# The Western Ghats

Deepa P. and Surya E.V.

# The Western Ghats

Deepa P. and Surya E.V.

Post Graduate Department of Botany
Korambayil Ahamed Haji Memorial Unity Women's College,
Manjeri, Narukara (PO), PIN: 676122, Malappuram (DT),
Kerala, India.

Edited by:

**Deepa P.**
Assistant Professor (Ad-hoc)
Post Graduate Department of Botany
Korambayil Ahamed Haji Memorial Unity Women's College,
Manjeri, Narukara (PO),
PIN: 676122, Malappuram (DT), Kerala, India.
Email: deepapsaj@gmail.com

**Surya E.V.**
Assistant Professor (Ad-hoc)
Post Graduate Department of Botany
Korambayil Ahamed Haji Memorial Unity Women's College,
Manjeri, Narukara (PO),
PIN: 676122, Malappuram (DT), Kerala, India.
Email: suryaev7@gmail.com



First Edition: March 2024

ISBN: 978-93-340-7821-3

Published by:

**Deepa P.**
Assistant Professor (Ad-hoc)
Post Graduate Department of Botany
Korambayil Ahamed Haji Memorial Unity Women's College,
Manjeri, Narukara (PO),
PIN: 676122, Malappuram (DT), Kerala, India.

**Surya E.V.**
Assistant Professor (Ad-hoc)
Post Graduate Department of Botany
Korambayil Ahamed Haji Memorial Unity Women's College,
Manjeri, Narukara (PO),
PIN: 676122, Malappuram (DT), Kerala, India.

Price: ₹750/-
Date of publication: March 2024
Printed at: Right Click, Manjeri, Malappuram (DT), Kerala, India.

# CONTENTS

# The Western Ghats: A closer look

Muhsina K. K.
Department of Botany, HM College of Science and Technology, Manjeri, Malappuram, Kerala, India, 676122
Corresponding author: muhsinahabeeb25@gmail.com

Western Ghats, being one of the global hotspots of biodiversity, supports an enormous flora along with fauna. Western Ghats or Sahyadris form a chain of mountains parallel to west coast almost stretching from Tapti River in the north to Kanyakumari in the south, covering a total area of about 160,000 $km^2$. It lies between 220 N to 80 N and covering western border of the states of south Gujarat, Maharashtra, Karnataka, Tamil Nadu and Kerala. Biogeographically, the Ghats subdivided in to 2 latitudinal regions which covers National Parks, Biosphere Reserves, Wildlife Sanctuary with rich flora and fauna including endemic species.

**Keywords:** Western Ghats, Biodiversity, Flora, Endangered, Hotspots

## 1. Introduction

The Western Ghats, also known as Sahyadri_Hills, are well known for their rich and unique assemblage of flora and fauna. It is sometimes called the Great Escarpment of India. It is a chain of mountains running parallel to India's western coast, approximately 30-50 km inland, the Ghats traverse the States of Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra and Gujarat. These mountains cover an area of around 160,000 km² in a 1,600 km long stretch that is interrupted only by the 30 km Palghat Gap at around 11°N. It is estimated that two-thirds of India's endemic plants are found here.

The total area of the Western Ghats zone is about 160,000 sq. km of which forests constitute roughly one-third. Of this, the evergreen forests of principal conservation interest cover some 15,000 sq. km or 9% of the zone. The forest zone stretches from the hills south of the Tapti River in the North to Kanyakumari in the South. The coast is lying parallel in the West. Just like biological diversity, the zone has great physical diversity too. Elevation ranges from 500 m to 2700 m from sea level. There are areas that receive 5000 mm rainfall per annum as well as areas with much less rainfall, as low as 600 mm per annum with prolonged dry seasons. This gradient produces a change from evergreen to semi-evergreen and moist deciduous to dry deciduous formations. The altitude imposes additional factors of cold and exposure, leading to the development of stunted montane communities. There are major biogeographic barriers or forest gaps such as the Moyar Gorge, Palghat Gap and Shenkottah Gap, which separate the Nilgiri, Anamalai and Agastyamalai mountain blocks.

As one of the world's hottest biodiversity hotspots and a UNESCO World Heritage Site, the Western Ghats is on the conservation watch-list for being a rich but highly vulnerable region in urgent need of biodiversity conservation efforts. Despite the negative effects of human activity and climate change, new species continue to be added to the endemic list of species that are recorded here including 16 birds, 124 reptiles, 159 amphibians, 16 mammals, 189 fishes, 69 odonates, 36 butterflies, and 1,600 flowering plants.

## 2. Plant diversity

The Western Ghats is very rich in its floristic diversity. Nearly 5800 species of flowering plants occur here of which 56 genera and 2100 species are endemic. Karnataka alone harbours 3900 species belonging to 1323 genera and 199 families while Nilgiris have 2611 species of flowering plants. Poaceae, Leguminosae, Orchidaceae, Acanthaceae, Euphorbiaceae, Asteraceae, Lamiaceae and Rubiaceae are the dominant angiosperm families. Unique feature of the endemic flora of Western Ghats is the prevalence of monotypic genera such as *Adenon, Calacanthus, Polyzyqus, Erinocarpus, Frerea, Gniffithella, Haplothismia, Jerdonia, Lamprochaenium, Nanothamnus, Wagatea and Willisia*. Some of the arborescent genera having maximum endemic taxa are *Memecylon* (16 sp.), *Litsea* (15 sp.). *Symplocos* (14 sp.), *Cinnamomum* (12 sp.), *Syzygium* (11 sp.), *Actinodaphne* (9 sp.), *Glochidion* (9 sp.), *Grewia* (9 sp.), *Diospyros* (8 sp.), *Dalbergia* (7 sp.), *Hopea* (6 sp.), *Drypetes* (6 sp.), *Poeciloneuron* (2 sp.), *Blepharistemma, Erinocarpus, Meteoromyrtus, Otonephelium* and *Pseudoglochidion*. The latter five genera are again monotypic. The Western Ghats region is also a rich germplasm centre of number of wild relatives of our crop plants such as the cereals and millets, legumes, tropical and sub-tropical fruits, vegetables, spices and condiments and a few others. Species of *Piper, Oryza, Myristica, Elettaria, Amomum, Zingiber, Phaseolus, Vigna, Atylosia, Cinnamomum* and *Curcuma* show great variability in southern Western Ghats. The Botanical· survey of India has listed 518 rare or endangered species, endemic in nature, for peninsular India. Most of them are in the Western Ghats. Of these, the Agastyamalai zone has 109 species; Nilgiri 93; Thirunelveli 52; and Anamalai 39 species.

## 3. Animal wealth

Very high levels of species diversity and endemism provide importance to the faunal wealth of Kerala. According to one estimate, 285 species of Vertebrate are reported to be endemic to Western Ghats, which include 12 mammals, 16 birds, 89 reptiles, 87 amphibians, and 84 fresh water fishes. Among large mammals, no species is endemic to Kerala. However, birds such as White breasted laughing thrush, Wayanad laughing thrush, White bellied short wing, Southern treepie, Rufous babbler are possible endemic birds which may slightly overlap state boundaries in the southern Western Ghats (Kerala Forest and Wildlife Departments).

The monotypic agamid genus *Dravidogecko* is reported from Anamalais only. Thirty species of lizards are reported endemic to Western Ghats which include *Calotes rouxi, Cnemaspis sisparensis, C. wynadensis* and *Chalcides pentadactylus*. Out of 57 endemic snakes in the Western Ghats, four species viz., *Boiga dightsni, Melanophidum bilineatum, Plectrurus aurenus* and *Rhinophis fergusonianus* are endemic to Kerala and adjacent forests. The southern Western Ghats have probably 40 species of endemic tree frogs. Among amphibia, *Bufonidae, Microhylidae, Ranidae, Rhacophoridae* and *Gymnophiona* are endemic genera of the Western Ghats. The notable species endemic to Kerala are *Melanobatrachus indicus, Nannobatrachus anamallaiensis*, *Nyctibatrachus major, N. phygameus, Uraeotyphlus malabaricus* and *U. menoni*. Among fish fauna, species like *Lepidopygopsus typus, Hysilobarbus kurali* have been reported to be endemic to southern Western Ghats. In a recent survey of the stream fishes in the Kerala segment of Nilgiri Biosphere Reserve 58 species with 25 species endemics to Western Ghats were reported from the streams in Wayanad. Butterflies, unlike birds are restricted in distribution and about 61 species are shared endemics between Western Ghats and Sri Lanka.

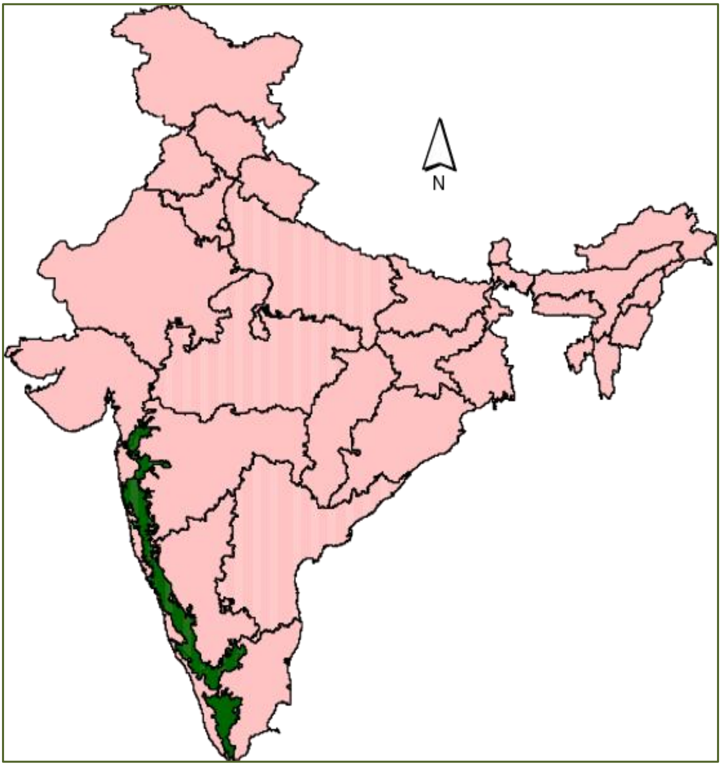


Figure 1. Western Ghats (Kumara, 2007).

## 4. Biogeographical sub-divisions of the Western Ghats

The Western Ghats can be divided into two distinct zones: Costal plains and Western Ghats mountains. The plains are a small unit, separated from the uplifted ghats in all geological and geographical classifications of India. The plains are totally deforested and have no protected areas. The Ghats are subdivided into 12 latitudinal regions as follows.

1. Dangs - Below Ghats Areas Surat and North Maharastra
2. Upper Krishna Drainage - Central and South Maharastra, Goa and North Karnataka
3. Kanara North - Central Karnataka
4. Coorg South - Central Karnataka
5. Mysore - Lower Nilgiri South Karnataka - North Tamil Nadu
6. Wayanad Plateau - North Kerala
7. Nilgiri North - Kerala and Tamil Nadu
8. Anamalai North - Central Kerala and Tamil Nadu
9. Palani - An easterly spur in Tamil Nadu
10. Periyar - Central Kerala and Tamil Nadu
11. Varushanad - Andipatty an easterly spur in Tamil Nadu
12. Agastyamalai - South Kerala and Tamil Nadu

These areas are having different communities of evergreen forests with distinctive assemblages of endemic taxa due to physical differences in geology, land form and climate. Kerala with a total area of 38,870 sq km is one of the most important forest areas of India. High rainfalls on the Ghats have blessed the state with tremendous biological values of great variety. The high levels of local endemism can be attributed to biogeographic barriers provided by the large valleys. Today Kerala has 15 protected areas totalling 2,308 sq km or 5.9% of the total land area, which is inadequate to protect the great biological wealth of the forests.

## 5. Major spots

### 5.1. Wayanad evergreen forests

It is spread across Kerala and Karnataka, floristically very rich, the tract has two small Sanctuaries: Aralam WLS with an extent of 55 sq km is in Kerala, the Brahmagiri WLS is in Karnataka. Located on the western slopes of the Ghats, Aralam is rich in wildlife. Elephant, deer, bison are common. The plant life is typical of evergreen and semi-evergreen forests of the Ghats. The altitude varies from 50m to 1145m from MSL. Temperature varies at the foothills from 21°C to 40°C whereas on the higher reaches it is between 8°C and 25°C. The average rainfall is about 300 mm. June to August are the wettest months. Adjacent to the three contiguous protected areas of Nagarhole, Bandipore and Mudumalai is the Wayanad Wildlife Sanctuary of Kerala with an extent of 144 sq km. It is also an integral part of the Nilgiri Biosphere Reserve which was established for the conservation of the biological diversity of the region. There is a large elephant population. In addition, there are different kinds of deer, monkeys and birds. Tree species and plants common to South Indian moist deciduous forests and west coast semi-evergreen forests are seen. Altitude varies from 650 m to 1150 m and temperature varies from 13°C to 32°C. Average rainfall is 2000 mm.

## 5.2. Upper Nilgiri

The Nilgiri plateau and its western slopes contain some of the finest forest wildlife habitats in India, hosting two small, partially adjacent protected areas: the Silent Valley National Park in Kerala and the Nilgiri Tahr Wildlife Sanctuary in Tamil Nadu. The Silent Valley National Park, covering 89 sq km, is the core of the Nilgiri Biosphere Reserve and boasts a long unbroken ecological history. The forests in this area belong to the biogeographical class of the Malabar Rain Forests, a relic of the ancient India-Malayan continuum, and harbor a thousand species of plants. The valley supports a diverse array of peninsular mammals, as well as numerous species of birds, butterflies, and moths. The Nilgiri Tahr Wildlife Sanctuary, while not detailed here, is known for its population of the Nilgiri Tahr, an endangered mountain goat endemic to the region. Both protected areas are crucial for biodiversity conservation and maintaining the ecological integrity of the Nilgiri Biosphere Reserve.

### 5.3 Anamalai hills

The Anamalai Hills face the Nilgiri plateau across the Palghat Gap. The topography is complex and causes a great diversity of climate and vegetation type. Anamudi (2700m) is the highest peak in the entire Western Ghats. The Palghat Gap has isolated the Anamalai Hills resulting in extensive speciation in several plant and animal groups. Elevation ranges between 150m and 2500m. Forests extending from lowland Dipterocarp communities to wet temperate shola forests to moist and dry deciduous formations contain the most varied set of habitats, and animal and plant species of any region in peninsular India. The existing Protected Area covers one National Park and four Sanctuaries in Kerala, and one large Sanctuary in Tamil Nadu. Eravikulam NP - 77 sq km, Chinnar WLS - 90 sq km, Parambikulam - 285 sq km, Peechi – Vazhani - 125 sq km, Chimmony - 90 sq km. The first three protected areas are interconnected with the Anamalai WLS in Tamil Nadu. Peechi- Vazhani WLS remains more or less buffer to the better Protected Areas. Both Chimmony and Parambikkulam WLS's a have major management problems with constant exploitation, plantation, fire, tribals and new access roads. There are of course, good quality evergreen forests in the reserve area bordering these sanctuaries. The Upper Pooyankutty forest, in the

Eravikulam-Chinnar area, comprising part of Malayattor and Anamudi RFs, is in one of the highest rainfall areas of Kerala, and has the only extensive low altitude forests (200-500 m) in the Malabar Ghats. It is the most likely place to maintain a viable Malabar civet population in Kerala. Chinnar WLS has some of the driest and steepest forest in the state, rising from 500 m to 2300 m in a few kilometers.

### 5.3. Periyar - Cardamom hills

The Periyar Tiger Reserve, covering an area of 777 sq km, is the most well-known Protected Area in Kerala. It features a core area of 350 sq km, which has the status of a National Park. Unfortunately, many of its conservation values have been threatened by the rapidly deteriorating status of forest lands on the adjacent Tamil Nadu border. The reserve contains vast tracts of Tropical Evergreen Forests (305 sq km), in addition to Semi-Evergreen Forests, Moist Deciduous Forests, and Savannah Grasslands. At higher altitudes, Montane Sub-tropical and Montane Temperate Forests are also present. The altitude in the reserve varies from 900 m to over 2000 m, and the area receives abundant rainfall, averaging 2500 mm annually. Periyar is one of India's major wildlife preserves, noted for its geomorphology, wildlife, and scenic beauty. The tract supports a variety of plant and animal species, making it a critical area for biodiversity conservation.

### 5.4. Agastyamalai hills

The Agastyamalai Hills are located at the extreme south of the Western Ghats, characterized by typical evergreen forests. These hills are separated from the northern hill forests by the Shenkottah Gap, resulting in many endemic taxa of flora and lesser fauna. There is a strong biological connection to the Sri Lankan forests, with at least 150 endemic species noted in the area. The altitude of the Agastyamalai Hills varies from 100 m to 2000 m. The region features several small wildlife sanctuaries, some of which are continuous while others are isolated. In Tamil Nadu, there are two wildlife sanctuaries, and in Kerala, there are three: Neyyar Wildlife Sanctuary (128 sq km), Peppara Wildlife Sanctuary (53 sq km) and Shenduruney Wildlife Sanctuary (100 sq km).

## 6. Conclusion

The Western Ghats is a 1,600 km mountain range along India's western coast, stretching from Maharashtra to Tamil Nadu. This UNESCO World Heritage Site is a biodiversity hotspot, home to thousands of species of flora and fauna, many of which are endemic. The range influences monsoon patterns, creating diverse climates from tropical to alpine. It hosts numerous protected areas like Periyar and Bandipur National Parks, rich in wildlife such as the Lion-tailed Macaque and Indian elephant. Despite its ecological importance, the Western Ghats face threats from deforestation, habitat fragmentation, and climate change, making conservation efforts vital for maintaining its unique ecosystems.

## References

1. Biogeographic Areas of Kerala Published by the Wildlife Wing of the Forest Department of Kerala. https://forest.kerala.gov.in › index.php › publications

 ISBN: 978-93-340-7821-3

2. Gadgil, M. (1996). Western Ghats: A Lifescape, Journal of the Indian Institute of Sciences, 76, 495-504.
3. Heydari, M., Omidipour, R., & Greenlee, J. (2020). Biodiversity, a review of the concept, measurement, opportunities, and challenges. Journal of Wildlife and Biodiversity, 4(4), 26-39.
4. Ramachandra, T. V. (2009). Sahyadri: Western ghats biodiversity information system. http://ces.iisc.ernet.in/biodiversity
5. Stephen, R., Suresh, C., & Livingstone (2015). Indian Biodiversity: Past, Present and Future. International Journal of Environment and Natural Sciences, 7, 13-28.
6. UNEP (1992). Convention on Biodiversity, Nairobi, Kenya: UNEP Environmental Laws and Institutions Programme Activity Centre. https://www.cbd.int › doc › legal › cbd-en.
7. Heywood, V. H. (1995). The Global Biodiversity Assessment. United Nations Environment Programme. Cambridge University Press, Cambridge. Pp. xi + 1140.
8. Kumara, H. N. (2007). Impact of local hunting on abundance of large mammals in three protected areas of the Western Ghats, Karnataka. Rufford Maurice Laing Foundation, UK, *48*.

 ISBN: 978-93-340-7821-3

# Conservation of medicinal plants located in Western Ghats

Sudheesha K.
PG Department of Botany, KAHM Unity Women's College, Manjeri, Malappuram, Kerala, India, 676122
Corresponding author: sudheeshasudhi212@gmail.com

Medicinal plants play a key role in the treatment of a number of diseases and source of medicines for majority of people in the developing world. The tropical regions of the world supply the bulk of current global demand for "natural medicine," albeit with increasing threat to populations in the world and its genetic diversity. India is a major centre of origin and diversity of crop and medicinal plants, and poses out 20,000 species of higher plants, one third of it being endemic and 500 species are categorized to have medicinal values. The Western Ghats is one of the major repositories of medicinal plants that harbours around 4,000 species of higher plants of which 450 species are threatened. Currently, the number of species added to the red list category in this region is increasing, and the valuable genetic resources are being lost at a rapid rate. Demand for medicinal plants is increasing that leads to unscrupulous collection from the wild and adulteration of supplies. Providing high-quality planting material for sustainable use and thereby saving the genetic diversity of plants in the wild is important. During the last 25 years of intensive research, Tropical Botanic Garden and Research Institute has developed *in vitro* protocol for rapid regeneration and establishment of about 40 medicinally important rare and threatened plants of Western Ghats.

**Key words***:* Biodiversity, Medicinal plants, Conservation, In situ conservation, Ex situ conservation

# 1. Introduction

In developing countries, where over 80% of the population relies on herbal medicine for basic health care, there is a renewed interest in plant-based drugs due to concerns about the health hazards associated with synthetic drugs. This global inclination towards herbal medicine has led to the expansion of plant-based pharmaceutical industries, particularly in India, where only a small percentage of medicinal plants are exclusively cultivated. India, positioned along the Tropic of Cancer, serves as a prominent hub for biodiversity, boasting 8% of the world's biodiversity within a mere 2.4% of its land area. Ranking 10$^{th}$ globally in plant richness and 4$^{th}$ in Asia, the country encompasses two of the planet's 25 hotspots, the Eastern Himalayas and Western Ghats. The Western Ghats, protected by the sea to the west, Vindhya and Satpura mountain ranges to the north, and the semi-arid Deccan plateau to the east, stretch over 1,600 km through Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala. This unique landscape, featuring altitudinal ranges up to 2,800 m and diverse climates and edaphic conditions, nurtures an exceptionally rich endemic flora, establishing the Western Ghats as a haven for diverse and distinctive plant species.

Medicinal plants exhibit diverse life forms, encompassing lichens, algae, ferns, herbs, shrubs, climbers and trees, spanning annuals to perennials. This botanical variety, with its intraspecific differences, represents a valuable reservoir of chemical and medicinal resources, evident in the long-standing traditions of natural drug utilization. Traditionally, the natural forests of the Western Ghats supplied nearly 500 medicinal plant species, some of which were integral to traditional and folk medicinal practices (Joy et al., 2001).

Among the plethora of species in the Western Ghats, around 50 hold significant value in folk and herbal health practices for treating various ailments (Suja, 2005). Modern medicine taps into the Western Ghat's medicinal flora, extracting phytochemicals like berberine, camptothecin, forskolin, L-dopa and reserpine from plants such as *Coscinium fenestratum*, *Nothapodytes foetida*, *Coleus forskohlii*, *Mucuna pruriens* and *Rauvolfia serpentina*. Unfortunately, comprehensive documentation and exploration of only a few higher plant species from the Western Ghats have been undertaken. Recent reports suggest that a mere 3-5% of terrestrial plants have undergone thorough investigation (Gilani, 2005).

Despite ongoing discoveries providing new drug leads, the utilization of plant-based medicines remains limited due to various factors. Challenges include the scarcity of sufficient plant material, the need for appropriate high-throughput screening bioassays, and the production of bioactive compounds in substantial quantities, as outlined by projected constraints (Ramavat et al., 2009). This underscores the imperative for extensive and intensive research on medicinal plants in general. Plant tissue culture is very useful in conserving the biodiversity of rare and endangered medicinal plant species that produce recalcitrant seeds and play a huge role mass multiplication and germplasm conservation. Also, this biotechnological approach facilitates the production of various pharmacologically valued plant products. This section is mainly focused on the micropropagation and conservation of the above mentioned highly threatened anticancer plants from the Western Ghats region of India.

## 2. Important medicinal plants in Western Ghats

### 2.1. *Acorus calamus* Linn.

*A. calamus* is one of the important herbs known for its immense medicinal potential. It is an aromatic herb with the creeping rhizome locally known by various names like Bachh and Sweet Flag, belongs to taxonomic family Acoraceae (Meena et al., 2010). It has a diverse range of pharmacological properties including the treatment of diseases like cancer, ulcer, hepatitis, spasm, schizophrenia, gout, arthritis, and anorexia (Singh et al., 2011; Ranjan et al., 2016). It is the source of innumerable phytoconstituents such as glycosides, tannins, alkaloids, saponins, flavonoids, phenols, and lectins. The essential oils obtained from this herb constitutes several volatile compounds such as calamene, calameone, calamenenol, α-pinene, β-pinene, p-cymene, camphene, eugenol, methyl eugenol, methyl isoeugenol, eugenyl acetate, isoeugenol, azulene, eugenol methyl ether, calamol, asaronaldehyde, dipentene, terpinolene, camphor, 1,8-cineole, caryophyllene, α-asarone, and β-asarone (Palani et al., 2009; Haghighi et al., 2017). Due to these biologically active phytocompounds, *A. calamus* is having a high demand, and thus over-exploited. The plant extracts have been documented to possess anticancer activity against various human carcinoma cells.

### 2.2. *Aristolochia indica* Linn.

*A. indica*, an endangered plant species with immense medicinal importance, belongs to Aristolochiaceae family. It is locally called by names, Garudakkodi, Eswaramooli, Iswaberusa and Ishrmul. It is a shrub with a long twining stem and is also known as “worm killer” because of its antihelminthic properties. This plant species is listed in a red data list of South Indian medicinal herbs. It is aromatic in nature and used to treat fever, cholera, ulcer, skin diseases, leprosy, snakebite, and cancers (Dey and De, 2011; Anilkumar et al., 2014). Some of the major phytoconstituents of *A. indica* include ishwarane, aristolochen, ishwarone, aristololactam N-β- D-glucoside, 6β-hydroxy-stigmast-4-en-3-one, 3β-hydroxy-stigmast-5-en-7-one, aristolochine alkaline, isoaristolochic acid, allantoin, pinocarvone, and α-pinene. Various solvent extracts of this plant possess antiproliferative activity against MCF-7, the human breast cancer cell line (Anilkumar et al., 2014; Subramaniyan et al., 2015). Likewise, aristolochic acid isolated from the ethanolic whole plant extract has shown to prevent oral cancer in Albino rats induced by 4-nitroquinoline 1-oxide (Mariappan, 2012).

### 2.3. *Clerodendrum serratum* (Linn.) Moon.

*C. serratum*, belonging to Verbenaceae, is commonly known as Bharangi and is found in the Western Ghats of India. The plant, valued in traditional medicine like Ayurveda, Unani, and Siddha, is known for its roots and leaves, believed to have therapeutic properties. It has been historically used to address various health issues such as typhoid, syphilis, jaundice, hypertension and cancer. Some key constituents in the plant include D-mannitol, hispidulin, cleroflavone, apigenin, scutellarein, serratagenic acid and others. Additionally, it has been traditionally employed for its anti-rheumatic, anti-asthmatic, febrifuge, encephalalgia and ophthalmic properties.

### 2.4. *Coscinium fenestratum* (Goetgh.) Colebr.

*C. fenestratum*, a dioecious woody climber from Menispermaceae, is critically endangered and listed in the red list of threatened plants in India. Despite its endangered status, it is a commercially traded medicinal herb used in over 60 ayurvedic preparations. The plant addresses various health issues like skin diseases, ulcers, inflammation, eye disorders, hypertension, diabetes, jaundice and snakebites.

The stem extract of *C. fenestratum* contains berberine, an insulin-stimulating compound with hypoglycemic effects. Additionally, the leaf extract contains ecdysterone, known for anabolic, adaptogenic, antidiabetic, hepatoprotective, antitumor and immunoprotective activities. Studies have revealed that berberine isolated from *C. fenestratum* exhibits an antiproliferative effect on lung, colorectal and acute myeloid leukemia cell lines. Moreover, the plant's crude water extract demonstrates cytotoxic effects on human metastatic squamous cell carcinoma of the pharynx, linked to the modulation of signal molecules, resulting in increased cell inhibition and apoptosis.

### 2.5. *Curculigo orchioides* Gaertn.

The endangered plant from the Hypoxidaceae, found in the Western Ghats, is a vital component in ayurvedic preparations like Kali or Shyah-Musali, known for rejuvenation. This perennial shrub has elongated, short fleshy roots and a 1 feet pulpy rhizome. Abundant in flavone glycosides, it's tubers contain curculigosaponins, curculigosides, phenyl glycosides, orcinol glycoside, corchioside A, hentriacontanol and the alkaloid lycorine. Renowned for its immunostimulatory, aphrodisiac, hepatoprotective, antioxidant, antidiabetic, and anticancer properties, this shrub plays a crucial role in Ayurvedic remedies for various ailments.

### 2.6. *Gloriosa superba* L.

*G. superba*, a perennial semi-woody herbaceous climber in Liliaceae, is employed in ayurvedic medicine for treating various ailments. It's medicinal properties of stem is due to alkaloids, primarily colchicine and gloriosine. The rhizomes and seeds contain colchicine, isoperlolyrine, tropolane alkaloids, β-sitosterol, glucoside, and 2-hydroxy 6-methoxy benzoic acid. It is traditionally used for conditions such as gout, arthritis, inflammation, rheumatism, ulcers, skin diseases, bleeding piles, leprosy, snakebites, and impotence. *G. superba* hydroalcoholic extract has exhibited anticancer activity against lung cancer cell lines.

### 2.7. *Hemidesmus indicus* R.Br. ex Schult.

*H. indicus*, also popularly known as "Anantmul," is a semierect shrub belonging to Asclepiadaceae. It is widely distributed throughout India and known as "God of Medicine" and used in a popular drug formulation of the ayurveda system of medicine to treat dysentery, diarrhea, skin diseases, syphilis, dyspepsia, leukoderma, diuresis, burning of body, chronic fever, and asthma and also acts as blood purifier. Pharmacological studies carried out with its extract and purified compounds indicated that this plant possesses antioxidant, hepatoprotective, antiulcer, antimicrobial, hypoglycemic, antihyperlipidemic, otoprotective, analgesic, anti-inflammatory, and immunomodulatory activities.

**2.8. *Leptadenia reticulata* (Retz.) Wight & Arn.**

*L. reticulata*, commonly known as Jivanti and belonging to Apocynaceae, is wide spread in tropical and subtropical regions. Unfortunately, over exploitation has led to its endangered status, prompting efforts for commercial cultivation in certain parts of India, driven by demand from pharmaceutical and nutraceutical industries. Traditionally used in ayurveda for conditions like hematopoiesis, tuberculosis, cough, emaciation, dyspnea, fever, dysentery, and cancer. The plant serves as a revitalizing and rejuvenating agent and rich in biologically active compounds such as α-amyrin, ferulic acid, diosmetin, β-sitosterol, luteolin, hentricontanol, stigmasterol, simiarenol, reticulin, and leptaculatin. The extracts are incorporated into various herbal preparations like speman, calshakti, envirocare, and chyawanprash. Notably, these extracts demonstrate effective activity against Dalton's ascites lymphoma in mice and inhibit various cancer cell lines in vitro.

**2.9. *Ophiorrhiza mungos* L.**

The endangered Mongoose plant, belonging to Rubiaceae and native to the limited regions of the Eastern and Western Ghats, is a medicinal plant of significance. Traditionally, its roots are utilized for cancer treatment and snakebite, while the root bark exhibits sedative and laxative properties. This half-woody, erect plant, reaching up to 30 cm in height, contains the cytotoxic quinoline alkaloid camptothecin (CPT), a highly valued anticancer compound.

Despite other plants like *Camptotheca acuminata* and *Nothapodytes nimmoniana* having higher CPT content, *Ophiorrhiza* species are valued for their herbaceous nature, allowing for large-scale cultivation. The plant, containing CPT and luteolin-7-O-glucoside, demonstrates potential anticancer activity, making it noteworthy in medicinal applications.

### 2.10. *Rauvolfia serpentina* L. Benth. Ex Kurz.

*Rauvolfia serpentina*, commonly known as “Sarpagandha” and belonging to Apocynaceae, has a rich medicinal history dating back several thousand years. The dried roots of this plant contain various biologically active compounds, including reserpine, deserpidine, rescinnamine, ajamalacine, neoajmalin, ajmaline, serpentine, and α-yohimbine.

Utilized as a sedative, these roots are employed to manage conditions such as anxiety, high blood pressure, epilepsy, insomnia, and schizophrenia. Additionally, *R. serpentina* finds application in snakebites, insect stings, mental disorders, and cancer treatment. The indole alkaloid compound reserpine, derived from this plant, exhibits effective antiproliferative activity against various cancer cell lines, suggesting its potential for further use in cancer chemotherapy.

## 3. Conservation approaches

### 3.1. In situ conservation of wild medicinal plants

Medicinal Plant Conservation Areas (MPCA) were sites with known medicinal plant richness, less disturbed but easily accessible, and relatively free from local rights/livelihood issues, form compact manageable units, and covered different forest/vegetation types and altitude ranges. The MPCAs were established to conserve the medicinal plants in the wild, to conduct studies on the status and conservation approaches of Wild medicinal plants, and to design and develop mechanisms for medicinal plant conservation. Depending on the status of data and assessment relating to the medicinal plant resources of a state or region, two types of MPCA were established: MPCAs that capture the diversity of native medicinal plants are referred to as “Diversity-Focus MPCAs”. Species-focus MPCAs were established to conserve prioritized medicinal plants of high conservation concern. For example, *Saraca asoca* occurs naturally in the states of Western Ghats like Maharashtra, Goa, Karnataka, and Kerala; in the states of Eastern Ghats like Odisha; and the north-east states, namely, Meghalaya and Mizoram.

### 3.2. Ex situ conservation

FRLHT also established several ex-situ conservation sites to complement in situ conservation. Ex situ conservation was undertaken to improve livelihood and enhance the use through the establishment of MPCPs. It comprises of nurseries, establishment of living collections of a limited number of specimens of the medicinal plants collected, and promotion of kitchen herbal gardens/home herbal gardens.

### 3.3. Micropropagation and conservation

Micropropagation refers to the mass production of plant propagules from any part of the plant or cell. A rapid in vitro propagation method was developed *D. hamiltonii* through shoot multiplication using shoot tip explants. When calli were subcultured on MS media added with KN (1.5 mg/l) and BAP (2.5 mg/l) exhibited better shoot regeneration rate (95%) and rooted well in 1 mg/l KN contained MS media. The nodal explants showed better morphogenetic response with 95% regeneration frequency compared to leaf explants (85%). All micropropagated plants exhibited superior growth properties in the field. In vitro rooting initiated better with the use of 1 mg/l IBA. Micropropagation and cloning of plant tissue based on different explants are commonly used to conserve different endangered plants. It enables fast, season independent, continuous multiplication, maintenance and conservation of rare and endangered plants by using any plant parts as explant source (Sarasan et al., 2006; Chandra et al., 2010). Steps in Micropropagation include:

- Initiation of culture from an explant like shoot tip on a suitable nutrient medium
- Initial shoot development can occur either directly from explant or through indirect way of callus-mediated de-differentiation of shoot initials
- Multiple shoots formation from the cultured explant
- Rooting of in vitro developed shoots
- Transplantation to the field following acclimatization

In vitro conservation refers to the conservation of germplasm under defined nutrient conditions in an artificial environment in the form of in vitro cultures. The culture systems may be in the form of shoots, meristems, embryos, plantlets, callus or cell suspension. In vitro conservation can be effectively used for multiplication as well as conservation of endangered taxa. For vegetatively propagated species, recalcitrant seed species and species with sterile seeds, in vitro conservation is the only reliable method for long-term conservation. The properties required for a successful in vitro conservation system as defined by Grout (1990) are following.

- The ability of the biological system to minimize the growth and development in vitro
- Maintain viability of the stored material at the highest possible level along with the minimum risk of genetic stability
- Maintain full developmental and functional potential of the stored material when it is returned to physiological temperatures
- Make significant savings in labour input, materials and commitment of specialized facilities

In vitro conservation is achieved through plant tissue culture technique. Plant Tissue culture (PTC) refers to the culturing of plant cell or tissue in vitro under sterile conditions for rapid multiplication. This makes use of the totipotent property of the cell, which is the ability of any plant cell to grow into a whole plant when provided with suitable nutrient medium and environmental conditions. Plant tissue Culture has many advantages over conventional methods of vegetative propagation listed as follows (Mathur, 2013).

- Only a small amount of tissue is required to regenerate millions of clonal plants in a year
- In vitro stock can be quickly proliferated as it is season independent
- Rapid multiplication of superior clones can be carried out throughout the year, irrespective of seasonal variations
- Multiplication of disease and virus free plants
- It is a cost-effective process as it requires minimum growing space
- Long term storage of valuable germplasm possible

 ISBN: 978-93-340-7821-3

Somatic embryogenesis refers to the development of somatic embryo from a single somatic cell or tissue. Somatic embryogenesis and organ development through organogenesis from various cultures of explants are the most commonly used technique applied to regenerate several endangered plants for the purpose of conservation. There is direct as well as indirect somatic embryogenesis. In direct somatic embryogenesis, the plants develop directly from explants without any callus formation whereas dedifferentiation of callus to produce plants occurs in indirect somatic embryogenesis. It has great application in the rapid multiplication of endangered medicinal plants.

### 3.4. Long-term conservation through cryopreservation

Cryopreservation, a method for long-term preservation of plant genetic material, involves maintaining living cells at ultra-low temperatures, typically in liquid nitrogen at -196 °C. This freezing halt cellular metabolic activities, preventing genetic changes. It’s valuable for conserving rare and endangered plant species by storing germplasm in suspended growth. Various tissues like seeds, pollen, embryos, and meristems can undergo cryopreservation. Notably, advantages include minimal maintenance, reduced contamination risks, and avoidance of continuous exposure to operator errors during frequent plant material manipulations. The principle behind cryopreservation is to bring the cells or tissues to a zero-metabolism stage by subjecting them to ultra-low temperature in the presence of cryoprotectants. In addition, modern techniques of Molecular Biology and Genetics can support to develop a simple and more efficient regeneration systems and to conserve plant materials through pollen banking, seed banking, or storing in liquid nitrogen.

### 3.5. Traditional methods of conserving medicinal plants

The rural people who constitute the bulk of population are heavily dependent on the vegetation around them for fuel wood and for medicine. They are mainly subsistence farmers, and cannot afford alternative fuels, let alone the high prices of modern medicine. As a results vegetation is lost and environmental degradation takes place. Major steps have been taken towards conserving the medicinal plants. They include discouraging cutting down indigenous trees and encouraging the local people to plant fast growing exotic and Indigenous trees for domestic use, the inauguration of a national tree planting day and the creation of nature reserves. However, despite this intensified drive towards conservation, it is still difficult to prevent local people from destroying the plants around them. The planting of fast growing exotics is not a complete solution to the problem of environmental degradation, mainly because the locals still need indigenous plants as a source of medicine and for crafts such as carving. Local people do not approve of the planting of medicinal plants because of their belief that indigenous plants lose their curative properties when cultivated.

### 3.6. Conclusion

The Institute of Biodiversity Conservation (IBC) has launched a project, the Conservation and Sustainable Use of Medicinal Plants (CSMPP), aiming to address the depletion of medicinal plant biodiversity caused by both human activities and natural disasters. This initiative recognizes the potential of medicinal plants not only for traditional healthcare but also as a source of income for farmers. The project aims to safeguard indigenous knowledge associated with the conservation and utilization of medicinal plants, which is rapidly diminishing. Conservation aims to promote sustainable development by safeguarding biological resources, preserving genetic diversity, and preventing the destruction of crucial habitats. It encompasses various activities such as collecting, propagating, characterizing, evaluating, indexing for diseases, eliminating threats, and storing for distribution. The conservation of plant genetic resources is recognized as a vital aspect of biodiversity preservation. Ex situ conservation, one of the methods employed, involves protecting plant populations outside their natural habitat. This approach is typically utilized to ensure the survival of endangered, at-risk, or deteriorating populations.

**References**

1. Aadhan, K., & Anand, S. P. (2019). Floristic conservation and phenological study on some valuable medicinal plant species in Sadhuragiri hills, Southern Western Ghats of Tamil Nadu, India. Environment and Ecology, 37(3), 649-663.
2. Ajithkumar, D., & Seeni, S. (1998). Rapid clonal multiplication through in vitro Axillary shoot proliferation of Aegle marmelos (L.) Corr., a Medicinal tree. Plant Cell Reports, 17: 422–426.
3. Ayyanar, M., Ignacimuthu, S., & Houghton, P. J. (2014). Threat status of medicinal plants used by the tribal people in Kalakad Mundanthurai Tiger Reserve, Southern Western Ghats, India. Proceedings of the

National Academy of Sciences, India Section B: Biological Sciences, 84, 419-429.
4. Biswas, S., Rawat, M. S., Tantray, F. A., & Sharma, S. (2017). Medicinal plants conservation and development areas (MPCDAs)-An initiative towards conservation of medicinal plants. Medicinal Plants-International Journal of Phytomedicines and Related Industries, 9(3), 143-149.
5. Fathima, T. I., Udayan, P. S., Somashekar, R. K., & Ved, D. K. (2018). Prioritization of medicinal plants in sholas of Western Ghats: a case study. Journal of Medicinal Plant Research, 6(1), 7-10.
6. Krishnan, P. N., Decruse, S. W., & Radha, R. K. (2011). Conservation of medicinal plants of Western Ghats, India and its sustainable utilization through in vitro technology. In Vitro Cellular & Developmental Biology-Plant, 47, 110-122.
7. Kumar, N. P. A., Shakeela, V., Lopus, M., & Krishnan, S. (2024). MS Swaminathan Botanical Garden-A Community Conservation Initiative in the Western Ghats of India. In Botanical Gardens and Their Role in Plant Conservation, CRC Press, 203-215.
8. Kumar, P., & Anand, A. (2016). Conservation of rare endangered and threatened (RET) medicinal plants of Western Ghats. Innovative Farming, 1(4), 147-154.
9. Navaneethan, P., Nautiyal, S., Kalaivani, T., & Rajasekaran, C. (2011). Cross-cultural ethnobotany and conservation of medicinal and aromatic plants in the Nilgiris, Western Ghats: A case study. Medicinal Plants. International Journal of Phytomedicines and Related Industries, 3(1), 27-45.

10. Paulsamy, S., Senthilkumar, P., & Vijayakumar, K. K. (2009). Medicinal plants for conservation priority in the Shola understories of Nilgiris, Western Ghats. MyForest, 45(4), 347-353.
11. Paulsamy, S., Vijayakumar, K. K., Murugesan, M., Padmavathy, S., & Senthilkumar, P. (2007). Ecological status of medicinal and other economically important plants in the shola understories of Nilgiris, the Western Ghats.
12. Pramanik, M., Diwakar, A. K., Dash, P., Szabo, S., & Pal, I. (2021). Conservation planning of cash crops species (Garcinia gummi-gutta) under current and future climate in the Western Ghats, India. Environment, Development and Sustainability, 23, 5345-5370.
13. Radha, R. K. (2020). In vitro multiplication and conservation of threatened medicinal plants of Western Ghats of South India. Conservation and Utilization of Threatened Medicinal Plants, 159-180.
14. Rajasekharan, P. E., & Wani, S. H. (Eds.). (2020). Conservation and utilization of threatened medicinal plants. Springer International Publishing, 525.
15. Rao, R. R., Murugan, R., & Kavitha, S. (2009). Botanical conservatories and ex situ conservation of some rare and endemic medicinal and aromatic plants: a case study from Western Ghats. Proceedings of the National Academy of Sciences India. Section B, Biological Sciences, 79(4), 350-368.
16. Rao, R. R., Sagar, K., & Syamasundar, K. V. (2006). Wild aromatic plant species of western ghats: Diversity, conservation and utilization. In International Seminar on

Multidisciplinary Approaches in Angiosperm Systematics, 358-71.

17. Sai Murali, R. S., Nageswara Rao, G., & Basavaraju, R. (2017). Looking through the lens of a conservation biologist: life of medicinal plants in the Eastern Ghats of Andhra Pradesh, India. International Journal of Conservation Science, 8(2).
18. Sivaraj, N., Kamala Venkateswaran, S. R. Pandravada, M. Thirupathi Reddy, and P. E. Rajasekharan. (2020). "Threatened medicinal plants of Eastern Ghats and their conservation." Conservation and Utilization of Threatened Medicinal Plants, 31-62.
19. Swamy, M. K., Paramashivaiah, S., Hiremath, L., Akhtar, M. S., & Sinniah, U. R. (2018). Micropropagation and conservation of selected endangered anticancer medicinal plants from the Western Ghats of India. Anticancer Plants: Natural Products and Biotechnological Implements, 2, 481-505.
20. Verma, P., Mathur, A. K., Jain, S. P., & Mathur, A. (2012). In vitro conservation of twenty-three overexploited medicinal plants belonging to the Indian sub-continent. The Scientific World journal, 2012.

ISBN: 978-93-340-7821-3

# Diversity of endemic ferns in Western Ghats

Surya E. V., Deepa P.
PG Department of Botany, KAHM Unity Women's College, Manjeri, Malappuram, Kerala, India, 676122
Corresponding author: suryaev7@gmail.com

The Western Ghats, extending along the western coast of India, are recognized as one of the world's eight 'hottest hotspots' of biological diversity. Spanning over 1,600 km and encompassing six states, this mountain range hosts a myriad of ecosystems ranging from tropical rainforests to montane grasslands. Among its rich flora, ferns represent a significant and diverse group, thriving in the moist, shady environments fostered by the dense forests and high rainfall characteristic of the region. Ferns in the Western Ghats are adapted to various ecological niches, from the humid understory of tropical rainforests to the cooler, mist-laden cloud forests at higher altitudes. These plants are particularly abundant in areas with consistent moisture, such as along streams, waterfalls, and in shaded ravines. The unique climatic and geological conditions of the Western Ghats create ideal habitats for fern growth. The ferns of the Western Ghats are an essential component of this biodiversity hotspot. Their conservation is vital not only for maintaining ecological balance but also for preserving the rich biological heritage of the region. Continued efforts in research, habitat protection, and community involvement are crucial to ensuring the survival of these unique and diverse plants.

**Key Words**: Conservation**,** Pteridophytes, Western Ghats, Endemic species, Urbanization, Habitat destruction

## 1. Introduction

Conservation of endemic ferns is crucial to maintaining the biodiversity and ecological balance of an ecosystem. Endemic ferns are those that are native to a specific region and are found nowhere else in the world. They often play a unique

 ISBN: 978-93-340-7821-3

role in their ecosystem and may have specialized adaptations to their local environments. Conservation effort for endemic ferns may include protecting their natural habitats from deforestation, urbanization and other forms habitat destruction, this can involve creating protected areas, such as national parks or reserves where these ferns can thrive undisturbed.

Western ghats is one of the 34 global biodiversity hot spots and harbors a rich diversity of flora and fauna with many endemic and RET species. Along with angiosperm plants, the western ghats is also a rich repository of pteridophytic plant wealth. Nowadays western ghats experiences exceptional level of plant endemism and higher levels of habitat destruction. The rugged range of hills stretching for about 1600 km along the west coast from south of Gujarat to the end of the Peninsula is interrupted only by a 30 km break in Kerala, the Palghat gap (Santhosh et al., 2016). The Western Ghats along with the Himalayas, Eastern ghats and parts of central India forms major Centre for the distribution of the ferns and fern allies. The major families of pteridophytes found in the Western Ghats are Aspleniaceae, Polypodiaceae, Thelypteridaceae, Selaginellaceae, Pteridaceae etc. Whereas on the generic level, maximum diversity is observed in the genus *Asplenium, Selaginella, Pteris, Athyrium, Diplazium* etc. The Western Ghats also harbours endemic species like *Polystichum manickamii, Cyathea nilgiriensis, Bolbitis semicordata, Selaginella radicata* etc.

India is a mega biodiversity country having many species of vascular plants including about 1000 species of ferns and ferns allies (Benniamine et al., 2008). Around 233 species of ferns occur in southern part of India. The pteridophytes are the nonflowering vascular plants including ferns and fern

 ISBN: 978-93-340-7821-3

allies. They form a conspicuous element of earth's vegetation and are important for evolutionary point of view as they show the evolution of vascular system and reflect the emergence of seed habitat in the plants. About 250 million years ago, they formed the dominant part of earth's vegetation, but in present day flora, they have been largely replaced by the seed plants. They grow luxuriantly in moist tropical and temperate forests and their occurrence in different eco geographically threatened regions from sea level to the highest mountains are of much interest (Dixit et al., 1969). Conservation efforts for endemic ferns in the western ghats are crucial for preserving the unique ecological balance and biodiversity of this region.

The International Union Code of Nomenclature (IUCN) report says that in India 7.7% of the plants are under threat. In Western Ghats, a number of epiphytic and lithophytic ferns are destroyed due to various deforestation activities, and 44 threatened ferns are facing extinction and the conservation of these species is a major concern of biologists although recent studies have shown that about 18% of the approximately 270 fern species found in southern India are endemic to the region (Manickam et al., 1995). Ultimately, the conservation of endemic ferns in important not only for their intrinsic value but also for the overall health and resilience of the ecosystems they inhabit. By preserving the unique species, we can help maintain the balance and diversity of our natural world.

## 2. Current status of pteridophytes

 ISBN: 978-93-340-7821-3

India, with its diverse climatic zones and varied topography, is home to a rich array of pteridophytes (ferns and their allies). These plants are predominantly found in the humid and shaded regions of the country, such as the Western Ghats, Eastern Ghats, the Himalayas, and the northeastern states. According to the IUCN Report in 1998, there listed 770 threatened species of Pteridophytes worldwide. Singh et al. (2015) had been reported 17 rare and endangered species of pteridophytes from India. The World Conservation Monitoring Centre at Cambridge, England, listed 1650 threatened species of Pteridophytes world-wide, under the following categories: Presumed Extinct - 20, Endangered - 67, Vulnerable - 91 and Rare - 354. India's pteridophyte diversity is significant, with around 70 genera and 1,200 species. However, these plants face various threats that require comprehensive conservation efforts. By protecting habitats, supporting research, and involving local communities, India can ensure the preservation of its rich pteridophyte heritage for future generations.

## 3. Pteridophyte diversity in the states traversed by the Western Ghats

Kerala, located in the southwestern corner of India, is bordered by the Western Ghats on the east and the Arabian Sea on the west. The state covers a geographical area of 38,852 $km^2$, with 20,321 $km^2$ of forest cover characterized by significant heterogeneity, resulting in various vegetation patterns. These patterns range from scrub forests in the rain shadow regions and plains to tropical deciduous forests and rainforests up to an elevation of 1,500 m, and shola forests above 1,500 m (Nayar, 2010). The diverse terrains and an

 ISBN: 978-93-340-7821-3

average annual rainfall of 2,990 mm make Kerala a suitable habitat for pteridophytes. The Palghat Gap, in particular, is highly diverse, supporting 239 species of ferns and fern allies (Manickam and Irudayaraj, 1992). Muktesh (1998) recorded 159 species of ferns and fern allies belonging to 70 genera and 29 families, noting that species once abundant in the Munnar forest, such as *Osmunda hugelina, Angiopteris evecta, Cyathea* spp., *Diplazium* spp., and *Polystichum* spp., have been observed. Kavitha et al. (2015) studied the diversity of pteridophytes in the Ponmudi hills, which are covered by thick tropical forests, and documented 28 species. Additionally, Joseph and Thomas (2015) collected 15 chasmophytic pteridophyte species from the Urumbikkara hills in the Idukki district, identifying species from 11 families and 11 genera.

Joseph et al. (2017) conducted a study on the pteridophyte flora of Dr. Salim Ali Bird Sanctuary in Thattekad, Ernakulam, documenting the presence of 30 species of ferns and fern allies belonging to 23 genera. Rekha and Athira (2017) investigated the pteridophyte diversity of Akamala forest station in the Thrissur district of Kerala, identifying 24 species of pteridophytes. Among these, 2 species were classified as 'endangered,' 4 as 'rare,' and 1 as 'at risk.' Tamil Nadu, with a geographical area of 130,060 km² and a forest cover of 26,281 km² (20.2% of the state's total area), features four major geographical divisions: the Eastern and coastal plains, central uplands, western Karnataka plateau, and the central Eastern Ghats (Ruma, 2018). The state hosts nine types of forests, with tropical dry deciduous forests comprising 46.98% of the total forest area. The average annual rainfall in Tamil Nadu ranges from 3,000 to 5,000 mm. The presence of both the Western Ghats and the Eastern Ghats in Tamil Nadu contributes to its rich pteridophyte flora. Sukumaran et al. (2009) recorded 24 species of pteridophytes in the miniature sacred forests of the Kanyakumari district in the Southern Western Ghats, including 3 endemic species, 3 endangered species, and 8 rare species. Abraham and Ramachandran (2013) added six species to the pteridophyte flora of the Nilgiris: *Asplenium bipinnatum* (Aspleniaceae), *Cheilanthes viridis* (Pteridaceae), *Huperzia phlegmaria* (Lycopodiaceae), *Selaginella ciliaris* (Selaginellaceae), *Selaginella intermedia* (Selaginellaceae), and *Trichomanes bipunctatum* (Hymenophyllaceae). Sathish and Vijayakanth (2016) also contributed to the fern flora of Kolli hills in Tamil Nadu by adding six fern species: *Adiantum latifolium*, *Oleandra musifolia*, *Diplazium cognatum*, *Bolbitis appendiculata*, *Leptochilus thwaitesianus* and *Phymatosorus membranifolium*. In 2017, Vijayakanth et al. reported two new ferns to the fern flora of Tamil Nadu: *Athyrium parasnathense* (Athyriaceae) and *Leptochilus metallicus* (Polypodiaceae). Kumari and Jeeva (2018) studied the pteridophytes along the Thamiraparani River in Tamil Nadu, identifying 65 species, of which 33% were terrestrial, 12% aquatic, 11% lithophytes, and 13.8% epiphytes.

Alagesaboopathi et al. (2018) documented 14 species of pteridophytes from the Kanjamalai Hills in Salem District. Packiaraj and Suresh (2019) studied the pteridophyte diversity of the Kilavarai freshwater river in Kodaikanal, reporting 36 species belonging to 25 genera and distributed among 19 families. The dominant species were from the Adiantaceae,

 ISBN: 978-93-340-7821-3

Polypodiaceae, Pteridaceae and Cheilanthaceae families. Karnataka, which encompasses a significant portion of the Central Western Ghats, is known for its pteridophyte diversity and endemism. Most pteridophyte species in Karnataka are found in the Central Western Ghats (Rajagopal and Bhat, 1998). The study of pteridophyte diversity in Karnataka began with Blatter and Dalmeida's "Ferns of Bombay" (1922), which recorded 75 species. Subsequent studies included Alston's (1945) documentation of four *Selaginella* species, Kammathy et al.'s (1967) listing of 25 species, and Holttum's (1976) inclusion of 10 fern species from the Thelypteridaceae family in the "Flora of Hassan District". Yoganarasimham et al. (1981) added 12 species in the "Flora of Chikmangalur District." Matchperson (1986) recorded 90 fern species from the North Canara district.

After a significant time gap, more research was conducted to provide detailed data on the pteridophyte diversity of Karnataka. Deepa et al. (2013) studied the distribution of pteridophytes in the Kigga forest of the Central Western Ghats in Karnataka. The species diversity was calculated using Shannon’s diversity index and Simpson’s diversity index, with *Aleuritopteris anceps* (Blanf.) Panigrahi being the most abundant species in the studied area. Later, Deepa et al. (2017) enumerated 23 pteridophytes in the Madhuguni forest of the Central Western Ghats in Karnataka. The majority of the pteridophyte species were terrestrial, with exceptions including two epiphytes, one aquatic, and one climbing fern. Ashwini and Parashurama (2014) documented the pteridophyte composition of the Banjalaya forest region, identifying 19 pteridophyte species belonging to 11 families.

 ISBN: 978-93-340-7821-3

*Athyrium hohenackeranum* (Kunze) T. Moore was found to be the most abundant species. Dudani et al. (2014) surveyed the wet evergreen forests of Sakleshpur, considered the 'hottest hotspot of biodiversity,' and reported a total of 45 species of pteridophytes from this region. Parashurama et al. (2016) assessed the pteridophyte diversity in Mudigere Taluk, Central Western Ghats, Karnataka, documenting 26 species of pteridophytes belonging to 17 families, with 22 species recorded as terrestrial. Maharashtra, with a geographic area of 307,713 km², has a forest cover of 21% and features mountain ranges with tropical rain forests. 17% of the state consists of deciduous forests. The state has 3 game reserves, 5 national parks, and 24 bird sanctuaries (Shelar and Madhuri, 2016). Sixty-four fern species have been reported from Maharashtra, most of which are confined to the northern Western Ghats (Manickam and Irudayaraj, 2003). A new addition to the flora of Maharashtra was made by Sachin et al. (2016). Goa has a geographical area of 3,702 km², with 2,229 km² designated as forest area. Due to the presence of four wildlife sanctuaries, 95% of its forest area holds 'protected area' status. Datar and Laksminarasimham (2010) compiled data on the pteridophyte diversity of Goa and concluded that the state has a pteridophyte flora comprising 47 species, belonging to 32 genera under 20 families.

Gujarat, with a land area of 196,244 km² and a forest cover of 14,757 km², has seen various studies on its pteridophyte diversity (Ruma, 2018). The Gujarat Ecological Commission documented 16 pteridophyte species from different parts of Gujarat in 1996. Subsequent studies by Patel et al. (2010), Dabgar (2012) and Modi and Dudani (2013) contributed further insights. In 2015, Modi published a paper documenting the presence of 16 pteridophyte species in Gujarat. Rajput et al. (2016) conducted a three-year field study to assess the pteridophyte diversity of Gujarat, collecting 23 species. The study noted that *Equisetum debile* was extinct in the wild and *Isoetes coromandeliana* was on the verge of extinction. Additionally, eight species were recorded for the first time in the state. Dudani et al. (2014) highlights the diversity of pteridophytes in the wet evergreen forests of Sakleshpur taluk in Hassan district, central Western Ghats. This area, particularly the Gundia river catchment, is noted as a significant biodiversity hotspot, hosting numerous endemic and threatened species. The survey conducted in various macro and micro habitats within this region documented 45 species of pteridophytes from 19 families. Key findings include the presence of South Indian endemics such as *Cyathea nilgirensis, Bolbitis subcrenatoides, B. semicordata* and *Osmunda huegeliana,* which emphasize the region's critical role in pteridophyte diversity. However, the rich biodiversity is under threat due to proposed hydro-electric projects targeting the perennial streams of the Western Ghats for irrigation and power. The diversity of pteridophytes in the shola forests of Kerala, part of the Western Ghats, has been relatively underexplored. This study focuses on assessing the pteridophyte diversity in Pampadum Shola National Park. A total of 44 species of pteridophytes, spanning 24 genera and 16 families, were documented in this region. Specifically, the findings include: Ferns: 14 families, 22 genera, and 39 species, Fern allies: 2 families, 4 genera, and 5 species. Notably, six species were newly recorded in this region, underscoring the significance of this study in contributing to the understanding of pteridophyte diversity in the shola forests of Kerala (Subina et al., 2021).

Table 1: State wise distribution of pteridophytes in Western Ghats and their conservation status (Kridhnan and Rekha, 2021)

| Sl. No. | Name of the species | Distribution in each state('+' denotes presence) | | | | | | IUCN status |
|---|---|---|---|---|---|---|---|---|
| | | Kerala | Tamil Nadu | Karnataka | Maharashtra | Goa | Gujarat | |
| 1 | *Abrodictyum obscurum* (Blume) Ebihara & K. Iwats. | + | | + | | | | |
| 2 | *Acrostichum aureum* L. | + | + | | | + | | LC |
| 3 | *Actiniopteris radiata* (J. Koenig ex Sw.) Link | + | | | + | | + | |
| 4 | *Actinostachys digitata* (L.) Wall. ex C. F. Reed | + | | | | | | EN |
| 5 | *Adiantum capillus veneris* L. | + | + | + | + | + | | LC |
| 6 | *Adiantum caudatum* L. | | + | | | | | |
| 7 | *Adiantum concinnum* Humb. & Bonpl. ex Willd. | | + | + | | | | |
| 8 | *Adiantum hispidulum* Sw. | + | + | | | | | |
| 9 | *Adiantum incisum* Forssk. | | + | + | + | | + | |
| 10 | *Adiantum incisus* subsp. *indicum* (Ghatak) Fraser-Jenk. | + | | | | | | |
| 11 | *Adiantum latifolium* Lam. | + | + | + | | | | |
| 12 | *Adiantum monochlamys* Eaton | + | | | | | | |
| 13 | *Adiantum nagnum* | | + | | | | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 14 | *Adiantum peruvianum* Klotzsch | | | | | + | | |
| 15 | *Adiantum philippense* L. | + | | | + | + | | |
| 16 | *Adiantum philippense* subsp. *philippense* | + | + | | | + | | |
| 17 | *Adiantum poiretii* Wikstr. | + | + | | + | | | |
| 18 | *Adiantum raddianum* C. Persl | + | + | + | + | | | |
| 19 | *Adiantum soboliferum* Wall. | + | + | + | + | | + | CR |
| 20 | *Adiantum tenerum* Sw. | + | | | | | | |
| 21 | *Adiantum unilateral* var. birii | + | + | | | | | |
| 22 | *Adiantum venustum* D.Don | + | | | | | | |
| 23 | *Adiantum zollingeri* Mett. ex Kuhn | | + | | | | | |
| 24 | *Aglaomorpha quercifolia* (L.) Hovenkamp & S. Linds. | + | | + | | + | | |
| 25 | *Aleuritopteris albomarginata* (C.B. Clarke) Ching | | | | + | + | | |
| 26 | *Aleuritopteris anceps* (Blanf.) Panigrahi | | | + | + | | | |
| 27 | *Aleuritopteris bicolor* (Roxb.) Fraser-Jenk. | | + | + | + | | + | |
| 28 | *Aleuritopteris farinosa* (Forsk.) Fée | + | + | | | + | + | |
| 29 | *Aleuritopteris formosana* (Hayata) Tagawa | | + | | | | | |
| 30 | *Aleuritopteris tenuifolia* (Burm. f.) Sw. | | | + | | | | |
| 31 | *Alsophila gigantea* Wall. ex Hook. | + | + | + | | + | | |
| 32 | Alsophila nilgirensis (Holttum) R.M.Tryon | + | + | + | | | | LC |
| 33 | *Alsophila nllgirensls var. lobatus* | | + | | | | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 34 | *Alsophila spinulosa* (Wall. ex Hook.) R. M. Tryon | + | + | + | | + | | |
| 35 | *Alsophila walkerae* (Hook.) J. Sm. | | + | | | | | |
| 36 | *Ampelopteris prolifera* (Retz.) Copel | | | + | | + | | |
| 37 | *Anemia schimperiana* subsp. *wightiana* (Gardner) Fraser-Jenk. | | + | | | | | EN |
| 38 | *Anemia tomentosa* (Sav.) Sw. | + | + | | | | | |
| 39 | *Angiopteris evecta* (G. Forst.) Hoffm. | + | + | | | + | | |
| 40 | *Angiopteris helferiana* C. Presl. | + | | + | + | | | |
| 41 | *Anisocampium cumingianum* C. Persl | + | + | | | | | |
| 42 | *Anogramma leptophylla* (L.) Link | + | | | + | | | EN |
| 43 | *Antrophyum plantagineum* (Cav.) Kaulf | + | | + | | | | |
| 44 | *Antrophyum reticulatum* (G. Forst.) Kaulf. | | + | | | | | |
| 45 | *Arachniodes amabilis* (Blume) Tindale | + | | | | | | |
| 46 | *Arachniodes aristata* (G. Forst.) Tindale | + | + | + | | | | |
| 47 | *Arachniodes coniifolia* (T. Moore) Ching | | + | | | | | |
| 48 | *Arachniodes sledgei* Fraser-Jenk. | | | + | | | | |
| 49 | *Arachniodes tripinnata* (Goldm.) Sledge | + | | + | | | | |
| 50 | *Arthropteris palisotii* (Desv.) Alston | | + | | | | | CR |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 51 | *Asplenium* aequibasis(C.Chr.) J.P.Roux | | + | + | | | | LC |
| 52 | *Asplenium aethiopicum* (Burm.f.) Bech. | + | | + | | | | VU |
| 53 | *Asplenium affine* Sw. | | + | | | | | EN |
| 54 | *Asplenium auritum* Sw. | + | + | | | | | CR |
| 55 | *Asplenium bipinnatifidum* Baker | | + | | | | | |
| 56 | *Asplenium cheilosorum* Kunze ex Mett. | + | + | + | | | | |
| 57 | *Asplenium crinicaule* Hance | + | + | + | | | | |
| 58 | *Asplenium decrescens* Kunze | + | + | + | + | | | |
| 59 | *Asplenium ensiforme* Wall. | | | + | | | | |
| 60 | *Asplenium exiguum* Bedd. | + | + | | | | | EN |
| 61 | *Asplenium fissum* Willd. | + | + | | | | | NT |
| 62 | *Asplenium formosum* Willd. | + | + | + | | + | | LC |
| 63 | *Asplenium grevillei* Wall. | + | | | | | | VU |
| 64 | *Asplenium hindusthanensis* Bir. | | + | | | | | |
| 65 | *Asplenium inaequilaterale* Bory ex Willd. | + | + | + | + | | | |
| 66 | *Asplenium indicum* Sledge | + | | | | | | |
| 67 | *Asplenium mysorense* Roth | + | + | + | | | | NT |
| 68 | *Asplenium nidus* L. | + | + | | | | | |
| 69 | *Asplenium normale* D. Don | | + | | | | | |
| 70 | *Asplenium phyllitidis* D.Don | + | | + | | | | |
| 71 | *Asplenium polyodon* G. Forst. | + | + | | + | | | |
| 72 | *Asplenium scalare* Rosenst. | + | | | | | | CR |
| 73 | *Asplenium semcula* Fee. | + | | | | | | |
| 74 | *Asplenium tenerum* G. Forst. | + | | | | | | NT |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 75 | *Asplenium trichomanes* L. | + | | | | | | LC |
| 76 | *Asplenium unilateral* Lam. | + | + | | | + | | |
| 77 | *Asplenium yoshinagae* Makino subsp. *indicum* (Sledge) Fraser-Jenk. | | | + | + | | | |
| 78 | *Asplenium zenkerianum* Kunze | + | | | | | | |
| 79 | *Athyrium anisopterum* Christ | | + | | | | | |
| 80 | *Athyrium dubium* Ching | | + | | | | | |
| 81 | *Athyrium falcatum* Bedd. | | + | + | + | | | |
| 82 | *Athyrium filix-femina* (L.) Roth | + | | | | | | LC |
| 83 | *Athyrium ghost* | + | | | | | | |
| 84 | *Athyrium hohenackeranum* (Kunze) T. Moore | + | | + | + | + | + | |
| 85 | *Athyrium micropterum* Fraser-Jenk. | | | | + | | | |
| 86 | *Athyrium parasnathense* (C. B. Clarke) Ching ex Mehra & Bir | | + | | + | | | |
| 87 | *Athyrium pectinatum* (Wall. ex Hope) C. Presl | | + | | + | | | |
| 88 | *Athyrium praetermissum* Sledge | | + | | | | | |
| 89 | *Athyrium puncticaule*(Blume) Moore | | + | | | | | |
| 90 | *Athyrium schipmeri* Moug.ex Fee. | | + | | | | | |
| 91 | *Athyrium solenopteris* (Kunze) T. Moore | | + | + | | | + | LC |
| 92 | *Athyrium tozanense* (Hayata) Hayata | + | + | | | | | |
| 93 | *Austroblechnum colensoi* (Hook. fil.) Gasper & V. A. O. Dittrich | | + | | | | | |

ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 94 | *Azolla microphylla* Kaulf. | | + | | | | | LC |
| 95 | *Azolla pinnata* R.Br. | + | + | + | + | | + | LC |
| 96 | *Blechnopsis orientalis* (L.) C. Presl | + | + | + | + | + | | |
| 97 | *Bolbitis × terminans* (Wall.) Gandhi & Fraser-Jenk. | | | + | + | + | | |
| 98 | *Bolbitis angustipinna* (Hayata) H. Itô. | | + | | + | + | | |
| 99 | *Bolbitis appendiculata*(Willd.) Iwatsuki | + | + | + | | + | | LC |
| 100 | *Bolbitis asplenifolia* (Bory) K. Iwats. | | | + | + | + | | DD |
| 101 | *Bolbitis prolifera* (Bory) C. Chr. & Tardieu ex Tardieu & C. Chr. | | + | - | + | | | |
| 102 | *Bolbitis repanda* (Blume) Schott | + | + | + | + | | | NT |
| 103 | *Bolbitis semicordata* (Moore) Ching | + | + | + | - | + | | VU |
| 104 | *Bolbitis subcrenata*(Hook & Grev.) Ching | + | | | | | | LC |
| 105 | *Bolbitis thommankunthiana* | | + | | | | | |
| 106 | *Bolbitis virens* (Wall. *ex* Hook. and Grev.) Schott | | + | | + | | | |
| 107 | *Bosmania membranacea* (D. Don) Testo | + | + | + | + | + | | |
| 108 | *Ceratopteris thalictroides* (L.) Brongn. | + | + | + | + | + | + | LC |
| 109 | *Cheilanthes viridis* (Forsk.) Sw. | | + | | | | | |
| 110 | *Cheilanthes tenuifolia* (Burm. fil.) Sw. | + | + | + | + | + | | |
| 111 | *Christella meeboldii* (Rosenst.) Holttum | | | | | + | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 112 | *Christella papilio* (C. Hope) Holttum | | + | | | + | | |
| 113 | *Christella parasitica* (L.) K. Iwats. | + | + | + | | + | | EN |
| 114 | *Christella quadrangularis* (Fée) Holttum | | + | + | | | | |
| 115 | *Crepidomanes bipunctatum* (Poir.) Copel. | | + | | | | | |
| 116 | *Crepidomanes campanulatum* (Roxb.) Panigrahi & Sarn. Singh | + | | + | | | | |
| 117 | *Crepidomanes christii* (Copel.) Copel. | + | | | | | | |
| 118 | *Crepidomanes intramarginale* (Hook. & Grev) Copel | + | + | + | | + | | EN |
| 119 | *Crepidomanes latealatum* (Bosch) Copel. | | | | + | | | |
| 120 | *Crepidomanes minutum* (Blume) K. Iwats. | + | | + | | | | |
| 121 | *Crepidomanes proliferum var.prollferum* | | + | | | | | |
| 122 | *Cyathea crinita* Copel. | + | | | | | | EN |
| 123 | *Cyclosorus ciliatus* (Wall. ex Benth.) Panigrahi | | + | | | | | LC |
| 124 | *Cyclosorus interruptus* (Willd.) H. Itô | + | + | + | | + | + | LC |
| 125 | *Cyrtomium caryotideum* (Wall. ex Hook. & Grev.) C. Presl | | + | | | | | |
| 126 | *Cyrtomium micropterum* (Kunze) Ching | | + | | | | | EN |
| 127 | *Davallia bullata* Wall. | + | + | | | | | |
| 128 | *Davallia denticulata* (Burm. fil.) Mett. ex Kuhn | + | | | | | | VU |
| 129 | *Davallia hymenophylloides* | + | + | | | | | EN |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (Blume) Kuhn | | | | | | | |
| 130 | *Davallia pulchra* D. Don | + | | + | + | + | | |
| 131 | *Davallia repens* (L. fil.) Kuhn | | + | | | | | VU |
| 132 | *Deparia lancea* (Thunb.) Fraser-Jenk. | | + | | | | | |
| 133 | *Deparia petersenii* (Kunze) M. Kato | | + | | + | | | |
| 134 | *Dicranopteris linearis* (Burm.f) var. *sebastiana* Panigrahi & Dixit | | + | | | | | |
| 135 | *Dicranopteris linearis* (Burm.f) var. *tenuis* Manickam & Irudayaraj | | + | | | | | |
| 136 | *Dicranopteris linearis* (Burm.f.) Underwood. | + | + | + | | + | | LC |
| 137 | *Didymoglossum bimarginatum* (Bosch) Ebihara & K. Iwats. | + | + | | | | | |
| 138 | *Didymoglossum exiguum* (Bedd.) Copel. | | + | | | | | EN |
| 139 | *Didymoglossum henzaianum* (Parish ex Hook.) Mazumdar | + | | | | | | EN |
| 140 | *Didymoglossum mindorense* (Christ) K. Iwats. | + | | | | | | CR |
| 141 | *Didymoglossum sublimbatum* (Müll. Berol.) Ebihara & K. Iwats. | + | | + | | | | VU |
| 142 | *Diphasiastrum wightianum* (Wall. ex Hook. & Grev.) Holub | + | + | | | | | |
| 143 | *Diplazium beddomei* C. Chr. | + | + | | | | | CR |
| 144 | *Diplazium brachylobum* (Sledge) Manickam & Irudayaraj | | | + | | | | |
| 145 | *Diplazium dialatulum* Bl. | + | | | | | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 146 | *Diplazium esculentum* (Retz.) Sw. | + | + | + | + | + | | LC |
| 147 | *Diplazium leptophyllum* Christ | + | + | | | | | VU |
| 148 | *Diplazium muricatum* (Mett.) Alderw. | + | | | | | | |
| 149 | *Diplazium polypodioides* Blume | + | + | + | | | | |
| 150 | *Diplazium sylvaticum* (Bory) Sw. | + | | | | | | |
| 151 | *Diplazium travancoricum* Bedd. | + | + | | | | | NT |
| 152 | *Doodia dives* Kunze. | | + | | | | | |
| 153 | *Doryopteris concolor* (Langsd. & Fisch.) Kuhn | + | + | + | | | | |
| 154 | *Dryopteris atrata* (Wall) Ching | + | + | | | | | |
| 155 | *Dryopteris austroindica* Fraser-Jenk. | | | + | | | | EN |
| 156 | *Dryopteris cochleata* (D. Don) C. Chr. | + | + | + | + | | | |
| 157 | *Dryopteris deparioides* subsp. *concinna* (Bedd.) C. Chr. | | + | | | | | CR |
| 158 | *Dryopteris hirtipes* (Blume) Kuntze | + | | + | | | | |
| 159 | *Dryopteris juxtaposita* Christ | | + | + | | | | |
| 160 | *Dryopteris macrochlamys* (Fée) Fraser-Jenk. | | + | | | | | |
| 161 | *Dryopteris odontoloma* (Moore) C. Chr. | + | + | | | | | NT |
| 162 | *Dryopteris scabrosa* (Kunze) Kuntze | + | + | | | | | VU |
| 163 | *Dryopteris sledgei* Fraser-Jenk. | | + | | | | | EN |
| 164 | *Dryopteris sparsa* (D. Don) | | + | + | + | | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Kuntze | | | | | | | |
| 165 | *Elaphoglossum beddomei* Sledge | + | + | | | | | NT |
| 166 | *Elaphoglossum commutatum* (Mett. ex Kuhn) Alderw. | | + | | | | | |
| 167 | *Elaphoglossum nilgiricum* Krajina ex Sledge | + | + | + | | | | EN |
| 168 | *Elaphoglossum stelligerum*(Wall. ex Baker) T.Moore ex Alston & Bonner | | + | | | | | LC |
| 169 | *Elaphoglossum stigmatolepis* (Fee) Moore | | + | + | | | | EN |
| 170 | *Equisetum ramosissimum* Desf. | + | + | | + | | + | LC |
| 171 | *Glaphyropteridopsis erubescens* (Wall. ex Hook.) Ching | | | + | | | | |
| 172 | *Haplopteris elongata* (Sw.) E. H. Crane | + | + | + | | | | |
| 173 | *Haplopteris ensiformis* (Sw.) E. H. Crane | | + | | | + | | VU |
| 174 | *Haplopteris flexuosa* (Fée) E. H. Crane | | + | | | | | |
| 175 | *Haplopteris microlepis* (Hieron.) Mazumdar | + | + | | | + | | EN |
| 176 | *Helminthostachys zeylanica* (L.) Hook. | + | + | | | | | |
| 177 | *Histiopteris incisa* (Thunb.) J. Sm. | | + | | | | | |
| 178 | *Huperzia serrata* (Thunb.) Trevis. | + | | | | | | |
| 179 | *Hymenasplenium hondoense* (N. Murak. & Hatan.) Nakaike | + | + | | | | | NT |
| 180 | *Hymenasplenium obscurum* | + | + | + | | | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (Blume) Tagawa | | | | | | | |
| 181 | *Hymenasplenium rivulare* (Fraser-Jenk.) Viane & S. Y. Dong | + | + | | | | | NT |
| 182 | *Hymenophyllum acanthoides* (Bosch.) Rosenst. | + | | | | | | CR |
| 183 | *Hymenophyllum denticulatum* Sw. | | | + | | | | |
| 184 | *Hymenophyllum exsertum* Wall. ex Hook. | + | | | | | | |
| 185 | *Hymenophyllum gardneri* Van. Den. Bosch. | | | + | | | | |
| 186 | *Hymenophyllum javanicum* Spreng. | | | | | + | | |
| 187 | *Hypodematium crenatum* (Forsk.) Kuhn | | + | | + | | | |
| 188 | *Hypolepis resistens* (Kunze) Hook. | + | | | | | | |
| 189 | *Isoetes coromandelina* L.f. | + | + | + | + | | + | LC |
| 190 | *Isoetes panchganiensis* G.K.Srivast., D.D.Pant & P.K.Shukla | | | | + | | | EN |
| 191 | *Isoetes udupiensis* P. K.Shukla, G. K. Srivast., S. K. Shukla & P.K. Rajagopal | | | + | | | | DD |
| 192 | *Japanobotrychum lanuginosum* (Wall. ex Hook. & Grev.) M. Nishida ex Tagawa | + | + | + | + | | | |
| 193 | *Lastreopsis tenera* (R. Br.) Tindale | + | + | | | | | VU |
| 194 | *Lepisorus amaurolepidus* (Sledge) Bir & Trikha | + | + | + | | | | |
| 195 | *Lepisorus nudus* (Hook.) | + | + | + | + | + | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Ching | | | | | | | |
| 196 | *Leptochilus axillaris* (Cav.) Kaulf. | + | + | + | | | | |
| 197 | *Leptochilus decurrens* Blume. | + | + | + | + | + | | LC |
| 198 | *Leucostegia truncata* (D. Don) Fraser-Jenk. | | + | + | + | | | |
| 199 | *Lindsaea ensifolia* Sw. | + | + | + | + | + | | |
| 200 | *Lindsaea heterophylla* Dryand. | | + | + | + | + | | |
| 201 | *Lindsaea malabarica* Baker | + | + | | | | | NT |
| 202 | *Lindsaea venusta* Kaulf. ex Kuhn | + | | | | | | EN |
| 203 | *Loxogramme chinensis* Ching | | + | | | | | |
| 204 | *Loxogramme cuspidata* (Zenker) M. G. Price | | + | | | | | |
| 205 | *Loxogramme involuta* (D. Don) C. Presl | + | | + | | | | |
| 206 | *Loxogramme parallela* Copel. | + | | | | | | |
| 207 | *Lycopodiella cernua* (L.)Pic.Serm. | + | + | + | | + | | LC |
| 208 | *Lycopodium clavatum* L. | + | + | | | | | LC |
| 209 | *Lycopodium japonicum* Thunb. | | + | | | + | | |
| 210 | *Lygodium flexuosum* (L.) Sw. | + | + | + | + | + | + | |
| 211 | *Lygodium longifolium* (Willd.) Sw. | + | | | | | | NT |
| 212 | *Lygodium microphyllum* (Cav.) R. Br. | + | + | + | | + | | LC |
| 213 | *Macrothelypteris ornata* (J. Sm.) Ching | | + | | | | | |
| 214 | *Macrothelypteris torresiana* (Gaudich.) Ching | + | | + | | + | | |
| 215 | *Marsilea crenata* C.Presl | | + | | | | | LC |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 216 | *Marsilea minuta* L. | + | + | + | + | | + | LC |
| 217 | *Marsilea quadrifolia* L. | | + | | | | | LC |
| 218 | *Metathelypteris flaccida* (Blume) Ching | | + | | | | | |
| 219 | *Mickelopteris cordata* (Hook. & Grev.) Fraser-Jenk. | + | + | + | | | | |
| 220 | *Microlepia majuscula* (E. J. Lowe) Moore | + | + | | | | | EN |
| 221 | *Microlepia platyphylla* (D. Don) J. Sm. | | + | | | | | |
| 222 | *Microlepia speluncae* (L.) Moore | + | + | + | + | | | |
| 223 | *Microlepia strigosa* (Thunb.) C. Presl | + | | | | | | |
| 224 | *Microsorum linguaforme* (Mett.) Copel | + | | | | | | |
| 225 | *Microsorum pteropus* (Blume) Copel. | + | | + | + | | | LC |
| 226 | *Microsorum punctata* (L.) Copel. | + | + | + | | | | |
| 227 | *Neolepisorus zippelii* (Blume) Li Wang | | | + | | | | |
| 228 | *Nephrolepis auriculata* (L.) Trimen | + | + | + | | + | | |
| 229 | *Nephrolepis biserrata* (Sw.) Schott | + | + | | | | | |
| 230 | *Nephrolepis brownii* (Desv.) Hovenkamp & Miyam. | + | + | + | | + | | |
| 231 | *Nephrolepis cordifolia* (L.) C.Presl | + | + | + | + | | | |
| 232 | *Nephrolepis exaltata* (L.) Schott. | | | | + | | | |
| 233 | *Nephrolepis falcata* (Cav.) C.Chr. | | | | | + | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 234 | *Nephrolepis undulata* (Afzel. *ex* Sw.) J.Sm. | | | + | + | | | LC |
| 235 | *Odontosoria chinensis* (L.) J. Sm. | + | + | + | | | | |
| 236 | *Odontosoria chinensis* subsp. *chinensis* | | | + | | | | |
| 237 | *Odontosoria chinensis* subsp. *tenuifolia* (Lam.) Fraser-Jenk. & Kandel | | | + | | | | |
| 238 | *Oeosporangium elegans* (Poir.) Fraser-Jenk. & Pariyar | | + | | | | | |
| 239 | *Oeosporangium elegans* (Poir.) Fraser-Jenk. & Pariyar | + | + | | | | | |
| 240 | *Oeosporangium thwaitesii* (Mett. ex Kuhn) Fraser-Jenk. | | + | | | | | |
| 241 | *Oleandra musifolia* (Blume.) C. Presl. | + | + | + | | | | |
| 242 | *Ophioglossum costatum* R. Br. | + | | + | + | | + | VU |
| 243 | *Ophioglossum gramineum* Willd. | + | + | + | + | + | + | LC |
| 244 | *Ophioglossum lusitanicum* L. | | | | + | | | CR |
| 245 | *Ophioglossum nudicaule* L. f. | | + | + | + | | + | VU |
| 246 | *Ophioglossum parvifolium* Hook. & Grev. | | | | + | | + | LC |
| 247 | *Ophioglossum petiolatum* Hook. | | + | | + | | | CR |
| 248 | *Ophioglossum polyphyllum* A. Braun | | + | | | | | DD |
| 249 | *Ophioglossum reticulatum* L. | + | + | + | + | | + | LC |
| 250 | *Ophioglossum vulgatum* L. | | + | - | - | | + | LC |
| 251 | *Oreogrammitis attenuata* (Kunze) Parris | + | + | | | | | EN |
| 252 | *Oreogrammitis austroindica* | | + | | | | | CR |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (Parris) Parris | | | | | | | |
| 253 | *Oreogrammitis medialis* (Baker) Parris | | + | + | | | | |
| 254 | *Oreogrammitis pilifera* (Ravi & J. Joseph) Parris. | + | | | | | | VU |
| 255 | *Osmolindsaea odorata* (Roxb.) Lehtonen & Christenh. | + | | | | | | |
| 256 | *Osmunda hilsenbergii* Hook. & Grev. | | | + | | | | |
| 257 | *Osmunda hugeliana* C.Presl | + | + | + | + | + | | LC |
| 258 | *Osmunda regalis* L. | | | + | | | | LC |
| 259 | *Parathelypteris beddomei* (Baker) Chin | + | | | | | | CR |
| 260 | *Pellaea boivinii* Hook. | + | + | | | | | VU |
| 261 | *Pellaea falcata* (R. Br.) Fée | + | | | | | | NT |
| 262 | *Pellaea longipilosa* Bonap. | + | + | + | | | | CR |
| 263 | *Phlebodium aureum* (L.) J. Sm. | | + | | | | | |
| 264 | *Phlegmariurus ceylanicus* (Spring) | + | | | | | | |
| 265 | *Phlegmariurus hamiltonii* (Spreng.) Á. Löve & D. Löve | + | + | + | + | | | |
| 266 | *Phlegmariurus niligaricus* (Spring) A. R. Field & Bostock | + | + | | | | | VU |
| 267 | *Phlegmariurus phlegmaria* (L.) Holub | + | + | | | | | |
| 268 | *Phlegmariurus phyllanthus* (Hook. & Arn.) R. D. Dixit | + | + | + | | | | |
| 269 | *Phlegmariurus squarrosus* (G. Forst.) Á. & D. Löve | + | | + | | | | |
| 270 | *Phlegmariurus vernicosus* (Hook. & Grev.) Á. & D. Löve | + | | | | | | CR |
| 271 | *Phymatosorus cuspidatus* | + | | | | | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | subsp. *cuspidatus* | | | | | | | |
| 272 | *Phymatosorus longissimus* (Blume) Pic. Serm. | + | | | | | | VU |
| 273 | *Phymatosorus membranifolium* (R. Br.) S. G. Lu | | + | | | | | |
| 274 | *Phymatosorus membranifolius* (R.Br) Tindale | + | + | | | | | |
| 275 | *Pityrogramma calomelanos* (Sw.) Link | + | + | + | + | + | | |
| 276 | *Pityrogramma calomelanos* var. *aureoflava* (Hook.) Weath. ex Bailey | | | + | | | | |
| 277 | *Pneumatopteris truncata* (Poir.) Holttum | | + | | | | | |
| 278 | *Polystichum anomalum* (Hook. et Arn.) J. Sm. | + | + | | | | | EN |
| 279 | *Polystichum auriculatum* (L.) C. Presl | | + | | | | | |
| 280 | *Polystichum harpophyllum* (Zenker ex Kunze ) Sledge | + | + | | | | | |
| 281 | *Polystichum manickamianum*Benniamin, Fraser-Jenk. & Irudayaraj | | + | | | | | CR |
| 282 | *Polystichum molluccense* | | + | | | | | |
| 283 | *Polystichum mucronifolium* (Blume) B. K. Nayar & Kaur | | + | | | | | |
| 284 | *Polystichum squarrosum* (D. Don) Fée | | + | | | | | |
| 285 | *Polystichum subinerme* (Kunze) Fraser- Jenk. | + | + | | | | | |
| 286 | *Polystichum subinerme* var. *orbiculata* | + | + | | | | | EN |
| 287 | *Pronephrium articulatum* | + | + | + | | | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | (Houlston & Moore) Holttum | | | | | | | |
| 288 | *Pronephrium triphyllum* (Sw.) Holttum | + | + | | | | | |
| 289 | *Prosaptia alata* (Blume) Christ | | + | | | | | CR |
| 290 | *Prosaptia contigua* (G. Forst.) C. Presl | + | + | | | | | CR |
| 291 | *Prosaptia obliquata* (Blume) Mett. | + | + | | | | | EN |
| 292 | *Pseudocyclosorus ochthodes* (Kunze) Holttum | | | + | | | | |
| 293 | *Pseudocyclosorus octhodes* var. *annamalaiensis* | | + | | | | | |
| 294 | *Pseudocyclosorus octhodes* var. *palniensis* | | + | | | | | |
| 295 | *Pseudocyclosorus tylodes* (Kunze) Ching | + | + | + | | | | |
| 296 | *Psilotum nudum* (L) P. Beauv. | + | + | | | | | CR |
| 297 | *Pteridium aquilinum* subsp. *wightianum* (Wall. ex J. Agardh) W. C. Shieh | + | | + | + | + | | |
| 298 | *Pteridium* pinetorumC.N.Page & R.R.Mill | + | + | | | + | | LC |
| 299 | *Pteridrys cnemidaria* (Christ) C. Chr. | + | | | | | | EN |
| 300 | *Pteridrys syrmatica* (Willd.) C. Chr. et Ching | + | + | | | | | CR |
| 301 | *Pteris argyraea* T. Moore | + | + | + | | | | |
| 302 | *Pteris arisanensis* Tagawa | | | + | | | | |
| 303 | *Pteris aspericaulis* Wall. ex J. Agardh | | + | | | + | | |
| 304 | *Pteris biaurita* L. | + | + | | + | + | | |
| 305 | *Pteris biaurita* L. subsp. *walkeriana* Fraser- Jenk. & | | | + | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Dom. Rajkumar | | | | | | | |
| 306 | *Pteris blumeana* J. Agardh | + | | + | + | | | |
| 307 | *Pteris confusa* T.G.Walker | + | + | + | | + | | |
| 308 | *Pteris cretica* L. | | + | | | | | LC |
| 309 | *Pteris cretica* subsp. *cretica* | | + | | | | | |
| 310 | *Pteris ensiformis* Burm. | | + | | | | | |
| 311 | *Pteris geminata* Wall. | + | + | | | | | EN |
| 312 | *Pteris gongalensis* T.GWalker | + | + | | | | | |
| 313 | *Pteris heteromorpha* Fee. | | | | + | + | | |
| 314 | *Pteris hookeriana* J. Agardh | + | | | | | | CR |
| 315 | *Pteris longifolia* L. | + | + | | | + | | |
| 316 | *Pteris longipes* D.Don | + | | | | | | |
| 317 | *Pteris mertensioides* Willd. | + | + | | | | | CR |
| 318 | *Pteris multiaurita* J. Agardh | | + | | | | | |
| 319 | *Pteris multifida* Poir. | + | | | | | | |
| 320 | *Pteris otaria* Bedd. | + | + | | | | | |
| 321 | *Pteris pellucida* C.Presl | + | | + | + | + | | |
| 322 | *Pteris praetermissa* T.GWalker | + | + | | | | | |
| 323 | *Pteris quadriaurita* Retz. | | + | + | | + | | |
| 324 | *Pteris scabripes* Wall. | + | + | + | | | | |
| 325 | *Pteris tripartita* Sw. | | + | | | | | EN |
| 326 | *Pteris venusta* Kunze | | | + | + | | | |
| 327 | *Pteris vittata* L. | + | + | + | + | + | + | LC |
| 328 | *Pyrrosia ceylanica* (Giesenh.) Sledge | + | | | | | | EN |
| 329 | *Pyrrosia heterophylla* (L.) M. G. Price | + | + | | | | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 330 | *Pyrrosia lanceolata* (L.) Farw. | + | + | + | + | + | | |
| 331 | *Pyrrosia piloselloides* (L.) M. G. Price | + | + | | | | | |
| 332 | *Pyrrosia porosa* (C.Presl) Hovenkamp | + | + | + | | | | |
| 333 | *Salvinia minima* Baker | + | | | | | | |
| 334 | *Salvinia* x *molesta* D.S. Mitch. | + | + | + | + | + | + | |
| 335 | *Sceptridium daucifolium* (Wall. ex Hook. & Grev.) Lyon | + | | + | | | | |
| 336 | *Schizaea dichotoma* (L.) Sm. | + | | | | | | VU |
| 337 | *Selaginella bryopteris* (L.) Baker | + | | | | | | |
| 338 | *Selaginella cataractarum* Alston. | + | + | | | | | CR |
| 339 | *Selaginella ciliaris* (Retz.) Spring. | + | + | + | + | | + | |
| 340 | *Selaginella crassipes* Spring. | | | | + | | | |
| 341 | *Selaginella delicatula* (Desv. *ex* Poir.) Alston. | + | | + | + | + | + | |
| 342 | *Selaginella ganguliana* R.D. Dixit | + | | | | | | |
| 343 | *Selaginella inaequalifolia* (Hook. Gerv) Spring | + | + | | | | | |
| 344 | *Selaginella intermedia* (Blume) Spring | | + | | | + | | |
| 345 | *Selaginella involuens* (SW.) Spring | + | + | | | | | |
| 346 | *Selaginella keralensis* R.D. Dixit | + | | | | | | |
| 347 | *Selaginella kraussiana* (Kunze) A.Braun | + | | | | | | LC |
| 348 | *Selaginella microdendron* | | + | | | | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baker | | | | | | | |
| 349 | *Selaginella miniatospora* (Dalzell) Baker. | | + | + | + | + | | NT |
| 350 | *Selaginella monospora* Spring. | | | + | | | | |
| 351 | *Selaginella plana* (Desv. ex Poir) Hieron. | | | + | | | | |
| 352 | *Selaginella proniflora* (Lam.) Baker | | | + | | + | | |
| 353 | *Selaginella radicata* (Hook.and grev) Spring | | + | | | + | | |
| 354 | *Selaginella repanda (Desv. ex Poir.) Spring.* | | | + | + | | + | |
| 355 | *Selaginella tamariscina (P.Beauv.) Spring* | | + | | | | | |
| 356 | *Selaginella tenera (Hook. &Grev.) Spring* | + | + | | + | + | | |
| 357 | *Selaginellavaginata Spring* | | + | | | | | |
| 358 | *Selaginella vogelii Spring* | | + | | | | | |
| 359 | *Selaginella wightii Hieron.* | | + | | | | | |
| 360 | *Selaginella willdenowii (Desv. ex Poir.) Baker* | + | | | | | | |
| 361 | *Selliguea hastata (Thunb.) Fraser-Jenk.* | | | + | | | | |
| 362 | *Selliguea lehmannii (Mett.) X. C. Zhang & L. J. He* | | + | | | | | EN |
| 363 | *Selliguea montana (Sledge) Hovenkamp* | + | | | | | | |
| 364 | *Selliguea oxyloba (Wall. ex. Kunze) Fraser-Jenk.* | | | + | | | | |
| 365 | *Sphaerostephanos arbusculus subsp. arbusculus* | | | + | | | | |
| 366 | *Sphaerostephanos subtruncatus (Bory) Holttum* | | + | | | | | |

 ISBN: 978-93-340-7821-3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 367 | *Sphaerostephanos unitus (L.) Holttum* | | + | | | | | |
| 368 | *Stenochlaena palustris (Burm.fil.) Bedd.* | + | + | | | + | | |
| 369 | *Tectaria cicutaria (L.) Copel.* | | | | | + | + | |
| 370 | *Tectaria coadunata (Wall. ex Hook. and Grev.) C. Chr.* | + | + | + | + | + | + | |
| 371 | *Tectaria fuscipes (Wall.) C. Chr.* | | | + | | | | |
| 372 | *Tectaria paradoxa (Fee) Sledge* | + | + | + | + | | | |
| 373 | *Tectaria polymorpha (Wall. ex Hook.) Copel.* | | | + | | | | |
| 374 | *Tectaria trimenii (Bedd.) C. Chr.* | + | | | | | | CR |
| 375 | *Tectaria wightii (C. B. Clarke) Ching* | + | + | + | | | | |
| 376 | *Tectaria zeilanica (Houtt.) Sledge* | + | + | | | | | EN |
| 377 | *Thelypteris confluens (Thunb.) C.V.Morton* | | + | | | | | CR |
| 378 | *Thelypteris dentata (Forssk.) H.St. John* | + | + | + | | + | | LC |
| 379 | *Thelypteris pozoi(Lag.) C.V.Morton* | + | | | | | | LC |
| 380 | *Thelypteris tetragona (Sw.) Small* | | | + | | | | LC |
| 381 | *Tomophyllum subfalcatum (Blume) Parris* | + | + | | | | | |
| 382 | *Trigonospora caudipinna (Ching)Sledge* | | + | + | | | | |
| 383 | *Trigonospora tenera (Roxb.) Mazumdar* | + | + | | | + | | |
| **Total number of species in each state** | | **227** | **249** | **148** | **82** | **73** | **27** | |

## 4. Conclusion

The conservation of endemic ferns in the Western Ghats is crucial for preserving the unique biodiversity and ecological balance of this region. Endemic ferns play a significant role in the ecosystem by providing habitat and food sources for numerous species, contributing to soil health, and maintaining overall ecosystem resilience. Efforts to conserve endemic ferns in the Western Ghats should focus on habitat protection, restoration, and sustainable management practices. This includes establishing protected areas, conducting research on fern populations, raising awareness about their importance, and engaging local communities in conservation efforts. By safeguarding endemic ferns in the Western Ghats, we not only protect these species themselves but also help to maintain the health and integrity of the entire ecosystem. Conservation actions taken today will have long-lasting benefits for future generations and ensure the continued existence of these unique and valuable plants in this biodiverse hotspot.

## Reference

1. Abraham, S., Ramachandran, V.S., 2013. Additions to the Pteridophytic Flora of Tamil Nadu, India., Annals of Plant Sciences. 2(8), 268-271.
2. Alagesaboopathi, C., Subramanian,G., Prabakaran, G., Vijayakumar, R.P., Jayabal, D., 2018. Pteridophytic flora of Kanjamalai hills, Salem district of Tamil Nadu, South India., International Journal of Pharmacy and Biological Sciences. 8(3), 371- 373.
3. Alston, A.H.G.,1945. An enumeration of the Indian species of *Selaginella*. Proceedings of the National Institute of Sciences of India., 11, 211-235.

4. Ashwini, S., Parashurama, T.R., 2014. Pteridophytic composition in Banajalaya forest region, Karnataka, South India., International Journal of Sciences and Research. 3(10): 954- 957.
5. Benniamin, A., Irudayaraj, V., Manickam, V.S., 2008. How to identify rare and endangered ferns and fern allies., Indian Fern Journal. 12, 108- 117.
6. Bhardwaja, T.N., Gena, C.B., Verma, S., 1987. Status survey of pteridophytic flora of Rajasthan with special reference to endangered ferns and fern allies., Indian Fern Journal. 4, 47-50.
7. Blatter, E.D., Almeida, J.E., 1922. The Ferns of Bombay. Bombay, D.B., Taraporevala Sons and Co. 56-103.
8. Dabgar, P.J., 2012. A contribution to the flora of Wadhvana wetland, Dabhoi Taluka (Gujarat) India., Biosciences. 3(2), 218-221.
9. Datar, M.N., Lakshminarasimhan, P., 2010, Habitat based Pteridophyte Diversity from Western Ghats of Goa, India., Phytotaxonomy.10, 70-76.
10. Deepa, J., Parashurama, T.R., Krishanappa, M., Nataraja, S., 2013. Distribution of pteridophytes in Kigga forest, Central Western Ghats, Karnataka, South India., Indian Fern Journal. 30, 18-24.
11. Deepa, J., Parashurama, T.R., Krishanappa, M., Nataraja, S., 2017. Enumeration of pteridophytes in Madhuguni forest, Central Western Ghats, Karnataka, South India., Indian Fern Journal. 28, 112-119.
12. Dixit, R.D., 1984. A Census of the Indian Pteridiphytes., BSI. 4, 1-177.
13. Dixit, R.D., Panigrahi G., 1969. Studies in Indian Pteridophytes-III the Family Marattiaceae (Sensu

Copeland, 1947) in India., Nelumbo - The Bulletin of the Botanical Survey of India, 2, 367–371.
14. Dudani, S.N., Mahesh, M.K., Subash, C.M.D., Ramachandra, T.V., 2014. Pteridophyte diversity in wet evergreen forests of Sakleshpur in Central Western Ghat., International Journal Plant Sciences. 3(1),28-39.
15. Holttum, R.E., 1976. Thelypteridaceae. In: Flora of Hassan district of Karnataka, India., Co Pvt Ltd. New Delhi.
16. Joseph, M.D., Rijuraj, M.P., Abi, P.K., 2017. Pteridophyte flora of Dr. Salim Ali birds' sanctuary, Thattekad, Ernakulam, Kerala – A preliminary study., International Journal of Current Research in Modern Education. 2(2), 153-158.
17. Joseph, J.M., Thomas, B., 2015. Chasmophytic Pteridophytes in Urumbikkara Hills of Idukki District, Kerala, India., International Journal of Research and Review. 2(2),41-45.
18. Kammathy, R.V., Rao, A.S., Rao, R.S., 1967. A contribution towards Flora of Biligirirangan Hills, Mysore state., Bulletin of the Botanical Survey of India. 9(1-4), 206-234.
19. Kavitha, C., G., Manoj, Murugan, K., 2015). Diversity of pteridophytes of Ponmudi hills., International Journal of Building Pathology and Adaptation S4. (10), 6180-6190.
20. Kumari, J., Jeeva, S., 2018. Diversity of Pteridophytes along the Stretches of Thamiraparani River (West), Kanyakuamri District, Tamilnadu, India., Journal of Emerging Technologies and Innovative Research. 5(1), 1091- 1095.

21. Manickam, S., 1995. Rare and endangered ferns of Western Ghats of south India., Fern Gazette. 15, 1-10.
22. Manickam, V.S., Irudayaraj, V., 1992. Pteridophyte Flora of the Western Ghats- South India., B I Publications, New Delhi.
23. Manickam, V.S., Irudayaraj, V., 2003. Pteridophyte flora of Nilgiris, South India. Dehradun, India: Bishen Singh 1129 Mahendra Pal Singh. Dehra Dun. 192.
24. Matchperson, T.R.M., 1986. List of ferns gathered in North Kanara., Journal of Bombay Natural History Society. 5, 375-377.
25. Modi, N.R., Dudani, S.N., 2013. Biodiversity Conservation through Urban Green Spaces: A Case Study of Gujarat University Campus in Ahmedabad., International Journal of Conservational Science. 4, 189-196.
26.
27. Muktesh Kumar, M.S., 1998. Studies on the fern flora of Kerala with special reference to Sylvan Valley, Munnar., KFRI Research Report.145,1-86.
28. Nayar, N.C., Daniel, P., 1986. The floistic diversity of western ghats of south India and its conservation., Proceedings of Indian Academy of sciences and suppliments. 12, 127-163
29. Nayar, B.K., Chandra, P., 1964. A New Species and Variety of Bolbitis from India., American Fern J. 54(1), 9-19.
30. Nayar, N.M., 2010. Agrobiodiversity in a biodiversity hotspot: Kerala State, India. Its origin and status., Genetic Resources.
31. Packiaraj, P., Suresh, K., 2019. Pteridophytic diversity of Kilavarai freshwater river in upper Palni hills of Southern

Western Ghats, Kodaikanal, Tamil Nadu, India. International Journal of Basic and Applied Research.9(7), 643-648.

32. Parashurama, T.R., Deepa, J., Kariyajjanavar, P., 2016. Pteridophyte diversity in Mudigere taluk, Central Western Ghats, Karnataka, south India., International Journal of Current Research. 8(10), 339-342.
33. Patel, R.S., Patel, K.C., Patel, N.B., Patel, K., Shah, R.B., Joshi,H., 2010. Floristic survey of campus of Art. Com. and Sci. College, Borsad (Gujarat), India., Plant Archives.10(1), 293-297.
34. Rajagopal, P.K., Bhat, K.G., 1998. Pteridophytic flora of Karnataka State, India., Indian Fern J. 15, 1-28.
35. Rajput, K.S., Kachhiyapatel, R.N., Patel, S.K., Raole,V.M., 2016. Assessment of pteridophyte Diversity. 337-348.
36. Ramachandra, T.V., Suja, A., 2006. Sahyadri: western ghats biodiversity information system. Biodiversity in Indian Scenario. 1, 1-22.
37. Rekha, K., Athira Krishnan., 2017. Diversity of pteridophyte flora in Akamala forest station, Thrissur, Kerala., Int. J. Fauna and Biol. Studies. 4(5),1-3.
38. Ruma Talukdar., 2018. A Synthesis of Information on State- Wise Forest Cover Change for the Period 2000-2017 in India., IJMTT. 54(6), 454-466.
39. Sahaya Sathish, S., Vijayakanth, P., 2016. New additions of fern flora to Kolli hills, Eastern Ghats, Tamilnadu, India., Indian Journal of Plant Sciences. 5,56–64.
40. Subina, S., Arun Sasi, S., Raju Antony, Gopikrishna, V.G., MaheshMohana, 2021. Pteridophyte diversity in

Pampadum shola national park southern Western Ghats, India., 1(1), 24-28.

41. Sukumaran, S., Jeeva, S., Raj, A.D.S., 2009. Diversity of Pteridophytes in Miniature Sacred Forests of Kanyakumari District, Southern Western Ghats., Indian Journal of Forestry. 32(3), 285-290.
42. Sumesh Dudani, N., Mahesh, M. K., M D Subash chandran, M.D., Ramachndra, T. V., 2014. Pteridophyte diversity in wet evergreen forests of Sakleshpur in central Western Ghats., Indian Journal of Plant Sciences. 3(1), 28- 36.
43. Vijayakanth, P., Sahaya Sathish, S. Mazumdar, J., 2017. New additions to fern flora of Tamil Nadu, India. International Journal of Advanced Research. 3(4), 1671-1674.

# The Green Dilemma: Conservation Challenges in the Western Ghats

Shifa M.

PG Department of Botany, KAHM Unity Women's College, Manjeri, Malappuram, Kerala, India, 676122

Corresponding author: shifashibu7@gmail.com

The Western Ghats, a UNESCO World Heritage Site and one of the world's most biologically diverse regions, face an array of conservation challenges stemming from anthropogenic activities and climate change. This chapter delves into the multifaceted nature of these challenges, encompassing habitat loss, livestock grazing, human-animal conflict, extraction of forest products, mining, deforestation, hunting, climate change impacts, and the complexities of effective management. Drawing from a synthesis of current research, reports, and on-the-ground observations, this chapter provides a comprehensive analysis of the conservation challenges confronting the Western Ghats. It explores the intricate interplay between human activities and ecological dynamics, shedding light on the urgent need for collaborative and adaptive conservation strategies to safeguard the ecological integrity and biodiversity of this globally significant landscape. Through a detailed examination of each challenge, this chapter aims to inform policymakers, conservation practitioners, and stakeholders about the critical issues at hand, ultimately advocating for proactive measures to address these challenges and ensure the long-term resilience of the Western Ghats' ecosystems.

**Keywords**: Western Ghats, Conservation, Biodiversity, Habitat loss, Deforestation, Mining.

## 1. Introduction

The Western Ghats, often referred to as the Sahyadri Mountains, form a majestic and ecologically vital range that spans the western coast of India (Viju, 2019). This expansive geographical feature encompasses a diverse mosaic of ecosystems, ranging from lush tropical forests and wetlands to high-altitude grasslands and montane forests (Chakraborty et al., 2023). Renowned for its exceptional biodiversity, the Western Ghats is internationally recognized as one of the planet's eight hottest biodiversity hotspots, teeming with a remarkable variety of plant and animal life found nowhere else on Earth. The biodiversity of the Western Ghats is unrivalled, boasting an extraordinary array of endemic species uniquely adapted to its diverse habitats. This region serves as a refuge for numerous plant and animal species, many of which are found in highly localized pockets within the Ghats' rugged terrain (Gunawardene et al., 2007). From the iconic Bengal tiger and Indian elephant to the elusive lion-tailed macaque and the vibrant Malabar trogon, the Western Ghats harbour an astounding richness of life that underscores its global significance in terms of biodiversity conservation (Das et al., 2006). Despite its ecological importance and protected status as a UNESCO World Heritage Site, the Western Ghats face formidable conservation challenges driven primarily by human activities (Sharma et al., 2022). Rampant deforestation, driven by agricultural expansion, urbanization, and infrastructure development, has resulted in extensive habitat loss and fragmentation, threatening the survival of countless species reliant on intact ecosystems (Bralower and Millet, 2021). Additionally, the introduction and proliferation of invasive species further exacerbate ecological imbalances, outcompeting native flora and fauna and disrupting natural ecosystems (Omondi and Merceline, 2023).

Moreover, pollution from various sources, including industrial effluents, agricultural runoff, and domestic waste, poses a significant threat to the Western Ghats' delicate ecosystems. Water bodies are contaminated, air quality is compromised, and crucial habitats are degraded, jeopardizing the health of both wildlife and human communities inhabiting the region (Dinakaran and Anbalagan, 2007). In the face of these mounting challenges, urgent action is needed to address the conservation issues plaguing the Western Ghats. Effective management strategies, informed by scientific research and supported by robust policy frameworks, are essential to mitigate the impacts of human activities and preserve the rich biodiversity and ecological integrity of this invaluable natural treasure.

## 2. Biodiversity and its richness

The Western Ghats, also known as Sahyadri, stands as a majestic mountain range spanning six Indian states, from Goa to Kanyakumari, and is renowned for its rich biodiversity (Varak, 2023). Originating from Maharashtra and Gujarat, these mountains stretch approximately 1600 km, covering an area of 1,29,037 sq km with an average elevation of 1200 meters according to the Madhav Gadgil report. Hosting an array of flora and fauna, the Western Ghats boasts 7402 species of flowering plants, 1814 species of non-flowering plants, and a diverse range of animal species, including 139 mammals, 508 birds, and 179 amphibians, among others. Notably, it shelters 325 globally threatened species and serves as vital wildlife corridors for flagship conservation projects like Project Elephant and Project Tiger (Amasiddha et al., 2012). With its ecological significance recognized globally, the Western Ghats was declared one of the eight 'hottest hotspots' of biodiversity by UNESCO, leading to the designation of thirty-nine spots as World Heritage Sites in 2012 (Miltenberger et al., 2018). However, rapid human migration and unsustainable developmental activities have posed grave threats to its delicate ecosystem, resulting in a governmental dilemma (Redford and Fearn, 2007). Two significant reports, led by environmentalists Madhav Gadgil and Dr. Kasturirangan, offered contrasting recommendations to address conservation and developmental concerns. While the Gadgil report proposed stringent measures to protect the region, including declaring it as an Ecologically Sensitive Area and imposing restrictions on dam constructions and mining activities, the Kasturirangan report suggested dilutions to accommodate developmental aspirations. Both reports faced criticism for neglecting the human aspect of the region, sparking public outrage and political opposition. As the government grapples with the complex task of balancing environmental preservation with socioeconomic development, the fate of the Western Ghats hangs in the balance, highlighting the intricate interplay between environmental, social, and political dynamics in decision-making processes (Sheela and James, 2013).

Biodiversity, the diversity of life forms within an ecosystem, encompasses various species of organisms, including plants, animals, and microorganisms, as well as the genes they possess and the ecosystems they form. According to Heywood and Baste (1995), biodiversity is defined as the number, variety, and variability of living organisms in a given ecosystem. However, biodiversity cannot be solely expressed in numbers; it also depends on the ecological structure of an area. Whittaker (1972) identified three types of diversity: alpha, beta, and gamma diversity. Alpha diversity represents diversity within each geographical group, while beta diversity reflects the proportion of diversity due to differences among geographical populations, and gamma diversity represents the total diversity within plants. Biodiversity can be further categorized into genetic, species, and ecosystem diversity. Genetic diversity refers to the variability in the individuals of

 ISBN: 978-93-340-7821-3

a species, characterized by numerous genes that result in differences in genetic makeup among individuals (Mukhopadhyay and Bhattacharjee, 2016). Genetic variability is crucial for a healthy breeding population as it contributes to resistance to disease and parasites and enables flexibility in coping with environmental challenges, ultimately preventing species extinction (Naskar et al., 2012).

Species diversity, on the other hand, pertains to the number of plant and animal species present in a region, known as species richness (Whittaker et al., 2001). Tropical rainforests, for example, support higher species diversity compared to desert ecosystems. Hotspots of biodiversity are areas abundant in species diversity, endemic species, and rare or threatened species (Marchese, 2015). Species diversity is essential for ecosystem functioning as it influences productivity and stability. Ecosystem diversity focuses on the diversity within and between ecosystems, which are the result of various biological, climatic, geological, and chemical factors. Ecosystems such as forests, grasslands, deserts, mountains, and aquatic ecosystems play a crucial role in supporting biodiversity. However, the exploitation or overuse of species within ecosystems can lead to productivity loss and deterioration (Chu, 2020).

The consequences of biodiversity loss are difficult to analyze based solely on genetic or species diversity. Various conservation strategies are necessary to address threats to biodiversity and ensure present and future human well-being. These strategies include habitat preservation, species protection, sustainable resource management, and raising

 ISBN: 978-93-340-7821-3

awareness about the importance of biodiversity conservation. Conservation strategies must be implemented on a large scale to address threats and mitigate the impacts of biodiversity loss on ecosystems and human well-being (Rawat and Agarwal, 2015). The biodiversity is facing many threats due to the human encroachment and their activities as well as few natural factors which can be enumerated below

## 3. Livestock Grazing

Livestock grazing within and bordering protected areas, particularly in the biodiverse ecosystem of the Western Ghats, presents a significant environmental challenge due to its detrimental impact on habitat integrity (Ramachandran et al., 2018). The region's lush forests and diverse wildlife face threats from high densities of cattle and goats, which degrade habitats through overgrazing, soil compaction, and trampling of vegetation (Rawat and Adhikari, 2015). As human populations in the surrounding areas grow, so does the demand for livestock, exacerbating the issue. This increase in livestock densities intensifies the pressure on already fragile ecosystems, leading to a vicious cycle of habitat degradation and biodiversity loss (Wassie, 2020). Furthermore, the rising demand for grazing land often encroaches upon protected areas, sparking conflicts between local villagers, who rely on livestock for their livelihoods, and forest department officials tasked with conservation efforts. These conflicts arise from competing interests, with villagers seeking to sustain their livelihoods through traditional practices while conservationists strive to protect the fragile ecosystems and biodiversity hotspots of the Western Ghats (Bijoy, 2019). The clash between these interests often results in tense standoffs,

 ISBN: 978-93-340-7821-3

hindering effective conservation measures and exacerbating habitat degradation. Such conflicts underscore the urgent need for holistic management strategies that balance the needs of local communities with the imperative of conserving the invaluable ecological resources of the Western Ghats. Collaborative efforts involving stakeholders from government agencies, local communities, and conservation organizations are essential to address this complex issue, ensuring the long-term sustainability of both livelihoods and biodiversity in the region (Jamal and Stronza, 2009).

One of the primary drivers of the conflict is the close relationship between livestock densities and human population growth. As human populations expand in the vicinity of protected areas, the demand for livestock increases to meet the growing needs of communities for food, income, and other resources. This, in turn, leads to a rise in livestock densities, exacerbating the pressure on natural habitats within and around protected areas. Consequently, conflicts between villagers and forest department officials escalate as villagers compete for limited grazing resources and resist efforts to regulate or restrict livestock grazing in protected areas (Herrero et al., 2013). The consequences of unchecked livestock grazing are severe and far-reaching. Habitat degradation not only threatens the survival of numerous plant and animal species but also undermines the ecosystem services provided by protected areas. Degraded habitats are less resilient to environmental stressors such as climate change, making them more susceptible to further deterioration and loss of biodiversity. Moreover, the conflicts arising from livestock grazing hinder conservation efforts and strain relationships between communities and conservation authorities, complicating the implementation of effective management strategies (Mori et al., 2013).

To address these challenges, it is crucial to adopt a collaborative and participatory approach that engages all stakeholders in finding sustainable solutions. This approach should involve the implementation of community-based conservation initiatives, promotion of alternative livelihood options that reduce dependence on livestock grazing, establishment of clear regulations and enforcement mechanisms, and provision of incentives for sustainable land management practices. By fostering cooperation and mutual understanding among stakeholders, it is possible to mitigate the adverse effects of livestock grazing and ensure the long-term protection of the Western Ghats' unique biodiversity and ecosystems (Dyani et al., 2022).

**4. Human- animal Conflict**

Human-animal conflicts in the Western Ghats of India present a multifaceted challenge, characterized by the coexistence of diverse wildlife and human populations (Oommen, 2021). The region's rich biodiversity, including species such as elephants and tigers, contributes to a complex dynamic where conflicts arise due to crop and livestock losses. These conflicts arise due to various factors, including the proximity of human settlements to wildlife reserves, land-use patterns, and agricultural practices prevalent in the region (Thomassen et al., 2011). The unique ecological landscape of the Western Ghats, characterized by its diverse vegetation cover and topographical variations, further complicates the dynamics of human-wildlife conflicts. The dense forests and fragmented habitats provide suitable habitats for wildlife, bringing them into close proximity to human settlements and agricultural lands. This spatial overlap increases the likelihood of conflicts, as wildlife venture into farmlands in search of food or water, resulting in crop depredation and damage to property (Choudhury et al., 2023).

Additionally, socio-economic factors also play a significant role in shaping the vulnerability of communities to wildlife-related losses in the Western Ghats. Household resources, such as land size and economic assets, influence the ability of communities to cope with and recover from conflict incidents. Furthermore, the adoption of mitigation measures, such as installing fencing, guarding livestock, or using deterrents like lighting, can mitigate the risk of conflicts and minimize losses (Rajvanshi et al., 2001). However, the implementation of these measures often depends on the financial resources and awareness levels of local communities. Access to compensation for losses incurred due to wildlife conflicts further adds complexity to the situation, with variations based on factors such as the species involved, the type of conflict, and the ability of households to report incidents. Despite the availability of compensation schemes, challenges associated with timely and equitable distribution often lead to dissatisfaction among affected communities (Barua et al., 2013).

The Western Ghats of India provide an ideal setting to study the intricate interplay of ecological, social, and economic factors driving human-animal conflicts. Effective management of these conflicts requires a holistic approach

 ISBN: 978-93-340-7821-3

that addresses both ecological conservation and socio-economic development goals. By understanding the underlying drivers of conflicts and implementing targeted mitigation strategies, it is possible to promote harmonious coexistence between humans and wildlife while safeguarding livelihoods and biodiversity in the region (Redpath et al., 2013).

## 5. Deforestation

Deforestation in the Western Ghats, a UNESCO World Heritage Site and one of the world's eight "hottest hotspots" of biological diversity, poses a grave threat to both the environment and human populations reliant on its resources (Kumar, 2019). The Western Ghats, spanning six states in India, harbour a unique and rich biodiversity, encompassing dense forests, diverse flora and fauna, and critical watersheds. However, rampant deforestation driven by various factors including agricultural expansion, logging, infrastructure development, and illegal encroachments is rapidly depleting this invaluable ecosystem (Raman et al., 2009). The conversion of forested lands for agriculture, particularly for cash crops like tea, coffee, and spices, has led to widespread habitat loss and fragmentation, disrupting ecological processes and threatening numerous endemic species found nowhere else on Earth (Sodhi et al., 2013).

The consequences of deforestation in the Western Ghats are multifaceted and far-reaching. Loss of forest cover not only diminishes the region's biodiversity but also exacerbates climate change by reducing carbon sequestration capacity and altering local weather patterns. Moreover, the disruption of natural habitats increases human-wildlife conflicts as animals are forced to venture into human settlements in search of food and shelter. This poses risks to both wildlife and local communities, leading to conflicts and loss of lives on both sides (Kumar and Srivastava, 2018). The Western Ghats are also crucial for providing ecosystem services such as regulating water flow, soil conservation, and supporting agricultural productivity in the surrounding areas. Deforestation disrupts these services, leading to soil erosion, reduced water availability, and decreased agricultural yields, thereby impacting the livelihoods of millions of people who depend on these resources for their sustenance (Kumar et al., 2022). Efforts to mitigate deforestation in the Western Ghats have been met with various challenges, including inadequate enforcement of environmental regulations, weak governance, and competing interests for land use. Despite the existence of protected areas and conservation initiatives, illegal logging and encroachments continue to persist due to limited resources for monitoring and enforcement (Garcia et al., 2010).

Addressing deforestation in the Western Ghats requires a multifaceted approach that integrates conservation efforts with sustainable development strategies. This entails strengthening environmental governance, enhancing law enforcement, promoting community-based conservation initiatives, and incentivizing sustainable land management practices among local communities and stakeholders (Kothari et al., 2013). Furthermore, raising awareness about the ecological significance of the Western Ghats and fostering a sense of stewardship among the public is crucial for ensuring the long-term conservation of this unique and irreplaceable ecosystem.

Only through concerted efforts and collaboration between governments, civil society, and local communities can we hope to safeguard the Western Ghats for future generations and preserve its invaluable biodiversity and ecosystem services (Naruka and Reddy, 2023).

## 6. Habitat loss

The Western Ghats, a UNESCO World Heritage Site and one of the world's biodiversity hotspots, faces significant challenges regarding habitat loss, posing a threat to its rich and unique ecosystems (Sharma et al., 2022). Spanning six states along the western coast of India, the Western Ghats are home to a diverse array of flora and fauna, including numerous endemic species found nowhere else on Earth. However, rampant human activities such as deforestation, urbanization, agricultural expansion, and infrastructure development have led to substantial habitat loss and fragmentation within this ecologically sensitive region. Deforestation stands out as one of the primary drivers of habitat loss in the Western Ghats. Historically, large swathes of forest cover have been cleared for timber extraction, agriculture, and settlement expansion, leading to the destruction of critical habitats for numerous plant and animal species (Viju, 2019). The loss of forest cover not only reduces biodiversity but also disrupts ecological processes, leading to imbalances in local ecosystems. Urbanization and agricultural expansion further exacerbate habitat loss in the Western Ghats. As human populations grow and urban centres expand, natural habitats are converted into residential and commercial areas, resulting in the fragmentation and isolation of remaining forest patches. Similarly, agricultural activities such as

plantation farming and monoculture practices lead to the conversion of natural habitats into agricultural landscapes, displacing native flora and fauna and reducing overall biodiversity (Liu et al., 2019).
Infrastructure development, including road construction, dam building, and mining activities, also contributes significantly to habitat loss in the Western Ghats (Mohit and Samant, 2013). The construction of roads and highways through forested areas not only results in direct habitat destruction but also creates barriers that hinder the movement of wildlife and disrupt ecological connectivity (Seiler, 2001). Similarly, the building of dams for hydroelectric projects and mining activities for mineral extraction led to the destruction of natural habitats and the fragmentation of landscapes, further threatening biodiversity in the region (Hughes, 2017).

The cumulative impact of these human activities has led to a severe decline in habitat quality and quantity across the Western Ghats. Fragmentation of habitats, loss of biodiversity, and disruption of ecological processes are some of the adverse effects observed due to habitat loss in this region (Fahrig, 2003). Additionally, habitat loss in the Western Ghats has broader implications for ecosystem services, including water regulation, soil conservation, and climate regulation, affecting the well-being of both local communities and the broader region (Srivasthsa et al., 2023).

Addressing habitat loss in the Western Ghats requires concerted efforts aimed at conservation and sustainable land management practices. Strategies such as protected area establishment, habitat restoration, community-based conservation initiatives, and sustainable development planning are essential to mitigate the adverse effects of habitat loss and preserve the unique biodiversity of this ecologically significant region. Moreover, collaborative efforts involving government agencies, conservation organizations, local communities, and other stakeholders are crucial for effective conservation action in the Western Ghats, ensuring the long-term survival of its diverse ecosystems and the species they support (Ghats and Hotspot, 2013).

## 7. Climate change

Climate change poses a formidable challenge to conservation efforts in the Western Ghats, a UNESCO World Heritage site renowned for its rich biodiversity and unique ecosystems (Kandekar and Srivastava, 2014). The region, characterized by diverse habitats ranging from dense tropical forests to montane grasslands, faces escalating threats from changing climatic conditions. One of the most significant impacts of climate change is the alteration of precipitation patterns, which can lead to shifts in vegetation distribution and changes in ecosystem composition (Grim et al., 2013). This, coupled with rising temperatures, threatens the survival of many endemic species that are adapted to specific climatic conditions. Habitat fragmentation is another critical issue exacerbated by climate change in the Western Ghats (Bhatt et al., 2018). As temperatures rise and precipitation patterns become erratic, habitats become fragmented, isolating populations and reducing genetic connectivity among species. This fragmentation not only disrupts ecological processes but also increases the vulnerability of species to extinction. Moreover, the Western Ghats are home to numerous endemic

species with narrow geographic ranges, making them particularly susceptible to the impacts of habitat fragmentation (Opdam and Wascher, 2004).
Invasive species also pose a significant threat to the biodiversity of the Western Ghats in the context of climate change. As temperatures increase, invasive species from lower altitudes or latitudes may expand their ranges into higher elevations or latitudes, outcompeting native species and disrupting fragile ecosystems. This can lead to the loss of biodiversity and ecosystem services essential for the well-being of local communities dependent on these ecosystems for their livelihoods (Dukes, 2011).

Addressing the impacts of climate change on conservation in the Western Ghats requires a multifaceted approach. Ecosystem-based adaptation strategies, such as habitat restoration and conservation corridors, can enhance the resilience of ecosystems to climate change impacts. Engaging local communities in conservation efforts, promoting sustainable land-use practices, and building community resilience are also crucial components of effective conservation strategies Naumann et al., 2011). Furthermore, integrating climate change considerations into conservation policies and management plans is essential to ensure the long-term viability of conservation efforts in the face of changing climatic conditions.

Research and monitoring programs play a vital role in understanding the impacts of climate change on biodiversity and ecosystems in the Western Ghats. By collecting data on species distributions, habitat dynamics, and ecosystem processes, researchers can inform evidence-based conservation decision-making and adaptive management strategies (Gillson et al., 2019). Ultimately, a collaborative approach involving policymakers, scientists, local communities, and civil society organizations is necessary to address the complex challenges posed by climate change and safeguard the biodiversity and ecosystems of the Western Ghats for future generations.

## 8. Mining

Mining activities in the Western Ghats have had a profound impact on biodiversity conservation in this ecologically sensitive region (Ramachandra et al., 2018). The expansion of mining operations has led to significant habitat destruction, fragmentation, and ecosystem degradation, posing serious threats to the survival of numerous species. One of the primary concerns regarding mining in the Western Ghats is the destruction of natural habitats. Mining activities often involve the clearing of large areas of vegetation, including forests and grasslands, to access mineral deposits (Sonder et al., 2014). This deforestation not only directly eliminates crucial habitat for many species but also disrupts important ecological processes such as nutrient cycling and water regulation. Additionally, the fragmentation of habitats caused by mining infrastructure further exacerbates the isolation of wildlife populations, leading to reduced genetic diversity and increased vulnerability to extinction (Thatte et al., 2018).

Furthermore, mining operations in the Western Ghats have detrimental effects on freshwater ecosystems. The extraction of minerals often requires the diversion and contamination of water sources, leading to the pollution of rivers, streams, and

 ISBN: 978-93-340-7821-3

wetlands. This pollution not only affects aquatic organisms directly but also has cascading impacts on terrestrial species that depend on freshwater resources for survival. Moreover, the disturbance of river systems and sedimentation resulting from mining activities can alter the hydrological regimes of entire watersheds, further disrupting the balance of ecosystems and threatening the survival of aquatic biodiversity (Wolkersdorfer and Mugova, 2021).

The influx of human populations associated with mining activities also poses additional pressures on biodiversity conservation in the Western Ghats (Nagarajan et al., 2015). Rapid urbanization, infrastructure development, and associated activities such as logging and agriculture further encroach upon natural habitats and exacerbate the fragmentation of ecosystems. This human-wildlife interface often leads to conflicts between humans and wildlife, resulting in retaliatory killings, habitat degradation, and disruption of ecological processes (Kumar et al., 2022).

Despite these significant impacts, the regulation and enforcement of environmental laws in the context of mining activities in the Western Ghats have often been inadequate. Weak governance, corruption, and lack of transparency in decision-making processes have facilitated the unchecked expansion of mining operations, exacerbating environmental degradation and biodiversity loss. Additionally, the socio-economic benefits derived from mining activities often overshadow environmental concerns, leading to a prioritization of short-term economic gains over long-term sustainability (Asuamah, 2023).

The mining activities in the Western Ghats have emerged as a major threat to biodiversity conservation in this globally significant region. The destruction of natural habitats, pollution of freshwater ecosystems, and associated human pressures have led to a decline in species populations and ecological integrity. Urgent measures are needed to address the root causes of environmental degradation, strengthen regulatory mechanisms, and promote sustainable development practices that prioritize biodiversity conservation in the Western Ghats.

**9. Extraction of forest products**

The Western Ghats, sustains a diverse array of flora and fauna crucial for ecological balance and human well-being. However, the extraction of forest products in this region has raised concerns regarding its adverse effects on biodiversity (Bawa and Seidler, 1998). This report aims to delve into the intricate relationship between forest product extraction and biodiversity loss in the Western Ghats, drawing upon authentic literature. Forests in the Western Ghats harbor a rich diversity of plant species, many of which serve as sources of livelihood for local communities through extraction for timber, non-timber forest products (NTFPs), and medicinal plants (Alex and Vidyasagaran, 2014). However, indiscriminate and unsustainable extraction practices pose a significant threat to the region's biodiversity. Studies have shown that overexploitation of commercially valuable species such as teak, rosewood, and sandalwood has led to the depletion of these species, disrupting the intricate ecological balance within the forests.

 ISBN: 978-93-340-7821-3

Moreover, the extraction of NTFPs like rattan, bamboo, and medicinal plants has also been identified as a major driver of biodiversity loss. Research indicates that overharvesting of these species not only diminishes their populations but also impacts associated flora and fauna dependent on them for survival (Razal and Guerrero, 2014). For instance, the depletion of bamboo forests affects the habitat of various endemic species like the Malabar giant squirrel and the Nilgiri langur, leading to a decline in their populations. Furthermore, the extraction of medicinal plants, which are integral to traditional healthcare practices in local communities, has raised concerns regarding the loss of genetic diversity and potential extinction of certain species. This is particularly alarming given the role of medicinal plants in providing novel compounds for pharmaceutical research and drug development (Hamilton, 2004).

The consequences of forest product extraction extend beyond direct impacts on plant species to affect the entire ecosystem. Deforestation and habitat degradation resulting from extraction activities fragment habitats, disrupt ecological processes, and escalate the vulnerability of species to extinction. This fragmentation restricts the movement of wildlife, reduces genetic connectivity, and diminishes species resilience to environmental stressors such as climate change.

The extraction of forest products in the Western Ghats poses a significant threat to biodiversity conservation efforts in the region. Unsustainable extraction practices driven by commercial interests not only deplete valuable plant species but also disrupt entire ecosystems, endangering the survival of numerous endemic species. Addressing this issue necessitates a holistic approach that integrates sustainable forest management practices, community involvement, and stringent conservation policies to safeguard the unique biodiversity of the Western Ghats for future generations.

## 10. Hydropower projects

The Western Ghats, a biodiversity hotspot in India, is under significant pressure due to various anthropogenic activities, including the development of hydropower projects (Jumani et al., 2013). These projects have been a subject of debate concerning their environmental impact, particularly on the region's rich and diverse flora and fauna. Hydropower projects in the Western Ghats region have led to the alteration of natural water flow patterns, which in turn disrupts the habitat of numerous species. Fragmentation of river systems due to dam construction isolates populations, affecting genetic diversity and potentially leading to the decline of endemic species. For instance, the construction of dams can obstruct fish migration routes, impacting fish populations and the livelihoods of communities dependent on fishing (Naniwadekar and Vasudevan, 2014). Moreover, the flooding of large areas for reservoir creation results in the submergence of terrestrial ecosystems, leading to habitat loss for various species, including amphibians, reptiles, and mammals. This loss of habitat exacerbates the threat of species extinction, particularly for those with specialized habitat requirements or limited dispersal abilities (Alho and Silha, 2012).

The altered flow regimes downstream of dams also affect riparian vegetation, which plays a crucial role in providing habitat, food, and shelter for diverse aquatic and terrestrial

 ISBN: 978-93-340-7821-3

species. Changes in water flow can lead to the loss of riparian vegetation, impacting biodiversity both directly and indirectly through altered ecological processes. Additionally, the construction phase of hydropower projects involves extensive land clearing, which further contributes to habitat destruction and fragmentation. This can lead to increased human-wildlife conflict as displaced wildlife may encroach upon human settlements in search of alternative habitats and resources Pandit and Grumbine, 2012).

To mitigate the adverse effects of hydropower projects on biodiversity in the Western Ghats, several measures have been proposed. These include the implementation of comprehensive Environmental Impact Assessments (EIAs) to evaluate potential impacts and identify mitigation measures before project approval. Additionally, the adoption of environmentally sustainable practices such as fish ladders and bypass channels can facilitate fish migration and mitigate the impacts of dam construction on aquatic biodiversity.

Furthermore, the conservation and restoration of riparian vegetation through afforestation and restoration initiatives can help maintain ecological connectivity and support biodiversity conservation in the region. Engaging local communities and stakeholders in conservation efforts and ensuring their participation in decision-making processes regarding hydropower projects can also enhance the effectiveness of biodiversity conservation measures. Hydropower projects in the Western Ghats region have significant implications for biodiversity, leading to habitat loss, fragmentation, and altered ecological processes. However, by implementing rigorous

 ISBN: 978-93-340-7821-3

environmental assessments and adopting sustainable practices, it is possible to mitigate these impacts and promote the conservation of biodiversity in this critical ecological hotspot.

**11. Hunting**

The Western Ghats, face a significant threat from hunting activities. This region, renowned for its rich biological diversity, is home to numerous endemic species of flora and fauna. However, the unchecked practice of hunting poses a severe risk to the delicate ecological balance of this vital ecosystem Kuriakose and Sebastian, 2016). Hunting in the Western Ghats has a profound impact on biodiversity, affecting various species across different trophic levels. Large mammals such as tigers, leopards, and elephants are targeted for their body parts, which are often traded in illegal wildlife markets. This indiscriminate hunting disrupts the natural predator-prey dynamics, leading to imbalances in the ecosystem. As key species are eliminated or reduced in number, it cascades down the food chain, affecting vegetation and smaller animal populations (Sethi et al., 2019).

Birds, both resident and migratory, are also vulnerable to hunting activities in the Western Ghats. Species like the Great Indian Bustard and the Malabar Grey Hornbill face threats from poaching for their feathers, meat, or as trophies. The loss of these avian species not only disrupts the intricate web of interactions within the ecosystem but also affects pollination and seed dispersal, ultimately impacting plant diversity (Saha and Mazumdar, 2017). Moreover, the practice of hunting for bushmeat, particularly of smaller mammals like deer, wild boar, and rabbits, has significant ecological ramifications. These animals play crucial roles in seed dispersal and herbivory, influencing vegetation dynamics and forest regeneration. Their decline due to hunting can lead to shifts in plant communities and affect the overall structure and composition of the forest ecosystem (Chardonnet et al., 2002).

Additionally, the use of indiscriminate hunting methods such as snares and traps not only target specific species but also results in the unintended capture of non-target species, including endangered or protected animals. This bycatch further exacerbates the pressure on already vulnerable populations and contributes to the overall decline in biodiversity (Figal et al., 2021). Furthermore, hunting disturbs wildlife behavior and distribution patterns, as animals alter their movements and habitats to avoid human disturbances. This displacement can lead to increased human-wildlife conflicts as animals encroach into human settlements in search of refuge, food, or new territories.

Hunting poses a significant threat to biodiversity in the Western Ghats, jeopardizing the survival of numerous species and disrupting the intricate ecological balance of this unique and ecologically important region. Urgent and concerted efforts are needed to address this issue through effective enforcement of wildlife protection laws, community-based conservation initiatives, and public awareness campaigns to curb illegal hunting practices and safeguard the biodiversity of the Western Ghats for future generations.

## 12. Conclusion

The Western Ghats face a myriad of challenges that threaten the delicate balance of its biodiversity. From livestock grazing to mining, deforestation to the extraction of forest products, and the looming impacts of climate change and hydropower projects, these pressures collectively endanger the unique ecosystems and species that call this region home. The urgency of conserving biodiversity in the Western Ghats cannot be overstated. It is not merely a matter of preserving natural beauty or safeguarding wildlife; it is essential for the sustenance of local communities dependent on ecosystem services and for the broader goal of global biodiversity conservation.

Addressing these challenges requires a multifaceted approach that involves policymakers, local communities, conservationists, and various stakeholders. Strategies must be implemented to regulate and mitigate the adverse effects of activities such as livestock grazing and mining, while promoting sustainable practices that prioritize conservation. Furthermore, efforts to minimize human-animal conflicts and adapt to the impacts of climate change are essential for the long-term survival of the Western Ghats' biodiversity. This necessitates robust conservation policies, effective enforcement mechanisms, community engagement, and investment in research and monitoring. Ultimately, the conservation of the Western Ghats' biodiversity is not only a moral imperative but also crucial for maintaining ecological balance and ensuring the well-being of current and future generations. By acknowledging the challenges and working collaboratively to address them, we can strive towards a future where the rich biodiversity of the Western Ghats is preserved for generations to come.

## References

1. Alex, A., & Vidyasagaran, K. (2014). Dependence on no timber forest products (NTFP) for the sustainable livelihood enhancement of tribals of western Attappady (Doctoral dissertation, Department of Forest Management and Utilisation, College of Forestry, Vellanikkara).
2. Alho, C. J., & Silva, J. S. (2012). Effects of severe floods and droughts on wildlife of the Pantanal wetland (Brazil)-a review. Animals, 2(4), 591-610.
3. Amasiddha Bellundagi, A. B., Jagadish Hosamani, J. H., Sripathy, K. V., & Itigi Prabhakar, I. P. (2012). Protection of south WesternGhats forest: a treasure of national biodiversity.88-93.
4. Anand, M. O., Krishnaswamy, J., Kumar, A., & Bali, A. (2010). Sustaining biodiversity conservation in human-modified landscapes in the Western Ghats: remnant forests matter. Biological Conservation, 143(10), 2363-2374.
5. Asuamah Yeboah, S. (2023). Digging Deeper: The impact of illegal mining on economic growth and development in Ghana. 2-45.
6. Barua, M., Bhagwat, S. A., & Jadhav, S. (2013). The hidden dimensions of human–wildlife conflict: Health impacts, opportunity and transaction costs. Biological Conservation, 157, 309-316.
7. Bawa, K. S., & Seidler, R. (1998). Natural forest management and conservation of biodiversity in tropical forests. Conservation biology, 12(1), 46-55.
8. Bhat, M., Nayak, V. N., Chandran, M. D., & Ramachandra, T. V. (2014). Impact of hydroelectric projects on finfish diversity in the Sharavathi River

estuary of Uttara Kannada District, central west coast of India. International Journal of Environmental Sciences, 5(1), 58-66.

9. Bijoy, C. R. (2019). Conservation and livelihoods: conflicts or convergence?. In *Research handbook on law, environment and the Global South*. Edward Elgar Publishing.286-303.

10. Biswas, S., & Biswas, A. (2018). Impact of mining on forests and its biological diversity at kirandul iron Ore Mines, Dantewada, South Bastar, Chhattisgarh: A Case Study. Journal of environmental science studies, 1(1), 16.

11. Chakraborty, S. K., Sanyal, P., & Ray, R. (2023). Diversity and Classification of Wetlands in International and National Perspectives. In Wetlands Ecology: Eco-biological uniqueness of a Ramsar site (East Kolkata Wetlands, India) Cham: Springer International Publishing. 167-226.

12. Chardonnet, P., Clers, B. D., Fischer, J., Gerhold, R., Jori, F., & Lamarque, F. (2002). The value of wildlife. Revue scientifique et technique-Office international des épizooties, 21(1), 15-52.

13. Choudhury, U. R., Margulies, J. D., Mariyam, D., Rajeev, B. R., & Karanth, K. K. (2023). Seeing animals like a state? Divergent forester subjectivities and the managing of human-wildlife conflicts in South India. Geoforum, 147, 103892.

14. Chu, L. M. (2020). Ecosystems: Diversity. In Terrestrial Ecosystems and Biodiversity. CRC Press.165-175.

15. Das, A., Krishnaswamy, J., Bawa, K. S., Kiran, M. C., Srinivas, V., Kumar, N. S., & Karanth, K. U. (2006). Prioritisation of conservation areas in the Western Ghats, India. Biological conservation, 133(1), 16-31.
16. Davidar, P., Arjunan, M., & Puyravaud, J. P. (2008). Why do local households harvest forest products? A case study from the southern Western Ghats, India. Biological Conservation, 141(7), 1876-1884.
17. Dhyani, S., Sivadas, D., Basu, O., & Karki, M. (2022). Ecosystem health and risk assessments for high conservation value mountain ecosystems of south Asia: a necessity to guide conservation policies. Anthropocene Science, 1(1), 211-225.
18. Dinakaran, S., & Anbalagan, S. (2007). Anthropogenic impacts on aquatic insects in six streams of south Western Ghats. Journal of Insect Science, 7(1), 37.
19. Dukes, J. S. (2011). Responses of invasive species to a changing climate and atmosphere. Fifty years of invasion ecology: The legacy of Charles Elton, 345-357.
20. Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. Annual review of ecology, evolution, and systematics, 34(1), 487-515.
21. Figel, J. J., Hambal, M., Krisna, I., Putra, R., & Yansyah, D. (2021). Malignant snare traps threaten an irreplaceable megafauna community. Tropical Conservation Science, 14, 1940082921989187.
22. Garcia, C. A., Bhagwat, S. A., Ghazoul, J., Nath, C. D., Nanaya, K. M., Kushalappa, C. G., & Vaast, P. (2010). Biodiversity conservation in agricultural landscapes: challenges and opportunities of coffee agroforests in the

Western Ghats, India. Conservation Biology, 24(2), 479-488.

23. Ghats, W., & Hotspot, S. L. B. (2013). In the Western Ghats Region of the Critical Ecosystem Partnership Fund. 2-11.
24. Gillson, L., Biggs, H., Smit, I. P., Virah-Sawmy, M., & Rogers, K. (2019). Finding common ground between adaptive management and evidence-based approaches to biodiversity conservation. Trends in Ecology and Evolution, 34(1), 31-44.
25. Grimm, N. B., Chapin III, F. S., Bierwagen, B., Gonzalez, P., Groffman, P. M., Luo, Y., & Williamson, C. E. (2013). The impacts of climate change on ecosystem structure and function. Frontiers in Ecology and the Environment, 11(9), 474-482.
26. Gunawardene, N. R., Daniels, A. E., Gunatilleke, I. A. U. N., Gunatilleke, C. V. S., Karunakaran, P. V., Nayak, K. G., & Vasanthy, G. (2007). A brief overview of the Western Ghats--Sri Lanka biodiversity hotspot. Current Science, 93(11).
27. Hamilton, A. C. (2004). Medicinal plants, conservation and livelihoods. Biodiversity and Conservation, 13, 1477-1517.
28. Herrero, M., Havlík, P., Valin, H., Notenbaert, A., Rufino, M. C., Thornton, P. K., & Obersteiner, M. (2013). Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. Proceedings of the National Academy of Sciences, 110(52), 20888-20893.

29. Hughes, A. C. (2017). Understanding the drivers of Southeast Asian biodiversity loss. Ecosphere, 8(1), e01624.
30. Jamal, T., & Stronza, A. (2009). Collaboration theory and tourism practice in protected areas: Stakeholders, structuring and sustainability. Journal of Sustainable tourism, 17(2), 169-189.
31. Joshi, M. A., & Madhusudan, M. D. (2010). Assessment of a unique conflict between gaur (Bo s gaurus) and humans in the northern Western Ghats, India. Nature Conservation Foundation, Mysore, Interim Report. The Rufford Small Grants Foundation.
32. Jumani, S., Rao, S., Kelkar, N., Machado, S., Krishnaswamy, J., & Vaidyanathan, S. (2018). Fish community responses to stream flow alterations and habitat modifications by small hydropower projects in the Western Ghats biodiversity hotspot, India. Aquatic Conservation: Marine and Freshwater Ecosystems, 28(4), 979-993.
33. Khandekar, V., & Srivastava, A. (2014). Ecosystem biodiversity of India. The Dynamic Balance of the Planet, 10, 233-274.
34. Kothari, A., Camill, P., & Brown, J. (2013). Conservation as if people also mattered: policy and practice of community-based conservation. Conservation and society, 11(1), 1-15.
35. Kumar, R., Kumar, A., & Saikia, P. (2022). Deforestation and forests degradation impacts on the environment. In Environmental Degradation: Challenges and Strategies for Mitigation Cham: Springer International Publishing.19-46.

36. Kumar, S. (2019). India's Environmental Challenges and their Solutions.
37. Kumar, S., & Srivastava, S. (2018). Biodiversity conservation and agricultural intensification in India through integration of IPR. In The role of intellectual property rights in agriculture and allied Sciences. Apple Academic Press.87-120.
38. Kuriakose, G., & Sebastian, J. (2016). History, biogeography, biodiversity and bioprospecting: scenario from the Western Ghats. South Indian Journal of Biological Sciences, 2, 292-301.
39. Liu, J., Coomes, D. A., Gibson, L., Hu, G., Liu, J., Luo, Y., & Yu, M. (2019). Forest fragmentation in China and its effect on biodiversity. Biological Reviews, 94(5), 1636-1657.
40. Marchese, C. (2015). Biodiversity hotspots: A shortcut for a more complicated concept. Global Ecology and Conservation, 3, 297-309.
41. Miltenberger, O., Leisz, S., Evangelista, P., & Pejchar, L. (2018). Gap analysis of India's Western Ghats protected area network: insights from new and understudied endemic species' distributions.
42. Mohite, S. A., & Samant, J. S. (2013). Impact of environmental change on fish and fisheries in Warna River Basin, Western Ghats, India. *Int Res J Environ Sci,* 2(6), 61-70.
43. Mori, A. S., Furukawa, T., & Sasaki, T. (2013). Response diversity determines the resilience of ecosystems to environmental change. Biological reviews, 88(2), 349-364.

44. Mukhopadhyay, T., & Bhattacharjee, S. (2016). Genetic Diversity: Importance and Measurements. Conserving Biological Diversity: A Multiscaled Approach. Research India Publications, New Delhi, 251-295.
45. Murthy, I. K., Bhat, S., Sathyanarayan, V., Patgar, S., Bhat, P. R., Bhat, D. M., & Saxena, R. (2014). Implications of Impacts of Climate Change on Forest Product Flows and Forest Dependent Communities in the Western Ghats, India. Journal of Forest and Environmental Science, 30(2), 189-200.
46. Nagarajan, A., Murari, K. K., Jayaraman, T., & Radhakrishnan, G. (2015). Appraising the debate on biodiversity conservation in the Western Ghats. Economic and Political Weekly, 49-56.
47. Naniwadekar, R., & Vasudevan, K. (2014). Impact of dams on riparian frog communities in the Southern Western Ghats, India. Diversity, 6(3), 567-578.
48. Naruka, K. P. S., & Reddy, P. B. (2023). Assessing the efficacy of in-situ vs. ex-situ biodiversity conservation measures. Recent advances in biodiversity research, 67.
49. Naskar, S., Gowane, G. R., Chopra, A., Paswan, C., & Prince, L. L. L. (2012). Genetic adaptability of livestock to environmental stresses. Environmental stress and amelioration in livestock production, 317-378.
50. Naumann, S., Anzaldua, G., Berry, P., Burch, S., Davis, M., Frelih-Larsen, A., & Sanders, M. (2011). Assessment of the potential of ecosystem-based approaches to climate change adaptation and mitigation

in Europe. Final report to the European Commission, DG Environment.

51. Omondi, A., & Merceline, A. (2023). Invasive Species and their Impacts on the Ecology of Lake Victoria: A Rapid Review. Pan Africa Science Journal, 3(02).
52. Oommen, M. A. (2021). Beasts in the garden: human-wildlife coexistence in India's past and present. Frontiers in Conservation Science, 2, 703432.
53. Opdam, P., & Wascher, D. (2004). Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. Biological conservation, 117(3), 285-297.
54. Pandit, M. K., & Grumbine, R. E. (2012). Potential effects of ongoing and proposed hydropower development on terrestrial biological diversity in the Indian Himalaya. Conservation Biology, 26(6), 1061-1071.
55. Rajvanshi, A., Brownlie, S., Slootweg, R., & Arora, R. (2011). Maximizing benefits for biodiversity: the potential of enhancement strategies in impact assessment. Impact Assessment and Project Appraisal, 29(3), 181-193.
56. Ramachandra, T. V., Bharath, S., Subash Chandran, M. D., & Joshi, N. V. (2018). Salient ecological sensitive regions of central Western Ghats, India. Earth Systems and Environment, 2, 15-34.
57. Ramachandran, R. M., Roy, P. S., Chakravarthi, V., Joshi, P. K., & Sanjay, J. (2020). Land use and climate change impacts on distribution of plant species of conservation value in Eastern Ghats, India: a simulation

 ISBN: 978-93-340-7821-3

study. Environmental monitoring and assessment, 192, 1-21.

58. Raman, N. D. T. S., Datta, A., & Krishnaswamy, J. (2006). Western Ghats: Sub-cluster Nominations. Natural Heritage Properties, 22.
59. Rawat, G. S., & Adhikari, B. S. (2015). Ecology and management of grassland habitats in India. ENVIS Bulletin: Wildlife & Protected Areas, 17.
60. Rawat, U. S., & Agarwal, N. K. (2015). Biodiversity: Concept, threats and conservation. Environment Conservation Journal, 16(3), 19-28.
61. Razal, R. A., & Guerrero, M. C. (2014). Scoping Study on Cutting-Edge Technology and Strategic Knowledge on ntfps for the Green Economy. NTFP-EP: Manilla, Phillipines.
62. Redford, K. H., & Fearn, E. (Eds.). (2007). Protected areas and human displacement: a conservation perspective. New York: Wildlife Conservation Society. 29.
63. Redpath, S. M., Young, J., Evely, A., Adams, W. M., Sutherland, W. J., Whitehouse, A., & Gutierrez, R. J. (2013). Understanding and managing conservation conflicts. Trends in ecology & evolution, 28(2), 100-109.
64. Saha, G. K., & Mazumdar, S. (2017). Wildlife biology: an Indian perspective. PHI Learning Pvt. Ltd.
65. Sethi, S., Goyal, S. P., & Choudhary, A. N. (2019). 12 Poaching, Illegal Wildlife Trade, and Bushmeat Hunting in India and South Asia. International wildlife management: Conservation challenges in a changing world, 157.

66. Shankar, U., Murali, K. S., Shaanker, R. U., Ganeshaiah, K. N., & Bawa, K. S. (1998). Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India. 4. Impact on floristic diversity and population structure in a thorn scrub forest. Economic Botany, 52, 302-315.
67. Sharma, L. K., Joshi, B. D., Thakur, M., & Chandra, K. (2022). Status, Issues, and Challenges of Biodiversity: Wild Animals. In Biodiversity in India: Status, Issues and Challenges. Singapore: Springer Nature Singapore.149-173.
68. Sheela, T., & James, J. (2013). The Gadgil-Kasturirangan reports on Western Ghats and concerns of the plantation sector. Rubber Science, 26(2), 167-174.
69. Sodhi, N. S., Brook, B. W., & Bradshaw, C. J. (2007). Tropical conservation biology. John Wiley & Sons. ISBN: 978-1-405-15073-6.
70. Sonter, L. J., Moran, C. J., Barrett, D. J., & Soares-Filho, B. S. (2014). Processes of land use change in mining regions. Journal of Cleaner Production, 84, 494-501.
71. Sreekumar, E. R. (2021). Modelling climate change impact on the high-altitude birds of Western Ghats, India (Doctoral dissertation, Department of Wildlife Science, College of Forestry, Vellanikkara).
72. Sridhar, H., Raman, T. S., & Mudappa, D. (2008). Mammal persistence and abundance in tropical rainforest remnants in the southern Western Ghats, India. Current Science, 748-757.

73. Srivathsa, A., Vasudev, D., Nair, T., Chakrabarti, S., Chanchani, P., DeFries, R., & Ramakrishnan, U. (2023). Prioritizing India's landscapes for biodiversity, ecosystem services and human well-being. Nature Sustainability, 1-10.
74. Thatte, P., Joshi, A., Vaidyanathan, S., Landguth, E., & Ramakrishnan, U. (2018). Maintaining tiger connectivity and minimizing extinction into the next century: Insights from landscape genetics and spatially-explicit simulations. Biological Conservation, 218, 181-191.
75. Thomassen, J., Linnell, J. D., & Skogen, K. (2011). Wildlife-human interactions: from conflict to coexistence in sustainable landscapes. NINA rapport. 15-83.
76. Varak, N. (2023). Understanding Pastoral Nomadic Perspective from the Western Ghats (Doctoral dissertation, Goa University).
77. Viju, B. (2019). Flood and Fury: Ecological Devastation in the Western Ghats. Penguin Random House India Private Limited.
78. Wassie, S. B. (2020). Natural resource degradation tendencies in Ethiopia: a review. Environmental Systems Research, 9(1), 1-29.
79. Whittaker, R. J., Willis, K. J., & Field, R. (2001). Scale and species richness: towards a general, hierarchical theory of species diversity. Journal of biogeography, 28(4), 453-470.

80 Wolkersdorfer, C., & Mugova, E. (2022). Effects of mining on surface water. Encyclopedia of Inland Waters, 4, 170-188.

# Invasive plants: Unveiling the invasion process, ecological effects and management approaches

Nahla Zakariya P.

PG Department of Botany, KAHM Unity Women's College, Manjeri, Malappuram, 676122, Kerala, India.
Corresponding author: nahlazakariya8@gmail.com

The ecological disruptions caused by the invasive species are increasingly recognized as a significant threat to global sustainability. Invasive Alien Plant Species (IAPS) are particularly concerning due to their role in biodiversity decline and consequent changes to ecosystem functions and socio-economic conditions through various means. While the ecological impacts of IAPS are well-documented, there is a lack of research on their economic assessment, effects on livelihoods, potential biotechnological applications such as phytoremediation, bio-energy, synthesis of nano particles, biomedical and industrial uses, and human health risks associated with them. The management strategies can be strengthened by integrating geo-spatial technologies like remote sensing and GIS to map and monitor the spread of IAPS. Additionally, the scope of IAPS management should include ecological indicators, bio-security measures, and risk assessment protocols with thorough discussion. Both positive and negative impacts of IAPS on the environment, health, ecosystem services, and socio-economy are outlined to inform the development of effective policy frameworks aimed at mitigating the human health implications associated with IAPS management.

**Key words:** Invasion, Biodiversity, Ecological indicators, Health risk, Sustainable management

## 1. Introduction

Biodiversity plays a crucial role in supporting human well-being and providing essential ecosystem services, including food production, medicine and environmental protection (Aerts et al., 2018; Stone et al., 2018; Jones, 2019). Species which cross over their natural distribution and get introduced to new habitats are known as alien species. Despite its significance, invasive alien plant species (IAPS) pose serious

threats to local biodiversity, ecosystem services, and human health (Pejchar and Mooney, 2009; Kueffer, 2017; Jones and Mc Dermott, 2018; Bartz and Kowarik, 2019). The United Nations' Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) warns that about one fifth of the Earth's surface including biodiversity hotspots, is at risk due to biotic invaders (IPBES, 2019). High income countries, particularly in the European Union, Australasia, and North America, face a higher prevalence of IAPS, driven by increased trade and transport activities (Seebens et al., 2018).
IAPS not only threaten ecosystems but also impede advancements in biomedical sectors due to global environmental changes induced by land-use and climate change (Ebi et al.,2017). Human-mediated transport continues to spread IAPS across diverse environments, disrupting ecosystems and contributing to their negative impact on human health (Rai, 2015; Kueffer, 2017). The complex interplay between IAPS, biodiversity loss and human health requires careful consideration in socio-ecological and socio-economic perspectives. Loss of native plant diversity through IAPS can affect air quality, carbon sequestration, and indirectly impact human health (Jones and McDermott, 2018).

## 2. Modes of plant invasion

Introduction of the species to the new location can either be accidental or intentional. ‘Invasion ecology’ refers to the examination of the human-mediated introduction of invasive alien plant species (IAPS) to areas beyond their native range. This involves processes such as transportation, establishment, colonization, and the spread across landscapes. Apart from intentional introductions by humans, there are instances of alien species being introduced through natural means. For instance, *Limnocharis flava* in Kerala is thought to have been introduced by ocean currents as coconuts have been dispersed to various locations, including islands, through waves and ocean currents. As a result, the scope of invasion ecology is steadily broadening.

The term commonly referenced as alien/non-native/exotic/introduced species pertains to organisms existing in a new region, distinct from their original habitat. Human activities play a key role in facilitating IAPS to overcome various bio-geographical barriers. Notably, the invasive potential of these species varies along the naturalization-invasion continuum. In essence, IAPS are plant species characterized by efficient reproductive strategies, both vegetative and through seeds, allowing them to sustain self-replacing populations, even in remote areas. The presence of IAPS can have a significant impact on native plants in the invaded region - those species that have evolved in a specific area without human intervention, thriving through natural processes.

Human-induced disruptions have not only caused the worldwide proliferation of IAPS, but have also significantly influenced the mechanisms of invasion (Kueffer, 2017). A comprehensive understanding of the fundamental mechanisms driving the success and impacts of IAPS is crucial for ecological and health risk assessments (Stohlgren and Schnase, 2006). The complexity of why IAPS succeed in diverse environments necessitates investigation within the context of specific IAPS. To achieve this, exploring species-specific mechanisms is essential, considering their varying invasive potential aligned with ecosystem attributes (Ehrenfeld, 2008). Several hypotheses, such as enemy release (ERH), novel weapon (NWH) and empty niche (EN), have been suggested to elucidate the invasion of IAPS into new environments. However, no single hypothesis is adequate to comprehensively explain IAPS invasions. Sharma et al. (2005) argue that the most relevant hypothesis is always specific to the particular IAPS under consideration. In this context, the ERH hypothesis suggests that certain IAPS thrive in new habitats due to the absence of natural enemies, such as pathogens and herbivores, present in their native environments (Blumenthal, 2006). For example, *Impatiens glandulifera* seeds in newly invaded regions are devoid of fungal pathogens (Najberek et al., 2018).

Allelopathy constitutes an ecological process involving biotic interference through bioactive molecules. Remarkably, allelochemicals are recognized as novel weapons (NW) that significantly suppress native species, facilitating the colonization of IAPS in new habitats. These allelochemicals, which are secondary metabolites like phenolics, terpenoids, and sesquiterpenes, exert adverse effects on native plant species (Pinzone et al., 2018). Phenolic compounds, among these allelochemicals, are widespread and often contribute to allelopathy. Certain IAPS, such as *Fallopia japonica* (Japanese knot weed) in the United Kingdom, release allelochemicals acting as novel weapons that profoundly alter food webs (Abgrall et al., 2018). Similarly, *Chromolaena odorata* secretes odoratin, a novel allelochemical, conferring the ability to defend against enemies, particularly soil-borne pathogens, thereby granting the IAPS a competitive advantage over native species (Zheng et al., 2015).

Moreover, a comprehensive understanding of plant-microbe and insect interactions, encompassing both mutualistic and antagonistic relationships, is crucial for unraveling the mechanisms of IAPS spread (Jack et al., 2017). Nutrient enrichment, both in terrestrial and aquatic ecosystems, plays a pivotal role in the success of IAPS in new habitats (Aragon et al., 2014). For instance, elevated nitrogen levels in soils are identified as a factor aiding *Bromus tectorum* (Cheat grass) in outcompeting native flora (Morris et al., 2016). Additionally, intriguing research reveals that the impact of IAPS on soil carbon pools and local climate correlates with differences in the traits of the IAPS and native species (Martin et al., 2017).

## 3. List of invasive alien plant species (IAPS)

According to the study conducted by Sajeev et al. (2012) under Kerala Forest Research Institute, 38 invasive alien plant species are found in the forests of Kerala. Of these, 10 are high risk, 12 pose medium risk, 10 pose low risk and the rest 6, are insignificant. High risk species represents a severe threat to native species and ecological communities. Medium risk species causes moderate threat while low risk species represents relatively low threat. Insignificant species represents an insignificant threat to native species and ecological communities. Further information regarding invasive alien plant species found in Kerala is given in Table 1.

### 3.1 High risk IAPS

### 3.1.1 *Acacia mearnsii* De Wild.

Identified as exceedingly invasive in Mannavanshola, Pambadumshola and Eravikulam National Park, this variety is a rapidly expanding, evergreen, nitrogen-fixing tree introduced to Kerala during the 1980s to reforest high-altitude grasslands. Its cultivation primarily targets the tannin-rich bark. Demonstrating aggressive colonization tendencies, especially in moist tropical environments resembling warm temperate climates, these trees generate copious long-lasting seeds that germinate massively post-fire events. Additionally, through the release of potent allelochemicals, they impede the establishment of native flora nearby. Invading neighboring grasslands, they heighten the risk of forest fires due to their tannin-laden bark. Consequences of their proliferation includes reduced stream flow, biodiversity decline, heightened soil erosion, and increased riverbank instability.

Table 1. Invasive alien plant species in Kerala

| Sl. No. | Species | Family | Risk category | Native place |
|---|---|---|---|---|
| | *Acacia mearnsii* De Wild. | Mimosaceae | High | Australia |
| | *Ageratina adenophora* (Spreng.) King & Robins. | Asteraceae | Medium | Central America |
| | *Ageratum conyzoides* L. | Asteraceae | Low | Central America |
| | *Alternanthera bettzickiana* (Regel) G. Nichols. | Amaranthaceae | Insignificant | America |
| | *Alternanthera brasiliana* (L.) Kuntze | Amaranthaceae | Low | Central and South America |
| | *Alternanthera* | Amaranthaceae | Insignificant | South |

 ISBN: 978-93-340-7821-3

| | | | | |
|---|---|---|---|---|
| | *philoxeroides* (Mart.) Griseb. | | | America |
| | *Amaranthus spinosus* L. | Amaranthaceae | Low | Central and South America |
| | *Asclepias curasavica* L. | Asclepiadaceae | Insignificant | America |
| | *Centrosema molle* Benth. | Fabaceae | Low | America |
| | *Cestrum aurantiacum* Lindl. | Solanaceae | Medium | Central America |
| | *Chromalaena odorata* (L.) King & H. Rob. | Asteraceae | High | America |
| | *Clidemia hirta* (L.) D. Don | Melastomataceae | Low | Central and South America |
| | *Erigeron karvinskianus* DC. | Asteraceae | Low | South America |
| | *Hyptis capitata* Jacq. | Lamiaceae | Medium | Central America |
| | *Hyptis suaveolens* (L.) Poit. | Lamiaceae | Medium | America |
| | *Ipomea purpurea* (L.) Roth | Convolvulaceae | Medium | Central America |
| | *Jatropha gossypifolia* L. | Euphorbiaceae | Insignificant | South America |
| | *Lantana camara* L. | Verbanaceae | High | Central and South America |
| | *Leucaena leucocephala* (Lam.) de Wit | Mimosaceae | Low | America |
| | *Merremia vitifolia* (Burm.f.) Hallier f. | Convolvulaceae | High | Asia |
| | *Mikania micrantha* Kunth | Asteraceae | High | South America |
| | *Mimosa diplotricha* C. Wight ex Sauvalle var. diplotricha C. wight ex Sauvalle | Fabaceae | High | South America |
| | *Mimosa diplotricha* C. Wight ex Sauvalle var. | Fabaceae | Low | South America |

 ISBN: 978-93-340-7821-3

| | | | | |
|---|---|---|---|---|
| | inermis (Adelb.) Veldk. | | | |
| | *Mimosa pudica* L. | Fabaceae | Low | South America |
| | *Mucuna breacteata* DC. ex Kurz | Fabaceae | High | Asia |
| | *Parthenium hysterophorus* L. | Asteraceae | Medium | South America |
| | *Pennisetum polystachyon* (L.) Schult. | Poaceae | Medium | Africa |
| | *Phytolacca octandra* L. | Phytolaccaceae | Insignificant | America |
| | *Prosopis juliflora* (Sw.) DC. | Mimosaceae | High | South America |
| | *Pueraria phaseoloides* (Roxb.) Benth. | Fabaceae | High | Asia |
| | *Senna hirsuta* (L.) Irwin & Barneby | Ceasalpiniaceae | Medium | America |
| | *Senna occidentalis* (L.) Link | Ceasalpiniaceae | Low | South America |
| | *Senna spectabilis* (DC.) Irwin & Barneby | Ceasalpiniaceae | Medium | America |
| | *Senna tora* (L.) Roxb. | Ceasalpiniaceae | Medium | America |
| | *Sphagneticola trilobata* (L.) Pruski | Asteraceae | High | America |
| | *Synedrella nodiflora* (L.) Gaertn. | Asteraceae | Insignificant | West Indies |
| | *Tithonia diversifolia* (Hemsl.) A. Gray | Asteraceae | Medium | Central America |
| | *Measopsis eminii* Engl. | Asteraceae | Medium | West and Central Africa |

### 3.1.2 *Chromolaena odorata* (L.) King & H

Unintentionally introduced from Assam in the 1940s, this rapidly growing, erect or sprawling perennial shrub is widely distributed across most forests in Kerala. Despite naturalizing in numerous areas, it still forms dense thickets capable of over topping plants up to 20 meters in height due to its phenotypic adaptability. The species exhibits high reproductive efficiency and its seeds are dispersed by wind, rendering its management challenging. Addressing this species necessitates re-establishment strategies where eradicating it is complemented by facilitating the regeneration of native plants to phase out the invasive species.

### 3.1.3 *Lantana camara* L.

Initially introduced for decorative purposes, this compact, upright, and robust shrub densely populates open, sunlit environments. It dominates as an undergrowth species, disrupting natural progression and diminishing indigenous biodiversity. The persistent growth of this shrub can effectively halt rainforest regeneration for extended periods. It represents a significant menace to disturbed forests, where vast swaths of land are overtaken by this singular species. Adopting mechanical eradication methods followed by the reintroduction of native plants is imperative to rehabilitate habitats and prevent these sites from serving as launching points for further incursions deep into the forest.

### 3.1.4 *Merremia vitifolia* (Burm. f.) Hallier f.

Frequently encountered along the edges and openings of forests, this perennial vine possesses the capacity to overwhelm indigenous vegetation entirely, obstructing sunlight access to the native species below. It spreads vigorously and reproduces asexually, proving exceedingly challenging to manually uproot, especially as the plant matures and its stem thickens over time. In instances where it ascends to the forest canopy, severing the main stem could desiccate the plant and heighten the risk of canopy fires by increasing the fuel load. Hence, any encroachment by this plant should be promptly addressed to prevent suppression of native flora.

### 3.1.5 *Mikania micrantha* Kunth

An expeditiously growing perennial vine deliberately introduced from South America as a ground cover for rubber plantations, exhibits extensive distribution throughout Kerala. It possesses the ability to ascend to the forest canopy from forest edges and spread across it, adversely affecting tree growth within the forest as well as the vegetation underneath. It aggressively occupies gaps created by fallen trees in natural forests. Numerous young teak plantations in moist environments suffer heavy infestations by *Mikania*. Reproduction occurs through both sexual and vegetative means; vegetative propagation from fragmented foliage thrives particularly in moist soil and air conditions. During flowering, it attracts a plethora of pollinators, including butterflies, thereby exerting competitive pressure on the regeneration of native species. As the foliage dries, it also poses a risk of canopy fires and should be eradicated upon establishment to mitigate this danger.

### 3.1.6 *Mimosa diplotricha* var. diplotricha

Originally introduced as a nitrogen-fixing ground cover for coffee plantations, this rapid-growing trailing plant can aggressively overrun native vegetation. Both spiny and non-spiny variants exist, with the former displaying the highest level of aggression. It scrambles vigorously over indigenous

 ISBN: 978-93-340-7821-3

plants, forming dense, tangled thickets reaching heights of up to 3 meters, inhibiting the regeneration, reproduction, and growth of native species. Due to its thorn presence, herbicide application is favored over mechanical removal. The species proliferates in non-forest areas, posing a significant risk of invasion into forests. Early detection and swift eradication are imperative to safeguard forests from this species.

### 3.1.7 *Mucuna bracteata* DC. ex Kurz

A swiftly proliferating perennial vine, creeping and vigorously climbing, deliberately introduced as a nitrogen-fixing ground cover that exhibits drought and shade tolerance. It has the capacity to suffocate, overwhelm, and stunt native trees through its prolific growth and climbing behavior. Reproduction primarily occurs through seeds and fibrous roots originating from nodes. This species has breached plantation borders and commenced aggressive incursions into forests from their perimeters. Once established, it becomes exceedingly challenging to eradicate. Stringent legislation is necessary to prevent its usage in plantations adjacent to forests.

### 3.1.8 *Prosopis juliflora* (Sw.) DC.

A thorny, rapid-growing, small to medium-sized evergreen tree with a squat, twisted trunk and expansive canopy has been a subject of extensive debate in India. While many view it as a species that fulfills the fuel requirements of communities in arid regions, it is also recognized as a formidable invasive species due to its capacity to diminish habitat carrying capacities. In Kerala, it is prevalent in the dry deciduous forests of Chinnar Wildlife Sanctuary. Left unchecked, it can establish dense, impenetrable thickets that pose significant threats to indigenous flora and fauna. Moreover, it can desiccate the soil and vie with other plants for water, particularly in arid regions. Given the context of global climate change, careful monitoring of this species is essential as it may compromise the resilience of native species.

### 3.1.9 *Pueraria phaseoloides* (Roxb.) Benth.

Introduced for utilization as a ground cover in rubber plantations owing to its nitrogen-fixing abilities and shade tolerance, this vigorous, deeply rooted, twining, and climbing legume thrives in various soil types. It proliferates abundantly in vacant lands and forest edges, with the capability to ascend to the canopy and envelop medium-sized trees completely. Legislative measures are warranted to regulate its deployment in plantations neighboring other plantations.

### 3.1.10 *Sphagneticola trilobata* (L.) Pruski

A creeping, mat-forming perennial herb indigenous to the tropical regions of Central America, this species is extensively cultivated for its aesthetic appeal, often erroneously utilized even in gardens adjacent to forest offices due to its striking yellow blooms juxtaposed against lush green foliage. Exhibiting a broad ecological adaptability, it thrives equally well in both sunlit and shaded environments. It effectively outcompetes native species, including numerous medicinal plants. Despite producing minimal viable seeds, its flowers are abundant in nectar, attracting pollinators away from indigenous species. Public awareness regarding the threat posed by this species must be disseminated widely to prevent its introduction into forests, as its removal necessitates long-term restoration strategies.

## 4. Impacts of plant invasion

### 4.1 Environmental impacts of IAPS

The impact of invasive alien plant species (IAPS) on ecosystem functioning is more pronounced in islands compared to the mainland. IAPS influence ecosystem functioning through three fundamental mechanisms: (a) diminishing the diversity of native plants and animals, (b) inducing significant alterations in the physico-chemical attributes of soils, primarily through allelopathy, and (c) amplifying ecosystems' responsiveness to modified fire regimes (Pysek et al., 2012). A well-documented consequence of IAPS is the reduction in the biodiversity of native plants, carrying potential adverse implications for environmental functioning, ecosystem services, and global climate change (Heshmati et al., 2019). The recognized role of IAPS in native biodiversity loss is widely acknowledged; however, their presumed contribution to extinction is a subject of debate among invasion ecologists. To either refute or confirm this, a consistent dataset across diverse habitats, especially in islands, is essential (Sax and Gaines, 2008). Intense competition for crucial resources regulating ecosystem functioning between IAPS and native flora may result in the phenomenon termed 'invasion meltdown'. According to the invasion meltdown hypothesis, the establishment of one invasive species in a new environment facilitates the invasion of other non-native species (Simberloff and Von Holle, 1999). It is noteworthy that the initial impact of IAPS, namely the reduction in biodiversity, is consistently observed globally.

 ISBN: 978-93-340-7821-3

Moreover, alien invaders have detrimental effects on wildlife. For example, *Spartina alterniflora* displaces native macrophytes (*Phragmites australis* and *Scirpus mariqueter*) in Chinese wetlands, leading to declines in avian populations due to movement and feeding restrictions (Gan et al., 2009). In aquatic systems, IAPS can invade through unique physiological characteristics such as high biomass and deep roots, hindering water flow and rendering it unsuitable for drinking and irrigation (Pejchar and Mooney, 2009). IAPS also contribute to increased flood frequency by narrowing stream channels and altering soil attributes like decreased water holding capacity and increased soil erosion, ultimately harming native plant communities and posing human health risks. Lizarralde (1993) reported that the IAPS, *Castor canadensis*, also disrupt water quality and increase flood risk.

IAPS further impact the quantity of surface and ground water (Shackleton et al., 2019). *Prosopis pallida*, a nitrogen-fixing IAPS in arid regions of Hawaii Island, exploits groundwater resources to an extent that alters the soil environment (Dudley et al., 2014). Some IAPS consume substantial amounts of water, exacerbating water scarcity impacts and causing shifts in socio-ecological regimes (Shackleton et al., 2019). Reports indicate that IAPS alter soil stability, leading to soil erosion (Pejchar and Mooney, 2009). Invasions by noxious IAPS, such as spotted knapweed (*Centaurea stoebe*), leafy spurge (*Euphorbia esula*), and cheat grass (*Bromus tectorum*), can profoundly impact the soil quality of grassland ecosystems (Gibbons et al., 2017). *Acacia dealbata*, an IAPS in the Mediterranean ecosystem, reduces native plant diversity by negatively affecting soil chemistry and microbial functioning (Lazzaro et al., 2014).

**4.2 Impacts of the IAPS on ecosystem services**
Numerous IAPS are recognized for their impact on various ecosystem services including aesthetic, recreational, cultural, and regulatory aspects (Pejchar and Mooney, 2009). As IAPS often obstruct water navigation, they can negatively influence recreation and tourism services (Eiswerth et al., 2005). Restrictions on the sale of ornamental IAPS to mitigate environmental harm have been reported to impact the aesthetic services of ecosystems. Many IAPS also affect regulatory ecosystem services linked to agriculture and forestry such as hazards mitigation, water treatment, pest management, pollination, and climate change (Pejchar and Mooney, 2009). The invasion of *Opuntia stricta* in the African region has adverse effects on the environment and economy, impacting the livelihoods of local people by reducing fodder and livestock health (Shackleton et al., 2017). The widespread cultivation of multi-purpose trees and shrubs is promoted to enhance bioenergy and industrial sectors (Rai et al., 2018). However, the introduction of IAPS as multi-purpose species, for example, the introduction of *Prosopis* sp. in South Africa, can significantly impact ecosystem services (Shiferaw et al., 2019).

**4.3 Economic impacts of the IAPS**

Several IAPS introduced for human welfare, are recognized for causing environmental and economic havoc. Therefore, understanding people's perceptions of IAPS and their local ecological knowledge becomes an effective approach to categorize the impacts of IAPS. In this context, *Acacia mangium*, an IAPS in the northern Brazilian Amazon, is noteworthy for its detrimental effects on the economy, environment, and indigenous people through alterations in water quality (Souza et al., 2018). The invasion of aquatic macrophytes such as *Eichhornia crassipes* (Water hyacinth) in Lake Victoria has become a menace for human welfare, reducing fish production and eco-tourism potential (Pejchar and Mooney, 2009). The invasion of *Tamarix ramossissima* has resulted in a substantial loss of water (1.4-3.0 billion cubic meters) in the USA, depriving various human needs (Zavaleta, 2000). Similarly, *Melaleuca quinquenervia* in Florida and *Eucalyptus* species in California, with their deep tap roots, utilize a significant quantity of groundwater (Schmitz et al., 1997).

**4.4 Impacts of the IAPS on human health**

Biodiversity and its fluctuations are intricately intertwined with human health, both positively and negatively. Positive impacts of IAPS include their applications in vector-borne control and ethno-medicinal uses. For example, a mosquito repellent is derived from *Lantana camara* (Mngong et al., 2011). Certain biotic invasive species affect human health through environmental contamination. For example, invasive plant pathogens like the emerald ash borer, causing massive devastation to ash trees in the United States, which previously acted as a sink for air pollutants (Jones and McDermott, 2018). Elevated levels of air pollutants can increase regional losses in tree diversity, resulting in severe health implications, including mortality (Jones and McDermott, 2018). Losses of host plants are known to spur the growth of pathogen populations, facilitating outbreaks of diseases like Tick-borne diseases, Tuberculosis, severe acute respiratory syndrome (SARS), acquired immunodeficiency syndrome (AIDS), and virulent Malaria (Hulme, 2014; Young et al., 2017; Stone et al., 2018). These severe human diseases and their sudden outbreaks across continents are reminiscent of biotic invasions themselves. An increase in the pathogen population due to host loss caused by land use change or global warming has led to the emergence of new diseases like Dengue and Yellow fever by *Aedes aegypti*, Lyme disease, African horse sickness, Chikungunya fever, Nipah virus disease etc (Hulme, 2014; Young et al., 2017; Stone et al., 2018).

Beyond public health, IAPS also affect the health of plants (Young et al., 2017). Several IAPS like cheat grass increase the outbreak of fungal pathogens, adversely affecting the health of native plants (Beckstead et al., 2010). In certain instances, pathogenic IAPS (blight fungus, *Cryphonectria parasitica*) completely eliminate existing dominant native life forms (*Castanea dentate* or American chestnut in the eastern deciduous forest of the US) (Parker et al., 1999). Furthermore, a high-risk plant invader *Parthenium hysterophorus* is demonstrated to spread phytoplasmas, a vegetable pathogen, characterized using molecular tools (16S rRNA and lineage-specific immune-dominant membrane protein genes). Interestingly, Cai et al. (2016) observed that phytoplasmas infecting vegetables belong to the same genetic lineage as *Parthenium. Ambrosia artemisiifolia, Parthenium hysterophorus, Ailanthus altissima, Acacia, Acer, Casuarina, Eucalyptus, Helianthus, Platanus* and *Xanthium* are some of the IAPS causing allergies in humans (Belmonte and Vila, 2004; Mazza et al., 2014; Stone et al., 2018).

## 5. Management of invasive plants

An essential aspect of addressing the threats posed by IAPS and formulating effective action plans for their management and biodiversity restoration is the economic evaluation. The Generic Impact Scoring System (GISS), a significant assessment protocol, identified 149 plants as the worst invaders among the 486 investigated IAPS in Europe (Vila et al., 2019). While scoring methods for impact quantification are valuable, they often focus on local and regional aspects, and the occurrence of cryptogenic/cryptic alien species presents a challenge in protocol formulations (Ricciardi et al., 2013). The risk analysis of IAPS remains incomplete due to insufficient data on ecological impacts, transparency/repeatability, and the inclusion of uncertainty factors in assessments (Vanderhoeven et al., 2017). Therefore, there is a need for concrete impact assessment protocols to quantify the environmental and socio-economic impacts of IAPS (Vila et al., 2019). Considering the negative implications of many IAPS, there is an urgent need to prioritize and formulate cost-effective and environmentally feasible strategies for their management. 'Biosecurity' emerges as a management strategy to minimize the harmful environmental, economic and human health impacts of IAPS (Pyšek and Richardson, 2010). Integrating biosecurity into biodiversity conservation policies, as closely linked to food security, is crucial for protecting crops from IAPS and insect invaders (Sileshi et al., 2019). Sustainable bio-control programs should be implemented for IAPS management in

 ISBN: 978-93-340-7821-3

both natural and agro-ecosystems. The international community should unite for an integrated approach to safeguard global biodiversity from IAPS and emerging infectious diseases (Zhou et al., 2019). Thus, we can follow certain guidelines as follows:

- Rigorous monitoring of all plants and soil entering forests for construction purposes, nursery saplings, etc. to detect any presence of IAPS in saplings, plant parts, or propagules
- Implementing quarantine procedures for imported cover crops for plantations to prevent further introductions of IAPS
- Restricting the movement of soil and plant parts from IAPS infested areas to other parts of the forest
- Regular surveillance of tourist and pilgrimage routes and areas within forests to promptly identify and eradicate new IAPS
- Managing weed-infested areas during the reproductive phase of AIS to prevent seed dispersal to uninfected areas.
- Simultaneously implementing both eradication and restoration programs in a time-bound manner.

An optimized and effective biosecurity surveillance of invaders can facilitate the implementation of mitigation measures at the initial invasion stage (Poland and Rassati, 2019). Further, optimizing biosecurity surveillance can prevent economic losses by managing insect invaders at an early stage of establishment (Yemshanov et al., 2019). Additionally, international and national biosecurity policies (International Standards for Phytosanitary Measures - ISPMs;

CBD) incorporate risk assessment as an integral component of overall plant/human health risk analysis (Lindgren, 2012). However, ranking the invaders, impacting the agriculture/human health biosecurity by predicting their risk is still inadequate. This must be prioritized by each nation for the effective threat analysis (Yemshanov et al., 2019).

**6. Conclusion**

Although invasive alien plant species (IAPS) often have negative effects on native biodiversity and ecosystem services, their exact role in species extinctions is a topic of debate among invasion ecologists. However, the UN-IPBES recently recognized biotic invaders as significant contributors to biodiversity decline. Human-induced disturbances are the primary factors driving biotic invasions. Continued anthropogenic disruptions may lead to the emergence of new IAPS, posing risks to both the environment and human health. However, by gaining a comprehensive understanding of the various mechanisms involved in the arrival, spread, and establishment of IAPS, we can effectively manage them in a sustainable manner. In invasion ecology, greater attention should be directed towards studying the chemical ecology of interactions between native and invasive plant species to better understand the mechanisms underlying biodiversity loss. It is essential to delve deeply into emerging global issues such as biodiversity loss, climate change, unsustainable agriculture, and environmental disturbances to comprehend their interconnected impacts on human health.

**References**

1. Abgrall, C., Forey, E., Mignot, L., Chauvat, M. (2018). Invasion by *Fallopia japonica* alters soil food webs through secondary metabolites. Soil Biology and Biochemistry. 127, 100–109.
2. Aerts, R., Honnay, O., Nieuwenhuys, A.V., (2018). Biodiversity and human health: mechanisms and evidence of the positive health effects of diversity in nature and green spaces. British Medical Bulletin. 127, 5–22.
3. Aragón, M.R., Montii, L.F., & Ayup, M.M., (2014). Exotic species as modifiers of ecosystem processes: litter de- composition in native and invaded secondary forests of NW Argentina. Acta Oecologica. 54, 21–28.
4. Bartz, R., Kowarik, I., (2019). Assessing the environmental impacts of invasive alien plants: a review of assessment approaches. NeoBiota 43, 69–99.
5. Beckstead, J., Meyer, S.E., & Huck, M.B. (2010). Cheatgrass facilitates spill-over of a seed bank pathogen onto native grass species. Journal of Ecology. 98, 168–177.
6. Belmonte, J., Vilà, M., (2004). Atmospheric invasion of non-native pollen in the Mediterranean region. American Journal of Botany. 91, 1243–1250.
7. Blumenthal, D.M. (2006). Interactions between resource availability and enemy release in plant invasion. Ecology Letters. 9, 887–895.
8. Cai, H., Zhao, Z., & Wang, S. (2016). Evidence for the role of an invasive weed in widespread occurrence of phytoplasma diseases in diverse vegetable crops: implications from lineage-specific molecular markers. Crop Prot. 89, 193–201.

9. Dudley, B.D., Hughes, R., Ostertag, R. (2014). Groundwater availability mediates the ecosystem effects of an invasion of *Prosopis pallida*. Ecol. Appl. 24 (8), 1954–1971.
10. Ebi, K.L., Frumkin, H., Hess, J., 2017. Protecting and promoting population health in the context of climate and other global environmental changes. Anthropocene. 19, 1–12.
11. Ehrenfeld, J.G. (2008). Exotic invasive species in urban wetlands: environmental correlates and implications for wetland management. Journal of Applied Ecology. 45, 1160–1169.
12. Eiswerth, M.E., & Agapoff, F.(2005). Input-output modeling, outdoor recreation, and the economic impact of weeds. Weed Science. 53, 130–137.
13. Gan, X., & Wang, Y., (2009). Potential impacts of invasive *Spartina alterniflora* on spring bird communities at Chongming Dongtan, a Chinese wetland of international importance. Estuarine, Coastal and Shelf Science. 83, 211–218.
14. Gibbons, S.M., Lekberg, S.W., & Smets, E. (2017). Invasive plants rapidly reshape soil properties in a grassland ecosystem. mSystems 2, e00178–e216.
15. Heshmati, I., Karami, A., & Kalami, M. (2019). Forthcoming risk of *Prosopis juliflora* global invasion triggered by climate change: implications for environmental monitoring and risk assessment. Environmental Monitoring and Assessment. 191, 72.
16. Hulme, P.E. (2014). Invasive species challenge the global response to emerging diseases. Trends in Parasitology. 30 (6), 277–1270.

17. IPBES, (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform.
18. Jack, C. N., & Capps, K. L. (2017). Third-party mutualists have contrasting effects on host invasion under the enemy-release and biotic-resistance hypotheses. Evolutionary Ecology Research. 31, 829–845.
19. Jones, B.A. (2019). Tree shade, temperature, and human health: evidence from invasive species-induced deforestation. Ecological Economics. 156, 12–23.
20. Jones, B.A., McDermott, S.M., (2018). Health impacts of invasive species through an altered natural environment: assessing air pollution sinks as a causal pathway. Environmental research journal.
21. Kueffer, C. (2017). Plant invasions in the Anthropocene. 358 (6364), 724–725.
22. Lazzaro, L., & Ferritti, E. (2014). Soil and plant changing after invasion: the case of *Acacia dealbata* in a Mediterranean ecosystem. Science of the Total Environment. 497–498.
23. Lindgren, C.J. (2012). Biosecurity policy and the use of geospatial predictive tools to ad-dress invasive plants: updating the risk analysis toolbox. Risk Analysis. 32 (1), 9–15.
24. Lizarralde, M.S. (1993). Current status of the introduced beaver (*Castor canadensis*) po-pulation in Tierra-del-Fuego, Argentina. Ambio 22, 351–358.

25. Martin, P.A., Newton, A.C., Bullock, J.M. (2017). Impacts of invasive plants on carbon pools depend on both species' traits and local climate. Ecology 98 (4), 1026–1035.
26. Mazza, G., Tricarico, E., Genovesi, P., Gherardi, F., (2014). Biological invaders are threats to human health: an overview. Ethology, Ecology and Evolution. 26 (2–3), 112–129.
27. Mng'ong'o, F.C., Sambali, J.J., Sabas, E., Rubanga, J., Magoma, J., Ntamatungiro, A.J. (2011). Repellent plants provide affordable natural screening to prevent mos- quito house entry in tropical rural settings-results from a pilot efficacy study. PLoSOne 6 (10), e25927.
28. Najberek, K., et al., (2018). The seeds of success: release from fungal attack on seeds may influence the invasiveness of alien *Impatiens*. Plant Ecology. 219, 1197–1207.
29. Parker, I.M., Simberloff, D., Lonsdale, W.M. (1999). Impact: toward a framework for understanding the ecological effects of invaders. Biological Invasions. 1, 3–19.
30. Pejchar, L., Mooney, H.A. (2009). Invasive species, ecosystem services and human well- being. Trends in Ecology and Evolution. 24 (9), 497–504.
31. Pinzone, P., & Przybylsk, M. (2018). Do novel weapons that degrade mycorrhizal mutualisms promote species invasion?. Plant Ecology 5(1), 539–548.
32. Poland, T.M., & Rassati, D., (2019). Improved biosecurity surveillance of non-native forest insects: a

review of current methods. Journal if pest science. 92, 37–49.
33. Pysˇek, P., & Pergl, J. (2012). A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species traits and environment. Global Change Biology. 18, 1725–1737.
34. Pysˇek, P., Richardson, D.M. (2010). Invasive species, environmental change and man- agement, and health. Annual review of environment and Resource. 35, 25–55.
35. Rai, P.K. (2018). Phytoremediation of Emerging Contaminants in Wetlands. CRC Press, Taylor & Francis, Boca Raton, Florida, USA, pp. 248.
36. Sajeev., & Santhoshkumar, P. A. (2012). Are alien invasive plants a threat to forests of kerala?. KFRI occasional papers 001.
37. Sax, D.F. & Gaines, S.D.(2008). Species invasions and extinction: the future of native bio- diversity on islands. Proceedings of National Academy of Sciences. 105, 11490–11497.
38. Schmitz, D.C., & Simberloff, R. H. (1997). The ecological impact of nonindigenous plants. In: Simberloff, D. (Ed.), Strangers in Paradise. Island Press, pp. 39–61.
39. Seebens, H., Dawson, W., & Pergl, B. (2018). Global rise in emerging alien species results from increased accessibility of new source pools.Proceedings of National Academy of Sciences.115 (10), 2264–E2273.

40. Shackleton, R.T., Shackleton, C.M., Kull, C.A. (2019). The role of invasive alien species in shaping local livelihoods and human well-being: a review. Journal of Environmental Management. 229, 145–157.
41. Shackleton, R.T., Witt, A.B.R., Piroris, F.M., van Wilgen, B.W. (2017). Distribution and socio-ecological impacts of the invasive alien cactus Opuntia stricta in eastern Africa. Biological Invasions. 19, 2427–2441.
42. Sharma, G.P., Raghubanshi, A.S., Singh, J.S. (2005). *Lantana* invasion: an overview.Weed Biology Management. 5, 157–165.
43. Shiferaw, H. (2019). Modelling the current fractional cover of an invasive alien plant and drivers of its invasion in a dryland ecosystem. Scientific Reports. 9, 1576.
44. Sileshi, G.W., Gebeyehu, S., Mafongoya, P. (2019). The threat of alien invasive insect and mite species to food security in Africa and the need for a continent-wide response. Food Security 11, 763–775.
45. Simberloff, D. & Von Holle, B. (1999). Positive interaction of nonindigenous species: inva- sional meltdown. Biological Invasions. 1, 21–32.
46. Souza, A.O., & Oliveira, F. M. (2018). Local ecological knowledge concerning the invasion of Amerindian lands in the northern Brazilian Amazon by *Acacia mangium* (Willd.). Journal of Ethnobiology. 14, 33.
47. Stohlgren, T.J., & Schnase, J.L. (2006). Risk analysis for biological hazards: what we need to know about invasive species. Risk Analysis. 26 (1), 163–173.

48. Stone, C.M., & Walsh, G. C. (2018). Would the control of invasive alien plants reduce malaria transmission: A review. Parasites Vectors. 11, 76.
49. Vanderhoeven, S., Cigar, J., & Gallardo, B. (2017). Beyond protocols: improving the reliability of expert- based risk analysis underpinning invasive species policies. Biological Invasions 19, 2507–2517.
50. Vilà, M., Kenis, M., & Essl, F. (2019). A review of impact assessment protocols of non-native plants. Biological Invasions. 21, 709–723.
51. Yemshanov, D., & Venette, R. C. (2019). Optimizing surveillance strategies for early detection of invasive alien species. Ecological Economics. 162, 87–99.
52. Young, H.S., Parker, I. M., & Nunn, C. L. (2017). Introduced species, disease ecology, and biodiversity–disease relationships. Trends in Ecology and Evolution. 32 (1), 41–54.
53. Zavaleta, E. (2000). The economic value of controlling an invasive shrub. Ambio. 29, 462–467.
54. Zheng, Y. L., Feng, Y. L., & Yang, J. (2015). Integrating novel chemical weapons and evolutionarily increased competitive ability in success of a tropical invader. New Phytologist. 205, 1350–1359.
55. Zhou, D., Yang, Y., & Yang, X. (2019). Biosafety and biosecurity. Journal of Biosafety and Biosecurity. 1, 15–18.

# An overview of bryophytes in Western Ghats

Nadiya K.T., Surya E.V., Deepa P.

PG Department of Botany, KAHM Unity Women's College, Manjeri, Malappuram, Kerala, India, 676122
Corresponding author: deepapsaj@gmail.com

The bryophytes of the Western Ghats are a vital component of the biodiversity and ecological functioning. Their conservation is essential not only for preserving the unique flora of the Western Ghats but also for maintaining the ecological balance of the region. Research, habitat protection and public awareness are key to ensuring the survival of the important plants. Mosses, belonging to the class Bryopsida, are a significant component of the bryophyte flora in the Western Ghats which are small, non-vascular plants that found in a wide range of habitats within the Western Ghats, from the lowland rainforests to the high-altitude montane regions. It plays a critical role in the ecology of the region, contributing to soil formation, water retention and providing microhabitats for various organisms. Liverworts, belonging to the division Marchantiophyta, are a significant group of non-vascular plants, often overlooked due to their small size and play an essential role in the ecology of the region. Liverworts are among the earliest land plants and thrive in the moist, shaded environments that characterize the Western Ghats.

**Keywords**: Liverworts, Mosses, Non-vascular plants, Western Ghats, Microhabitats

## 1. Introduction

Bryophytes, a group of non-vascular plants, include mosses, liverworts and hornworts that play a crucial role in the ecosystem by contributing to soil formation, water retention and providing habitats for microfauna (Qing et al., 1999). The Western Ghats is a biodiversity hotspot in India, known for its rich flora and fauna, including a variety of bryophytes together with different pteridophytes and angiosperms (Subramanyam and Nayar 1974). The Western Ghats provide an ideal environment for bryophytes due to its varied climate

and topography and hosts over 850 species, making it one of the richest areas for bryophyte diversity in India. Mosses are the most dominant group, followed by liverworts and hornworts which are commonly found in moist, shaded environments such as forest floors, tree trunks, rocks and along streams (Kumar et al., 2011).
The term Bryophyta was derived from two Greek words; Bryon meaning moss and Phyton meaning plant, that introduced by Robert Brown in 1864 to include the algae, fungi, lichens and mosses. Recently, the term has been used to mention the group of plants which includes the members of non-vascular cryptogams. The bryophytes are highly specialized group of plants having enormous surviving capacity as they survive under wide variety of environmental conditions (Mogensen, 1981). They grow in different habitats like forests, wet lands, desert etc. Though basically terrestrial, some of them are aquatic like *Riccia fluitans, Ricciocarpus natans* and *Riella* spp., while *Cryptothallus* and *Buxbaumia* are saprophytic genera of liverworts. Mosses on contrary to the rest of the bryophytes are autotrophic. Generally, they have been classified under three diversified classes viz., Hepaticae, Anthocerotae and Musci (liverworts, hornworts and mosses respectively).

Bryophytes play an important role in nutrient cycling, soil formation and provide microhabitat for other plants and animals. Beyond this, they have been widely used for pollution monitoring and bioremediation (Wei and Fang, 2004). Due to rapid urbanization and pressures inflicted by growth of human population and their intense activities, the bryophyte diversity is greatly influenced. Hence, the

 ISBN: 978-93-340-7821-3

conservation of bryophyte is very important in ecosystem dynamics which can be established by creating moss gardens and protected areas, sacred groves and in-vitro technique. The regular monitoring and periodic collection of data on rare and threatened species is also relevant in conservation strategy (Das et al., 2006). The bryophytes are the second largest group of plants after angiosperms. Due to the wide distribution, recent researches regarding Molecular Biology, Anatomy, Systematics, Cytology etc. are focused on the group.

## 2. Diversity in bryophytes

Bryophyte are diverse and heterogenous division of the plant kingdom include three groups, *viz*. Liverworts, Hornworts, and Musci (True moss). They are viewed as three monophyletic lineages emerging from the earliest land plants by observing from the cell ultrastructure and Molecular Biology including Liverwort (Hepaticopsida), Moss (Bryopsida) and Hornwort (Anthocerotopsida) (Troitsky et al., 2007).

### 2.1. Liverwort

Liverworts include a number of species ranges from 5000, consists of 141 genera and 59 tribes (Grace, 1995). Leafy forms are represented by nearly 85% that show extensive amount of morphological, anatomical and ecological diversity. The plants with leafy shoot system are the predominant growth forms in this class (*Radula*, *Frullania*, *Jubulopsis* and *Cololejeunea*). Thalloid forms such as Metzgeriales and Marchantiales are widely seen in semi aquatic places and wet climate forests. Sporophyte of liverworts grows with the gametophyte up to the time of the capsules. The dispersal

 ISBN: 978-93-340-7821-3

mechanism of the spores is by the twisting motion of elaters and by splitting of sporophyte into four segments (Fenton and Frego, 2005).

## 2.2. Mosses

Mosses are the largest group with estimates of the number of species ranging from 10000 to 15000. In India mosses portray 2300 species in 330 genera. It is one of the dominant plants in the highlands that grows in cold and humid conditions (Groombridge and Jenkins, 2002). In most cases, leaves are arranged spiral and have leaf veins. For the effective spore dispersal, the capsule has a unique structure called peristome. The sphagnum mosses are one of the most economically and ecologically important types of bryophytes (Bahuguna et al., 2014).

## 2.3. Hornworts

Hornworts consists of approximately 200 species in the world. This class similar to liverwort except the thalloid gametophyte in the form of discs and chiselled edges. It possesses *Nostoc* colonies ventrally in their thallus. These algae show the symbiotic nature of providing organic nitrogen for thallus metabolism and the thallus provide food and shelter. This type has sporangia like a cylindrical horn called sporophyte. The released spore from sporophytes takes place gradually over a long period. The spores are dispersed through water movement and not by wind. Hornworts is different from all other land plants in having only one large, algal-like chloroplast in each thallus (Feldberg et al., 2021).

 ISBN: 978-93-340-7821-3

## 3. Classification

Bryophytes, the non-vascular plants, are typically small and complete their life cycle in moist environments that include mosses, liverworts and hornworts. These are classified into three main classes based on their morphological and reproductive features including Hepaticopsida, Bryopsida and Anthocerotopsida (Renzaglia et al., 2007).

Hepaticopsida members has thalloid or leafy structure with simple, lobed leaves arranged in two or three rows. Rhizoids (root-like structures) are unicellular and reproduce asexually through gemmae and sexually through antheridia and archegonia. The sporophyte is relatively simple and often lacks stomata. The class includes *Marchantia* and *Riccia* species.

The Bryopsida possesses the most common and diverse group of bryophytes having leafy gametophytes with spirally arranged leaves and multicellular rhizoids. The sporophyte has a complex structure with a capsule and stomata which reproduce sexually, with a prominent sporophyte that is attached to the gametophyte. *Funaria* and *Polytrichum* include in the class with specific features.

The species of Anthocerotopsida have thalloid gametophytes with a flattened, lobed appearance. They have a unique horn-like sporophyte that grows continuously from the base. Stomata are present in the sporophyte which is photosynthetically active. Each cell typically contains a single large chloroplast. *Anthoceros* and *Notothylas* are the prominent species of the class. These classes represent the diversity within bryophytes, showcasing different adaptations to their environments and life cycles (Shaw and Goffinet, 2000).

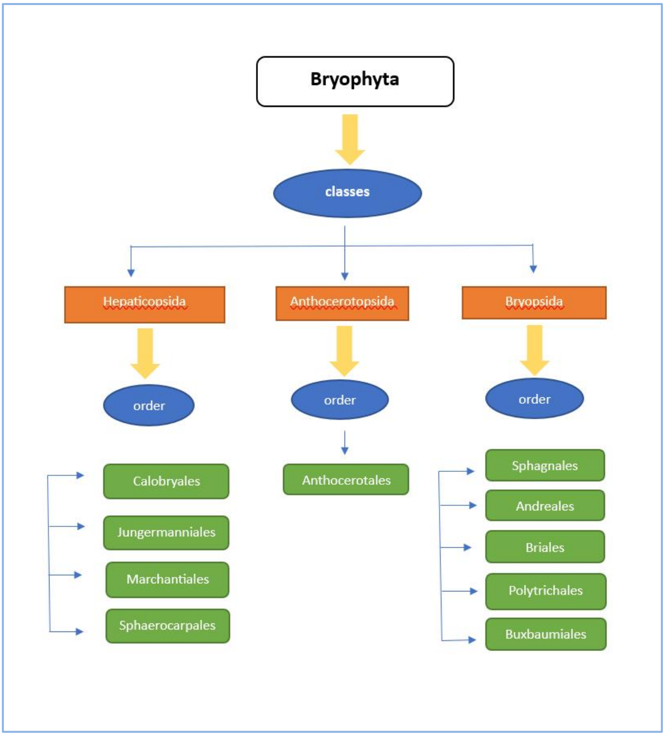


Figure 1. Classification of bryophytes

## 4. Ecological importance

Bryophytes have many ecological uses in turn balance the ecosystem, even though these are smaller flora. Some of the important roles of bryophytes are given below which maintain the normal functioning of the ecosystem.

### 4.1. As pioneer colonizers in succession

The nutrient-poor, barren areas, where no other plants may flourish, are normally colonized by bryophytes. Following a protracted period, these bryophyte colonies formed an organic layer on that desolate area, aiding in the development of microorganisms. These microorganisms alter the mineral state of substratum, making the area favourable for the growth of more vegetation. During periods of excessive moisture, the colonies of epiphytic bryophytes that grow on tree trunks and branches absorb water. As a result, the branches break and their weight increases. As a result, a new succession is created together with the breakdown wood, changes in moisture and lighting conditions (Ogwu, 2020).

### 4.2. As pollution and heavy metal indicator

Bryophytes are heavy metal accumulators and bioindicators of pollution in the air and water. Under such disturbed environmental conditions viz. air pollution, communities of liverworts, lichens and mosses gradually shrink. With the exception of a few resilient species including *Bryum*, *Ceratodon*, *Dicranoweisia*, *Funaria*, *Hyophila* and *Tortula*, mosses vanish from such contaminated regions. A good picture of the level of pollution can be obtained by examining the relationship between the distribution of communities, Index of Atmospheric Purity (IAP) values, and sulfur dioxide levels. The vegetative propagule, protonemata, is particularly sensitive to the contaminant that affect the growth of microflora. While, mosses can flourish in environments with even low $SO_2$ concentrations. Hydrogen fluoride (HF) can harm bryophytes, even at low concentrations (0.001 to 0.1 ppm), as they are highly sensitive to it. When exposed to an HF-polluted environment, *Pylaisiella* and *Orthotrichum* have been found to alter the color of their leaves as a result of chlorophyll degradation (Leblanc and Rao, 1974). *Sphagnum* is utilized to filter contaminated waste water and has a unique ability to bind radioactive substances through cation exchange. Caesium can accumulate in certain species of *Anomodon*, *Dicranum*, *Eurhynchium*, *Leucodon*, *Mnium*, *Rhynchostegium*, and *Thuidium*. It has been discovered that leafy liverworts are more susceptible to ionizing radiation. More strontium can be concentrated by species of *Brachythecium*, *Buxbaumia*, and *Grimmia* than can be found in their substrata. Similarly, certain alien bryophytes can store uranium. Many moss-sporophytes growth is inhibited by high amounts of contaminants such as heavy metals, sulphur dioxide, fluoride and acidified rain. Because aquatic bryophytes can accumulate heavy metals and release them only after decomposing, they are the greatest monitoring agents for heavy metal contamination. Some bryophytes have high cadmium concentrations, which causes a noticeable shift in these lower plant's growth rate and pigmentation. Zinc concentrations greater than 50 ppm inhibit spore germination in *Marchantia* and *Funaria*. Certain species of *Bryum*, *Dicranella* and *Polytrichum* can withstand high concentrations of copper (2700 ppm), cadmium (610 ppm), and zinc (55000 ppm) in their tissues (Printarakul and Meeinkuirt, 2022).

### 4.3. As site indicators

Compared to vascular plants, bryophytes have a greater capacity to hold onto certain minerals in their substrata. For this reason, they are employed in geobotanical research. *Barbula*, *Gymnocolea*, *Mereya*, *Mielichhoferia*, *Scopelophila* and *Solenostoma* species are found on zinc, iron and lead sulphides, and they grow best in substrates containing high copper concentrations (320-770 ppm). Several species belonging to *Campylopus*, *Barbula*, *Brachythecium*, *Bryum* and *Gymnostomum* have been shown to flourish on gypsum (pH 4.9-7.8) and to frequently have this material encrusted on them (Tewari and Pant 1998). Certain bryophytes accumulate deposits of tufa and the precipitation of calcium from the surrounding soil produces calcareous tufas. Certain species are related to the seed plants because the particular community of seed plants provide a favourable habitat for the bryophytic plants. As a result, it helps to describe a site in certain contexts, even when the vascular plant dies, bryophyte vegetation can provide information about the particular community. They can also be used as markers to plant specific taxa in that region and can show the sort of flora that was present in the past. *Solenostoma* thrives on the seepage water from copper mines. Certain bryophytes are able to grow in such soil, which has a high concentration of copper which collect copper from the soil (Hylander et al., 2002). Rainfall readily accumulates K, Ca, and Mg in mosses. The patterns found on *Hyophila*, *Oxystegus*, and *Zygodon* denote substrates containing iron hematite at that specific location. Bryophytes have a well-defined ecological range and are useful for assessing soil quality and environmental conditions. A sign of acidic soil is *Polytrichum* which flourish in acidic conditions. A few indicators of soil pH were listed by Hydbom et al. (2012), including *Atrichum undulatum* (4.5-6.0), *Marchantia polymorpha* (6-7.5), *Tortula rhyzophylla* (6.1-7.4) and others.

## 4.4. Ecophysiology of the group

Globally, bryophytes are extensively dispersed and play a role in the cycling of nutrients, water retention, availability, increased biomass in plants and community maintenance (Song et al., 2015). Therefore, the services, activities and processes of the ecosystem benefit other members of the ecological community of bryophytes. The water that bryophytes collect benefits other plants ecologically by utilizing it for internal operations (Atwood and Buck, 2020). In general, these services might be referred to as 'buffer systems'. Because of their diversity of chemical groups and sensitivity to atmospheric moisture levels, bryophytes serve as indicators of environmental quality. According to Lobs et al. (2019), bryophyte responses to environmental variations are a reflection of their ecological and reproductive strategies for ensuring their establishment, permanence and spread. The results of Perera-Castro et al. (2022) have refuted an earlier concept that suggested bryophyte fertility declines with increasing latitude and consequently climate severity. Furthermore, their sex expression is persistent over extended periods of time, irrespective of locales, seasons and small environmental differences; yet, the maturity of gametangia and sporophytes may be influenced by seasonal variations (Maciel-Silva et al., 2012). In mosses, carbon fixation reaches saturation at moderate light levels. According to Proctor and Smirnoff (2011), mosses have a high capacity for photosynthetic electron transfer to oxygen, a high level of non-photochemical quenching that is activated at high irradiance, and a high tolerance to reactive oxygen species as means of protecting themselves against excess excitation energy. According to Wagner et al. (2014), bryophytes, being poikilohydric organisms, adjust to external moisture conditions quite quickly. Moreover, bryophyte development and survival are heavily reliant on their external environment because of their poikilohydric strategy for nutrients and water (Marschall, 2017).

**5. Diversity of bryophytes in Western Ghats**

The checklist reports that total 2489 taxa of bryophytes recorded from India, comprising 1786 species in 355 genera of mosses, 675 species in 121 genera of liverworts and 25 species in six genera of hornworts (Sathish et al., 2013). The bryophyte flora of the *Agasthyamalai* Biosphere Reserve consists of 90 taxa (58 mosses, 32 liverworts), of which 16 species are newly reported for the Peninsular India (*Asterella reticulata, Bazzania sumbavensis, Cephalozia pandei, Clastobryopsis muelleri, Cyathophorella adiantum, Dicranoloma subreflexifolium, Herbertus dicranus, Himantocladium cyclophyllum, Hypnum plumaeforme, H. sikkimense, Leucobryum cucullifolium, Radula grandifolia, Symblepharis vaginata, Symphyodon echinatus, Trichocolea udarii* and *Trichostelium boschii*) and another 6 are new for the Kerala State (*Campylopus involutus, Cephaloziella willisiana, Frullania ericoides, Macromitrium moorcroftii, Metzgeria decipiens* and *Leucobryum mittenii*) (Manju and Rajesh, 2009). Coorg District of Karnataka, a small area of the Western Ghats, includes 18 species of liverworts and hornworts as well as 76 species of mosses. 27 species of mosses are newly reported for the state of Karnataka, in which 6 species are new for Coorg province. *Holomitrium javanicum*

 ISBN: 978-93-340-7821-3

is reported as new one to India and *Campylopus sedgwickii* described from Sri Lanka (Schwarz and Frahm, 2013).

Table 1. Species of bryophytes in Western Ghats

| Sl. No | Species | Family |
|---|---|---|
| 1 | *Asterella reticulata* | Aytoniaceae |
| 2 | *Dumortiera hirsuta* | Marchantiaceae |
| 3 | *Plagiochasma appendiculatum* | Marchantiaceae |
| 4 | *Targionia hypophylla* | Targioniaceae |
| 5 | *Riccardia tenuicostata* | Aneuraceae |
| 6 | *Metzgeria decipiens* | Metzgeriaceae |
| 7 | *Pallavicinia lyellii* | Pallaviciniaceae |
| 8 | *Pallavicinia ambigua* | Pallaviciniaceae |
| 9 | *Trichocolea udarii* | Trichocoliaceae |
| 10 | *Chandonanthus birmensis* | Jungermanniaceae |
| 11 | *Schistochila aligera* | Schistochilaceae |
| 12 | *Jubula hutchinsiae* | Jubulaceae |
| 13 | *Frullania ericoides* | Jubulaceae |
| 14 | *Frullania tamarisci* | Jubulaceae |
| 15 | *Bazzania tridens* | Lepidoziaceae |
| 16 | *Bazzania sumbavensis* | Lepidoziaceae |
| 17 | *Cephalozia pandei* | Cephaloziellaceae |
| 18 | *Cephaloziella willisiana* | Cephaloziellaceae |
| 19 | *Cephalozia willisiana* | Cephaloziellaceae |
| 20 | *Cephalozia andreana* | Cephaloziellaceae |
| 22 | *Cylindrocolea tagawae* | Cephaloziellaceae |
| 23 | *Herbertus dicranus* | Herbertaceae |
| 25 | *Radula grandifolia* | Radulaceae |
| 26 | *Cololejeunea lanciloba* | Lejeuneaeceae |
| 27 | *Lejeunea obfusca* | Lejeuneaeceae |
| 28 | *Lejeunea eifrigii* | Lejeuneaeceae |
| 29 | *Cheilolejeunea serpentina* | Lejeuneaeceae |
| 30 | *Spruceanthus semirepandus* | Lejeuneaeceae |
| 31 | *Plagiochila beddomei* | Plagiochilaceae |
| 32 | *Plagiochila devexa* | Plagiochilaceae |
| 33 | *Plagiochila fruticosa* | Plagiochilaceae |
| 34 | *Plagiochila nepalensis* | Plagiochilaceae |
| 35 | *Pogonatum leucopogon* | Polytrichaceae |
| 36 | *Pogonatum microstomum* | Polytrichaceae |

 ISBN: 978-93-340-7821-3

| | | |
|---|---|---|
| 37 | *Diphyscium mucronifolium* | Diphysciaceae |
| 39 | *Entosthodon wichurae* | Funariaceae |
| 40 | *Calymperes afzelii* | Calymperaceae |
| 41 | *Calymperes lonchophyllum* | Calymperaceae |
| 43 | *Fissidens anomalus* | Fissidentaceae |
| 45 | *Dicranoloma subreflexifolium* | Dicranaceae |
| 46 | *Campylopus ericoides* | Dicranaceae |
| 47 | *Campylopus flexuosus* | Dicranaceae |
| 48 | *Campylopus involutus* | Dicranaceae |
| 49 | *Campylopus pilifer* | Dicranaceae |
| 50 | *Symblepharis vaginata* | Dicranaceae |
| 51 | *Leucobryum cucullifolium* | Leucobryaceae |
| 52 | *Leucobryum juniperoideum* | Leucobryaceae |
| 53 | *Leucobryum mittenii* | Leucobryaceae |
| 54 | *Leucoloma amoene-virens* | Leucobryaceae |
| 55 | *Leucoloma taylorii* | Leucobryaceae |
| 57 | *Tortella tortuosa* | Pottiaceae |
| 58 | *Bryum paradoxum* | Bryaceae |
| 59 | *Bryum wightii* | Bryaceae |
| 60 | *Rhodobryum roseum* | Bryaceae |
| 61 | *Pyrrhobryum spiniforme* | Rhizogoniaceae |
| 62 | *Racopilum orthocarpum* | Racopilaceae |
| 63 | *Macromitrium sulcatum* | Orthotrichaceae |
| 64 | *Macromitrium moorcroftii* | Orthotrichaceae |
| 65 | *Garovaglia plicata* | Pterobryaceae |
| 68 | *Himantocladium cyclophyllum* | Pterobryaceae |
| 69 | *Homaliodendron flabellatum* | Pterobryaceae |
| 70 | *Homaliodendron microdendron* | Pterobryaceae |
| 71 | *Trachypus bicolor* | Trachypodaceae |
| 72 | *Aerobryum speciosum* | Meteoriaceae |
| 73 | *Meteoriopsis squarrosa* | Meteoriaceae |
| 74 | *Pinnatella calcutensis* | Neckeraceae |
| 75 | *Thuidium cymbifolium* | Thuidiaceae |
| 76 | *Thuidium pristocalyx* | Thuidiaceae |
| 77 | *Symphyodon echinatus* | Symphyodontaceae |
| 78 | *Cyathophorum adiantum* | Hypopterigiaceae |
| 79 | *Hypopterygium aristatum* | Hypopterigiaceae |
| 80 | *Chionostomum rostratum* | Sematophyllaceae |
| 81 | *Clastobryopsis muelleri* | Sematophyllaceae |
| 82 | *Foreauella orthothecia* | Sematophyllaceae |
| 83 | *Taxiphyllum taxirameum* | Sematophyllaceae |

 ISBN: 978-93-340-7821-3

| | | |
|---|---|---|
| 84 | *Trichostelium boschii* | Sematophyllaceae |
| 85 | *Isopterygium albescens* | Isopterygiaceae |
| 86 | *Wijkia surcularis* | Isopterygiaceae |
| 87 | *Ctenidium lychnites* | Isopterygiaceae |
| 88 | *Vesicularia vesicularis* | Isopterygiaceae |
| 89 | *Hypnum plumaeforme* | Hypnaceae |
| 90 | *Hypnum sikkimense* | Hypnaceae |
| 91 | *Ectropothecium sikkimense* | Hypnaceae |
| 92 | *Macrothamnium macrocarpum* | Hylocomiaceae |
| 93 | *Sphagnum ceylanicum* | Sphagnaceae |
| 94 | *Atrichum aculeatum* | Polytrichaceae |
| 95 | *Atrichum flavisetum* | Polytrichaceae |
| 96 | *Atrichum longifolium* | Polytrichaceae |
| 97 | *Atrichum obtusulum* | Polytrichaceae |
| 98 | *Atrichum pallidium* | Polytrichaceae |
| 99 | *Atrichum subserratum* | Polytrichaceae |
| 100 | *Lyellia aspera* | Polytrichaceae |
| 101 | *Lyellia platycarpa* | Polytrichaceae |
| 102 | *Pogonatum aloides forma- neesii* | Polytrichaceae |
| 103 | *Pogonatum decolyi* | Polytrichaceae |
| 104 | *Pogonatum himalayanum* | Polytrichaceae |
| 105 | *Pogonatum junghuhnianum* | Polytrichaceae |
| 107 | *Pogonatum leucopogon* | Polytrichaceae |
| 108 | *Pogonatum microstomum* | Polytrichaceae |
| 109 | *Pogonatum juniperinum* | Polytrichaceae |
| 110 | *Diphyscium fasciculatum* | Diphysciaceae |
| 111 | *Diphyscium involutum* | Diphysciaceae |
| 112 | *Diphyscium mucronifolium* | Diphysciaceae |
| 113 | *Theriotia lorifolia* | Diphysciaceae |
| 114 | *Timmia megapolitana* | Timmiaceae |
| 115 | *Entosthodon buseanus* | Funariaceae |
| 116 | *Entosthodon diversinervis* | Funariaceae |
| 117 | *Entosthodon perrottetti* | Funariaceae |
| 118 | *Entosthodon pulchra* | Funariaceae |
| 119 | *Entosthodon wichurae* | Funariaceae |
| 120 | *Funaria buseana* | Funariaceae |
| 121 | *Funaria diversinervis* | Funariaceae |
| 122 | *Funaria hygrometrica* | Funariaceae |
| 123 | *Funaria hygrometrica* var.*calvescens* | Funariaceae |
| 124 | *Funaria hygrometrica* var. | Funariaceae |

 ISBN: 978-93-340-7821-3

| | | |
|---|---|---|
| | *hygrometrica* | |
| 125 | *Funaria perrottetti* | Funariaceae |
| 126 | *Funaria physcomitrioides* | Funariaceae |
| 127 | *Funaria submarginata* | Funariaceae |
| 128 | *Physcomitrium coorgense* | Funariaceae |
| 129 | *Physcomitrium insigne* | Funariaceae |
| 130 | *Physcomitrium repandum* | Funariaceae |
| 131 | *Dryptodon fuscoluteus* | Grimmiaceae |
| 132 | *Racomitrium crispulum* | Grimmiaceae |
| 133 | *Schistidium apocarpum* | Grimmiaceae |
| 134 | *Glyphomitrium calycinum* | Ptychomitriaceae |
| 135 | *Archidium birmannicum* | Archidiaceae |
| 136 | *Fissidens angustiusculus* | Fissidentaceae |
| 137 | *Fissidens anomalus* | Fissidentaceae |
| 138 | *Fissidens asperisetus* | Fissidentaceae |
| 139 | *Fissidens asperisetus* var. *andamanensis* | Fissidentaceae |
| 140 | *Fissidens biformis* | Fissidentaceae |
| 141 | *Fissidens bryoides* | Fissidentaceae |
| 142 | *Fissidens ceylonensi* | Fissidentaceae |
| 143 | *Fissidens ceyloninsis* | Fissidentaceae |
| 144 | *Fissidens ceylonensis* var. *ceylonensis* | Fissidentaceae |
| 145 | *Fissidens crenulatus* var. *crenulatus* | Fissidentaceae |
| 146 | *Fissidens cristatus* | Fissidentaceae |
| 147 | *Fissidens crispulus* var. *crispulus* | Fissidentaceae |
| 148 | *Fissidens crispulus* var. *robinsonii* | Fissidentaceae |
| 149 | *Fissidens curvatoinvolutus* | Fissidentaceae |
| 150 | *Fissidens diversifolius* | Fissidentaceae |
| 151 | *Fissidens dubius* | Fissidentaceae |
| 152 | *Fissidens ganguleei* | Fissidentaceae |
| 153 | *Fissidens grifithii* | Fissidentaceae |
| 154 | *Fissidens hyalinus* | Fissidentaceae |
| 155 | *Fissidens incognitus* | Fissidentaceae |
| 156 | *Fissidens intromarginatulus* | Fissidentaceae |
| 157 | *Fissidens involutus* subsp. *involutus* | Fissidentaceae |
| 158 | *Fissidens jungermannioides* | Fissidentaceae |
| 159 | *Fissidens kalimpogensis* | Fissidentaceae |
| 160 | *Fissidens kalimpongensis* | Fissidentaceae |
| 161 | *Fissidens minutes* | Fissidentaceae |
| 162 | *Fissidens nymanii* | Fissidentaceae |

 ISBN: 978-93-340-7821-3

| | | |
|---|---|---|
| 163 | *Fissidens pulchellus* | Fissidentaceae |
| 164 | *Fissidens pullucidus* | Fissidentaceae |
| 165 | *Fissidens serratus* var. *serratus* | Fissidentaceae |
| 166 | *Fissidens subangustus* | Fissidentaceae |
| 167 | *Fissidens subryoides* | Fissidentaceae |
| 168 | *Fissidens subpulchellus* | Fissidentaceae |
| 169 | *Fissidens sylvatus* var. *auriculatus* | Fissidentaceae |
| 170 | *Fissidens sylvatus* var. *teraicola* | Fissidentaceae |
| 171 | *Fissidens sylvatus* var. *zippenlianus* | Fissidentaceae |
| 172 | *Fissidens teraicola* | Fissidentaceae |
| | *Fissidens virens* | Fissidentaceae |
| 173 | *Fissidens xiphioides* | Fissidentaceae |
| 174 | *Ceratodon purpureus* var. *purpureus* | Ditrichaceae |
| 175 | *Ceratodon purpureus* var. *stenocarpous* | Ditrichaceae |
| 176 | *Ceratodon stenocarpous* | Ditrichaceae |
| 177 | *Ditrichum amoenum* | Ditrichaceae |
| 178 | *Garckea flexuosa* | Ditrichaceae |
| 179 | *Garckea phascoides* | Ditrichaceae |
| 180 | *Trematodon brevicalyx* | Bruchiaceae |
| 181 | *Trematodon ceylonensis* | Bruchiaceae |
| 182 | *Trematodon schmidii* | Bruchiaceae |
| 183 | *Aulacopilum abbreviatum* | Erpodiaceae |
| 184 | *Aulacopilum mangiferae* | Erpodiaceae |
| 185 | *Solmsiella biseriata* | Erpodiaceae |
| 186 | *Solmsiella ceylonica* | Erpodiaceae |
| 187 | *Oreoweisia laxifolia* | Rhabdoweisiaceae |
| 188 | *Symblepharis vaginata* | Rhabdoweisiaceae |
| 189 | *Braunfelsia edentula* | Dicranaceae |
| 190 | *Campylopodium griffithii* | Dicranaceae |
| 191 | *Campylopodium khasianum* | Dicranaceae |
| 192 | *Dicranella divaricata* | Dicranaceae |
| 193 | *Dicranoloma fragile* | Dicranaceae |
| 194 | *Dicranum crispifolium* | Dicranaceae |
| 195 | *Dicranum lorifolium* | Dicranaceae |
| 196 | *Dicranum psathyrum* | Dicranaceae |
| 198 | *Leptotrichella assamica* | Dicranaceae |
| 199 | *Leptotrichella schmidii* | Dicranaceae |
| 200 | *Leucoloma amoene-virens* | Dicranaceae |
| 201 | *Leucoloma brevifolium* | Dicranaceae |
| 202 | *Leucoloma insigne* | Dicranaceae |

| | | |
|---|---|---|
| 203 | *Leucoloma rennauldii* | Dicranaceae |
| 204 | *Leucoloma taylorii* | Dicranaceae |
| 205 | *Leucoloma tennerum* | Dicranaceae |
| 206 | *Microdus brasiliensis* | Dicranaceae |
| 207 | *Campylopus albescens* | Leucobryaceae |
| 208 | *Campylopus ericoides* | Leucobryaceae |
| 209 | *Campylopus flexuosus* | Leucobryaceae |
| 210 | *Campylopus goughii* | Leucobryaceae |
| 211 | *Campylopus involutus* | Leucobryaceae |
| 212 | *Campylopus laetus* | Leucobryaceae |
| 213 | *Campylopus pilifer* | Leucobryaceae |
| 214 | *Campylopus recurvus* | Leucobryaceae |
| 215 | *Campylopus richardii* | Leucobryaceae |
| 216 | *Campylopus schmidii* | Leucobryaceae |
| 217 | *Campylopus schimperi* | Leucobryaceae |
| 218 | *Campylopus zollingerianus* | Leucobryaceae |
| 219 | *Leucobryum aduncum* | Leucobryaceae |
| 220 | *Leucobryum bowringii* | Leucobryaceae |
| 221 | *Leucobryum cucullifolium* | Leucobryaceae |
| 222 | *Leucobryum humillimum* | Leucobryaceae |
| 223 | *Leucobryum javense* | Leucobryaceae |
| 224 | *Leucobryum juniperiodeum* | Leucobryaceae |
| 225 | *Leucobryum mittenii* | Leucobryaceae |
| 226 | *Leucobryum scalare* | Leucobryaceae |
| 227 | *Anoectangium walkeri* | Pottiaceae |
| 228 | *Barbula indica* | Pottiaceae |
| 229 | *Didymodon recurvus* | Pottiaceae |
| 230 | *Hydrogonium consanguineum* | Pottiaceae |
| 231 | *Hymenostomum edentulum* | Pottiaceae |
| 232 | *Hymenostylium recurvirostre* | Pottiaceae |
| 233 | *Hymenostylium recurvirostre* var. *aurantiacum* | Pottiaceae |
| 234 | *Hymenostylium recurvirostrum* var. *recurvirostrum* | Pottiaceae |
| 235 | *Oxystegus cylindricus* | Pottiaceae |
| 236 | *Oxystegus stenophyllus* | Pottiaceae |
| 237 | *Oxystegus tenuirostris* | Pottiaceae |
| 238 | *Semibarbula orientalis* | Pottiaceae |
| 239 | *Splachnobryum indicum* | Pottiaceae |
| 240 | *Tayloria indica* | Splachnaceae |
| 241 | *Tayloria subglabra* | Splachnaceae |

| | | |
|---|---|---|
| 242 | *Tayloria subglabra* var. *nosa* | Splachnaceae |
| 243 | *Meesia indica* | Meesiaceae |
| 244 | *Meesia triquetra* | Meesiaceae |
| 245 | *Anomobryum auratum* | Bryaceae |
| 246 | *Anomobryum cymbifolium* | Bryaceae |
| 247 | *Anomobryum schmidii* | Bryaceae |
| 248 | *Brachymenium acuminatum* | Bryaceae |
| 249 | *Brachymenium capitulatum* | Bryaceae |
| 250 | *Bryum argenteum* | Bryaceae |

*Physcomitrium eurystomum* is a temperate to tropical species, located on the way to Mattupetty from Munnar of Idukki district in the Western Ghats of Kerala. *Splachnobryum obtusum* observed from the lateritic midland of Malappuram district of Kerala. Both these species are of rare occurrence and poorly known in the Western Ghats (Manju et al., 2023). *Acidodontium indicum* is described and illustrated from the Western Ghats of Kerala. Since the genus has not been reported from India, it represents a new generic record as well. *Acidodontium indicum* is distinguished by small broadly lanceolate to more or less spathulate leaves having a strong, short excurrent costa, margin completely entire, bordered by 1-4 rows of long incrassate cells, short setae, capsule clavate with short apophysis, operculum conic without apiculus and endostome with high basal membrane and forked endostome segments diverging at a different angle (Vineesha et al., 2023). The Anamudi Shola NP is composed of three shola patches, Mannavan Shola, Pullaradi Shola and Idivara Shola and ranging between the altitude zone of 1600 to 2440 m in the Western Ghats of Idukki district of Kerala. A total of 153 species of bryophytes identified from the Western Ghats, especially the hilly areas (Rajilesh, 2019). The mosses *Chaetomitrium papillifolium, Entodon ovicarpus, E. scariosus, Glossadelphus bilobatus, Pseudobarbella ancistrodes, Sematophyllum micans* and *Taxithelium kerianum*, earlier known to be distributed in the Himalaya, Northeast or the Andaman and Nicobar Islands, are recorded for the Western Ghats (Singh, 2020).

## Conclusion

Bryophytes play a crucial ecological role in the unique ecosystem of the Western Ghats, a biodiversity hotspot in India. The humid and shaded environments of Western Ghats provide an ideal habitat for a rich diversity of various bryophytes including mosses, liverworts and hornworts. These bryophytes contribute to soil stabilization, water retention and nutrient cycling that supporting the rich vegetation of the areas. Together with this, the Western Ghats are home to several endemic and rare bryophyte species; hence the conservation of botanical diversity is significant for proper maintenance of ecosystem.

## References

1. Atwood, J.J., Buck, W.R., 2020. Recent literature on bryophytes., The Bryologist. 123(3), 547-583.
2. Bahuguna, Y.M., Gairola, S., Semwal, D.P., Uniyal, P.L., 2014. Species diversity and composition of bryophytic vegetation in Garhwal Himalaya with special reference to Kedarnath Wildlife Sanctuary (KWLS), Uttarakhand, India., International Journal of Ecology and Environmental Sciences. 40(2-3), 75-85.

3. Das, A., Krishnaswamy, J., Bawa, K.S., Kiran, M.C., Srinivas, V., Kumar, N.S., Karanth, K. U., 2006. Prioritisation of conservation areas in the Western Ghats, India., Biological conservation. 133(1), 16-31.
4. Feldberg, K., Schaefer-Verwimp, A., Renner, M. A., Von Konrat, M., Bechteler, J., Mueller, P., Schmidt, A. R., 2021. Liverworts from Cretaceous amber., Cretaceous Research. 128, 104-987.
5. Grace, M., 1995. A key to the growthforms of mosses and liverworts and guide to their educational value., Journal of Biological Education. 29(4), 272-278.
6. Groombridge, B., Jenkins, M., 2002. World atlas of biodiversity: earth's living resources in the 21st century., University of California Press.
7. Hydbom, S., Odman, A.M., Olsson, P.A., Cronberg, N., 2012. The effects of pH and disturbance on the bryophyte flora in calcareous sandy grasslands., Nordic Journal of Botany. 30(4), 446-452.
8. Hylander, K., Jonsson, B.G., Nilsson, C., 2002. Evaluating buffer strips along boreal streams using bryophytes as indicators., Ecological applications. 12(3), 797-806.
9. Kumar, S.N., Aggarwal, P.K., Rani, S., Jain, S., Saxena, R., Chauhan, N., 2011. Impact of climate change on crop productivity in Western Ghats, coastal and northeastern regions of India., Current Science. 332-341.
10. Leblanc, F., Rao, D.N., 1974. A review of the literature on bryophytes with respect to air pollution., Bulletin de la société botanique de France. 121(2), 237-255.

11. Lobs, N., Walter, D., Barbosa, C.G., Brill, S., Cerqueira, G.R., de Oliveira Sa, M., Weber, B., 2019. Microclimatic and ecophysiological conditions experienced by epiphytic bryophytes in an Amazonian rain forest., Biogeosciences Discussions. 2019, 1-36.
12. Maciel-Silva, A.S., Marques Valio, I. F., Rydin, H., 2012. Altitude affects the reproductive performance in monoicous and dioicous bryophytes: examples from a Brazilian Atlantic rainforest., AoB plants.
13. Manju, C.N., Rajesh, K. P., Madhusoodanan, P.V., 2009. Contribution to the bryophyte flora of India: Agasthyamalai biosphere reserve in Western Ghats., Taiwania. 54(1), 57-68.
14. Manju, C.N., Vineesha, P.M., Mufeed, B., Rajesh, K. P., 2023. Physcomitrium eurystomum Sendtn.(Funariaceae: Bryophyta) and Splachnobryum obtusum (Brid.) Müll. Hal. (Splachnobryaceae: Bryophyta), two rare moss species from the Western Ghats of Kerala., Journal of Threatened Taxa. 15(2), 22731-22736.
15. Marschall, M., 2017. Ecophysiology of bryophytes in a changing environment., Acta Biologica Plantarum Agriensis. *5*(2), 61-70.
16. Mogensen, G.S., 1981. The biological significance of morphological characters in bryophytes: the spore., Bryologist. 187-207.
17. Ogwu, M.C., 2020. Ecological and Economic Significance of Bryophytes., Current state and future impacts of climate change on biodiversity IGI Global. 54-78.
18. Pant, G., Tewari, S.D., 1998. Bryophytes as biogeoindicators: Bryophytic associations of mineral-

enriched substrates in Kumaon Himalaya., Topics in Bryology. Allied Publishers Ltd., New Delhi, India. 165-184.

19. Perera-Castro, A.V., Gonzalez-Rodriguez, A.M., Fernandez-Marin, B., 2022. When time is not of the essence: constraints to the carbon balance of bryophytes., Journal of Experimental Botany. 73(13), 4562-4575.
20. Printarakul, N., Meeinkuirt, W., 2022. The bryophyte community as bioindicator of heavy metals in a waterfall outflow., Scientific reports. 12(1), 6942.
21. Proctor, M.C., Smirnoff, N., 2011. Ecophysiology of photosynthesis in bryophytes: major roles for oxygen photoreduction and non-photochemical quenching., Physiologia Plantarum. 141(2), 130-140.
22. Qing, W.A.N.G., Shan-An, H.E., Peng-Cheng, W.U., 1999. The role of bryophytes in biodiversity., Biodiversity Science. 7(4), 332.
23. Rajilesh, V.K., 2019. Systematic studies on the bryophyte flora of mathikettan shola national park Kerala., KSCSTE-Malabar Botanical Garden and Institute for Plant Sciences Kozhikode Calicut University.
24. Renzaglia, K.S., Schuette, S., Duff, R.J., Ligrone, R., Shaw, A.J., Mishler, B.D., Duckett, J. G., 2007. Bryophyte phylogeny: advancing the molecular and morphological frontiers., The bryologist. 110(2), 179-213.
25. Sathish, S.S., Kavitha, R., Kumar, S.S., 2013. Bryophytes in India-the current status., International Journal of Research in Engineering and Bioscience. 1(4), 23.

26. Schwarz, U., Frahm, J.P., 2013. A contribution to the bryoflora of the Western Ghats in Karnataka State, India., Polish Botanical Journal. 58(2), 511-524.
27. Shaw, A. J., Goffinet, B., 2000. Bryophyte biology., Cambridge University Press.
28. Singh, P., 2020. Floristic diversity of India: an overview., Biodiversity of the Himalaya: Jammu and Kashmir State. 41-69.
29. Song, L., Zhang, Y. J., Chen, X., Li, S., Lu, H.Z., Wu, C.S., Shi, X.M., 2015. Water relations and gas exchange of fan bryophytes and their adaptations to microhabitats in an Asian subtropical montane cloud forest., Journal of Plant Research. 128, 573-584.
30. Subramanyam, K., Nayar, M.P., 1974. Vegetation and phytogeography of the Western Ghats., Ecology and biogeography in India. 178-196.
31. Troitsky, A.V., Ignatov, M.S., Bobrova, V.K., Milyutina, I. A., 2007. Contribution of genosystematics to current concepts of phylogeny and classification of bryophytes., Biochemistry. 72, 1368-1376.
32. Vineesha, P.M., Sajitha, M.S., Manju, C.N., Spence, J.R., 2023. Acidodontium indicum (Bryaceae: Bryophyta)—a new species from the Western Ghats of India., Bryophyte Diversity and Evolution. 46(1), 56-63.
33. Wagner, S., Bader, M.Y., Zotz, G., 2014. Physiological ecology of tropical bryophytes., Photosynthesis in bryophytes and early land plants. 269-289.
34. Wei, H.Y., Fang, Y.M., 2004. Review on bryophyte and airborne heavy metal pollution.

biomonitoring., Journal of Nanjing forestry university. 47(05), 77.

Published by:

Deepa P.; M.Sc., B.Ed., Ph.D.
Assistant Professor (Adhoc)
PG Department of Botany
Korambayil Ahamed Haji Memorial Unity Women's College
Manjeri, Narukara (PO), PIN: 676122, Malappuram (DT), Kerala, India

Surya E.V.; M.Sc.
Assistant Professor (Adhoc)
PG Department of Botany
Korambayil Ahamed Haji Memorial Unity Women's College
Manjeri, Narukara (PO), PIN: 676122, Malappuram (DT), Kerala, India

ISBN: 978-93-340-7821-3

978-93-340-7821-3

MRP. ₹750/-