the species richness is directly related to rainfall and humidity where as it was inversely with temperature. The correlations are highly significant also. In this circumstance, the regression analysis was done to make a model for prediction of richness based on various climatic conditions. Correlations were worked out with data and based on it some regression equations were developed for prediction purposes.

The model $\text{Richness} = 1.997782 * \text{Humidity} - 116.035$ is found good for prediction of richness based on humidity at Madayipara. Since the F in ANOVA is significant, the model is good. Also the variable humidity is significant in the regression with high precision. R square value 0.532354 shows that the 53.235% variation in the data can be explained by humidity itself. (Table 4.18)

Incorporating the variable Rainfall to this model a much better regression equation is obtained. The new model is having an R² of 0.7747, indicating 77.47% variation in the data can be explained by humidity and rainfall. The model is written as

$$\text{Richness} = 0.030465 * \text{Rainfall in mm} + 1.528949 * \text{Humidity} - 84.$$

Both the variables are significant in the regression with high precision. (Table 4.19)

By introducing Temperature, a much better regression equation with an R² of 0.81355, were obtained and it indicate 81.355% variation in the data can be explained by humidity, rainfall and temperature. The final model is written as

$$\text{Richness} = 1.537386 * \text{Humidity} + 0.019341 * \text{Rainfall} - 4.08193 * \text{Temperature} + 37.18196$$

All the variables are significant in the regression with high precision (Table 4.20).

Table 4.19 statistical analysis of humidity with species richness

R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	Sig. F Change
0.72962596	0.5323	0.51726	16.63667	0.532354	35.2894	0.00
	Unstandardized Coefficients			Standardized Coefficients	T	Sig.
			Std. Error	Beta		
(Constant)		-116.035	30.31243		-3.82797	0.000588
HUMIDITY		1.997782	0.336299	0.729626	5.940494	0.0000
	Sum of Squares		df	Mean Square	F	Sig.
Regression	9767.374		1	9767.374	35.2894	0.000
Residual	8580.141		31	276.7787		
Total	18347.52		32			

Table 4.20 statistical analysis of humidity and rainfall with species richness

R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics	F Change	Sig. F Change
0.88017515	0.7747	0.759689	11.73818	0.242354	32.272	0.00
	Unstandardized Coefficients			Standardized Coefficients	T	Sig.
(Constant)		-84.1701	22.1105		-3.8067	0.00064
HUMIDITY		1.528949	0.25122	0.5584	6.0860	0.0000
RAINFALL		0.030465	0.00536	0.521222	5.6808	0.0000
Regression		14213.97	2	7106.986	51.580	0.0000
Residual		4133.543	30	137.7848		
Total		18347.52	32			

Table 4.21 statistical analysis of humidity, rainfall and temperature with species richness

R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics	F Change	Sig. F Change
0.90197118	0.813552	0.794264	10.86097	0.038844	6.041728	0.02
	Unstandardized Coefficients			Standardized Coefficients	T	Sig.
(Constant)	37.18196	53.44131			0.695753	0.4921
HUMIDITY	1.537386	0.232473	0.561481	6.613178	0.0000	
RAINFALL	0.019341	0.006716	0.330909	2.87999	0.0074	
TEMPERATURE	-4.08193	1.660676	-0.27329	-2.45799	0.0202	
Regression	14926.66	3	4975.553	42.17979	0.0000	
Residual	3420.857	29	117.9606			
Total	18347.52	32				

CHAPTER 5

SUMMARY AND CONCLUSION

Madayipara, like other lateritic plateaus of Northern Kerala, is rich in plant diversity. The flora of the plateau comprises mainly of ephemeral and seasonal herbaceous vegetation. The diversity and dynamics of vegetation associated with Madayipara has been least documented by botanists and the ecosystem characteristics highly neglected by conservationists. High rainfall and humidity results in high moisture content in the atmosphere enhancing the vegetation and high temperature with less rainfall and humidity result in low moisture content which results in decline of the vegetation.

In this study, a total of 100 angiosperm species were recorded which were distributed in 9 microhabitats. The vegetation between microhabitats may vary and each microhabitat may vary in vegetation structure and composition based on seasonal changes driven by weather parameter. The vegetation in December was dominated by grasses like *Arundinella leptochloa*, *Arundinella metzii* and *Ischaemum indicum*. From May onwards some grass species (*Murdannia loriformis*, *Desmodium triflora*), began to flourish and the temperature was slightly lower than March (30.5°C). After the dry phase, wet phase starts from June with the onset of Southwest monsoon. The highest amount of rainfall was recorded in the month of June (1120.86mm). Ephemeral flush vegetation and small ephemeral pools were visible in the monsoon season with high species richness. Ephemeral flush vegetation flourished with *Mimosa pudica*, *Murdannia loriformis*, *Utricularia reticulate*, *Utricularia cecili* etc. and small ephemeral pools were dominated by *Parasopubia hofmannii* var. *albiflora*, *Rotala malampuzhensis*, *Rotala malabarica* and *Utricularia reticulate*. The land was covered with *Utricularia* species from middle of June. *Neonotis hohenackiri*, *Rotala malabarica* and *Utricularia malabarica* flourished from July onwards followed by *Eriocaulon cuspidatum* and *Eriocaulon madayiparens*. They covered most of the area dominating over *Utricularia* species and then the *Utricularia* species decreased gradually. In August, most of the microhabitats were occupied by *Eriocaulon*

species and in soil filled depression *Xyris indica* and *Rhingospora wightiana* dominated. During September the vegetation in soil enriched area and small ephemeral pools were dominated by *Murdania semeteres* and *Alysicarpus bupleurifolius*. Four new species that were absent in 2013 and 2015 were found in different microhabitats. *Cissus repans* and *Ziziphus nummularia* were found in the microhabitat T. *Cyperus iria* was found in SRA and EFV whereas *Xyris indica* was found in SFD.

Among all microhabitats Ephemeral flush vegetation (EFV) had high species richness. About 37 species were present in EFV whereas only 8 species were found in Boulders (B) which had the lowest species richness. The least species diversity was observed in the microhabitats associated with the rock which includes CEC, RCF and RB that had only 10, 12, and 8 species respectively.

Soil organic carbon content in February was least in all microhabitats because of burning on land that cause conversion of biomass into char. This leads to increase in inert carbon content and decrease in organic carbon content. T, SEP microhabitats were having high water holding capacity because their textures were sandy clay loam and sandy clay. Clay soils are having more micropores so their water holding capacity is very high. Nitrogen, Phosphorus, Potassium, Calcium and Magnesium content in the soil were highest during February and then during June. Higher nutrient content in the month of February is due to the burning of land and in June is due to the availability of rain and new species that emerged during the month. The sulphur content was lower in the month of February because of burning of land that reduces the sulphur content in the soil. Nitrogen, Potassium, Calcium and Magnesium content were lowest in August due to decrease in rainfall and nutrient consumption by the plants.

The natural ecosystems and human livelihoods of the Madayipara laterite hillock are highly dependent on the monsoon (June- Sept) rainfall and even the slightest vagaries can trigger a change in the ecosystem. The global climate change scenario has its toll in the monsoonal system. Uncertainties in rainfall has been a major issue and studies have shown that there has been a decrease in the summer

monsoon rainfall (Ghosh *et al.*, 2009) and an increase in hot days with subsequent decrease in cold nights over the region for the period from 1971 to 2005. Krishnakumar *et al* (2009) has reported that monsoon rainfall over Kerala during the 20th century has been declining. He has further reported that the contribution of June-July rainfall to monsoon rainfall is declining while the contribution of August-September showed an increasing trend. A cyclic trend of 40-50 years is noticed in annual rainfall of Kerala with significant decline in recent decades. The moisture index across the state of Kerala was moving from B4 to B3 humid, indicating that the State was moving from wetness to dryness within the humid climate (Gopakumar, 2011). The study upon generalization reveals that high rainfall, high humidity and low temperature enhances the vegetation. In future, increase in temperature and decrease in rainfall will adversely affect the flora of Madayipara and subsequently the fauna depending on the habitat of Madayipara. In latest study Gopakumar (2017) has reported that the average temperature of the state of Kerala has increased by 0.65°C during the period 1956-2014. An increase of 0.99°C was observed in the case of day temperature while the increase of night temperature was only 0.31°C during the same period. When the same pattern repeat in future it will adversely affect the flora of Madayipara.

The lack of awareness on the conservation value of these habitats leads to varied types of anthropogenic disturbances like brick and clay mining, road and building construction, land filling, seasonal fire etc. together with biotic pressures like invasion of exotic weeds (Plate. 14). All these factors cause serious threat to the rich flora and fauna of these habitats and hence demands urgent attention from the part of policy / decision makers. Being the type locality of nine angiosperm taxa, of which three are named after Madayipara, in-situ conservation of the entire habitat is the only solution since ex-situ conservation measures cannot provide complex microclimatic requirements artificially. Geologically and ecologically important midland lateritic hillocks of Northern Kerala are slowly vanishing as the soil and rock are enormously scrapped off to meet the demand of land developers. The rich biodiversity together with the threats associated with the area reiterates the need for conserving the area on a war foot basis.

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ABSTRACT

Madayipara Laterite hills in Kannur District is a biodiversity rich area. The geographical and climatical features make Madayipara and the adjacent laterite hillock system support a unique assemblage of species. It is the home of unique and sparsely distributed endemic plants such as *Nymphoides krishnakesara*, *Rotala malabarica*, *Justicia ekakusuma*, *Lepidagathis keralensis* etc. In this study nine different microhabitats were identified and the species composition noted each month. A total of 52 plots of 5x5m were taken in 5 regions of Madayipara. Soil samples were collected from 9 different microhabitats in the study site for soil analysis. Daily weather parameters like temperature and humidity were recorded using hygrometer whereas rainfall data was obtained from rain gauge installed at the site.

In this study, a total of 100 angiosperm species were recorded which were distributed in 9 microhabitats. The vegetation in December was dominated by grasses like *Arundinella leptochloa*, *Arundinella metzii* and *Ischaemum indicum*. From May onwards some grass species (*Murdannia loriformis*, *Desmodium triflora*), began to flourish and the temperature was slightly lower than March (30.5°C). After the dry phase, wet phase starts from June with the onset of Southwest monsoon. Ephemeral flush vegetation and small ephemeral pools were visible in the monsoon season with high species richness. Ephemeral flush vegetation flourished with *Murdannia loriformis*, *Utricularia reticulate*, *Utricularia cecili* etc. and small ephemeral pools were dominated by *Parasopubia hofmannii* var. *albiflora*, *Rotala malampuzhensis*, *Rotala malabarica* and *Utricularia reticulate*. *Neonotis hohenackiri*, *Rotala malabarica* and *Utricularia malabarica* flourished from July onwards followed by Eriocaulon species. In August, most of the microhabitats were occupied by Eriocaulon species. During September the vegetation in soil enriched area and small ephemeral pools were dominated by *Murdannia semeteres* and *Alysicarpus bupleurifolius*.

Among all microhabitats Ephemeral flush vegetation (EFV) had high species richness. About 37 species were present in EFV whereas only 8 species

were found in Boulders (B) which had the lowest species richness. The least species diversity was observed in the microhabitats associated with the rock which includes CEC, RCF and RB that had only 10, 12, and 8 species respectively. Only 2 (SRA and EFV, SRA and EP) of them out of 36 combinations were found to have more than 50% similarity (Table 2) which clearly indicates the diversity of habitats within the lateritic hillock. On the other hand, 1 microhabitat was found to be 100% dissimilar.

Nitrogen, Phosphorus, Potassium, Calcium and Magnesium content in the soil were highest during February and then during June. Available nitrogen is lowest in the month of August. Crust edges or Cliffs show low nitrogen content during August (44.78ppm) because of decrease in the amount of rain and vegetation. Tree cover and tree associated microhabitats had low phosphorus content of 1.16ppm during February. Among the microhabitats, soil enriched area had the least K content and rock crevices had the highest K content. Rock crevices had a K content of 145.14 ppm during February. Higher nutrient content in the month of February is due to the burning of land and in June it is due to the availability of rain and new species that emerge during the month. The sulphur content was lower in the month of February because the burning of land reduces the sulphur content in the soil. Nitrogen, Potassium, Calcium and Magnesium content were lowest during August due to the decrease in rainfall and the nutrients being used up by the plants.

Heavy rainfall coupled with high humidity results in high moisture content in the atmosphere which enhances the vegetation and high temperature coupled with low humidity reduces the vegetation. The correlation study showed that the species richness is directly related to rainfall and humidity where as it was inversely related with temperature. The correlations were highly significant. In this circumstance, the regression analysis was done to make a model for prediction of richness based on various climatic conditions.

Richness = 1.537386 * Humidity + 0.019341 * Rainfall -4.08193 * Temperature + 37.18196.

All the variables were significant in the regression with high precision.

In a recent study, Gopakumar (2017) has reported that the average temperature of the state of Kerala has increased by 0.65°C during the period 1956-2014. In future, Kerala will experience unprecedented warming due to natural and anthropogenic reasons. In Madayipara, increase in temperature will adversely affect the vegetation and may result in decrease in the number of species thus affecting the biodiversity. Anthropogenic disturbances like brick and clay mining, road and building construction, land filling, seasonal fire etc. together with biotic pressures like invasion of exotic weeds cause serious threat to Madayipara. Conservation and protection of the biodiversity of Madayipara deserves urgent attention.

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