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Case Study

Impact of flood on biodiversity of Kerala: A case study from Malappuram district of Kerala, India

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Abstract

The Kerala state has witnessed the worst flood of the century during 2018 monsoon, most devastated at Nilambur Taluk of Malappuram district. The present study at this location, precisely Mathilmoola colony and nearby areas of Chaliyar Panchayath assessed the impacts of flood on vegetation with focus on plant species diversity and invasive plant dissemination. Ten 10×10 m quadrants are taken in the study area, 5 represented floods affected and 5 represented non flood affected regions, having same topography. Species density, frequency, abundance and relative density are calculated. The result substantiates that invasive plant dissemination is relatively high in flood affected area. The relative density of invasive species is more (79.07%) in flood affected area compared to that (65.03%) in the non-affected area. This clearly shows that the flood has favored the distribution of diverse exotic alien species and accelerated the growth of invasive plant species already inhabited in the area. Even if relative density of invasive species is high, they are not frequently and uniformly distributed in the flooded quadrants. This gives the clear idea about influence of fury on the carrying and re-distribution of species in its natural habitat during flood.

Keywords: Kerala flood, biodiversity loss, invasive species, Nilambur, Western Ghats.

Introduction

The State of Kerala has witnessed the worst flood of the century during 2018 monsoon[1]. The fury of water devastated most parts of the State. The heavy rain led to a natural disaster in the forms of flood, debris flow and landslide. The last one in Kerala often recounted in public memory as the great flood was in 1924. The most striking similarity between the floods of 1924 and 2018 is that roughly the same locations were devastated[2]. Flash floods that cause heavy and rapid downpour are more dangerous and destructive[3].

Flood of 2018 mainly affected Nilambur of Malappuram district and Munnar of Idukki district[4]. Nilambur received 398mm rain on 8th August which was the highest record during 2018 southwest monsoon[5]. Heavy downpour due to global climate change is considered as the main cause of flood in the state. Kerala flood had opened the gates for invasive plant species and depletion in the biodiversity[6].

Invasive plants are non-indigenous/exotic plant species that occur outside their natural adapted ranges and dispersal potential[7]. Their presence is a threat to the ecosystem since it harmfully affects the biodiversity by causing species extinctions, changes in hydrology and ecosystem function[8]. The wild dissemination of invasive plants has become a major environmental threat in the state and needs immediate attention. This study was meant to examine the impacts of flood of 2018 on the biodiversity of Kerala, with special concern on biodiversity loss and invasive plant dissemination.

The aims of the study were: to record and describe the plant diversity and it's features of the study area, to study the impacts of flood on the biodiversity of the study of the area, to assess the density of endangered species of the study area, and to study the diversity and dissemination of invasive plant species of the study area.

Methodology

Study area: The study area comes under Chaliyar panchayath (11°20'33.67"N Lattiutde, 76°12'28.79"E Longitude at 52m AMSL), of Malappuram district, Kerala. The total area of panchayath consists of 57% reserve forest and remaining 43% is used as cultivating lands[9,10].

Method of study: Plant Survey: Extensive field visits were conducted and plant specimens along with vegetative and reproductive structures were collected. The plants specimens were taxonomically identified and validated with the help of Biodiversity documentation for Kerala[11], The Flora of Nilambur[12] and Flora of Presidency of Madras[13]. Interaction with natives: A questionnaire was prepared and distributed among natives and officials, authorities and requested for response.

Population Study: The quadrant method was performed according to Bargali et al, with minor modifications[14]. Two large study plots of 90x15meter were marked on the opposite banks of Kanjirappuzha stream, one represented flood affected and another one represented non- affected regions with same topography. A total of ten quadrants of 10×10m, 5 quadrants at each site (flood affected and non-flood affected) were randomly established at large within the 90x15m large study plots.

Analysis of Data: The quantitative characteristics as species diversity indices; Shannon index (H) and Simpson reciprocal index (1/D) were calculated.

Shannon index (H) = $\sum_{i=1}^{s}$ pi |lnpi|

Simpson reciprocal index = $\frac{1}{D} = \frac{1}{\sum p_i^2}$

And, species density, frequency, abundance and relative density were also calculated.

Density: The expression of the numerical strength of a species or a category.

$$\text{Density} = \frac{\text{Total number of individuals of a species or a category in all quadrats}}{\text{Total number of quadrats studied}}$$

Frequency: The degree of dispersion of individual species or a category in an area.

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which the species or category occured}}{\text{Total number of quadrats studied}} \text{ X } 100$$

Abundance: The number of individuals of different species or category in the community per unit area.

$$\text{Abundance} = \frac{\text{Total number of individuals of a species or a category in all quadrats}}{\text{Total number of quadrats in which the species or category occured}}$$

Relative density: The numerical strength of a species or specific category in relation to the total number of individuals of all the species.

$$\text{Relative density} = \frac{\text{Number of individual of the species or a specific category}}{\text{Number of individual of all the species}} \text{ X } 100$$

Dissemination of invasive species: From the total flora recorded, invasive plants were sorted out and their characters were studied. The 'People's biodiversity register kept at panchayath office, document and development plans available at panchayath and agriculture office along with available literatures were also used for sorting out the invasive plant species[12,15,16].

Results and discussion

Biodiversity of the study area: A total of 101 angiosperm species (31 herbs, 32 shrubs, 8 climbers, one creeper and 24 trees, Figure-2) belong to 36 families and, three pteridophyte species viz. *Pteris vittata* L., *Drynaria quercifolia* (L.) J. Sm. and *Selaginella delicatula* (Desv. ex Poir.) Alston are recorded from the whole stretch of study area (ie, 90x15m study plots of both flooded and non-flooded regions) in Mathilmoola colony during the study. The recorded vegetation includes different categories based on their ethno-botanical importance. Nearly half of the listed plants are known medicinal plants of folk use, some are aromatic (*Abelmoschus moschatus* Medik., *Blumea axillaris* (Lam.) DC.), wood yielding (*Tectona grandis* L.f., *Macaranga peltata* (Roxb.) Mull. Arg., *Butea monosperma* (Lam.) Taub.), dye yielding (*Mallotus philippensis* (Lam.) Mull. Arg.), potential ornamental (*Blumea axillaris* (Lam.) DC., *Alternanthera bettzickiana* (Regel) G. Nicolson), rootstock in horticulture (*Solanum torvum* Sw.), beverage yielding (*Hemidesmus indicus* (L.) R.Br.), poisonous (*Crassocephalum crepidioides* (Benth.) S. Moore) etc. An endangered herb 'Nilapana' (*Curculigo orchioides* Gaertn.) belongs to family Hypoxidaceae (formerly placed under Amaryllidaceae) is identified in the present study area, which is reported as lost at the time of 2018 flood in some parts of Kerala[8]. Along with this taxon, another red listed plant species such as *Typhonium bulbiferum* Dalz. (endangered-EN) of the family Araceae and *Hoppea fastigiata* (Gris.) C.B. Clarke (least concern-LC) of Gentianaceae are also recorded from the study area. Moreover, a sacred grove species *Getonia floribunda* Roxb. (Combretaceae) is also recorded. Among the families, Fabaceae is the most specious family represented by 17 species, followed by Malvaceae and Euphorbiaceae, both have 9 species in this study area. 17 families are represented by only one species (Figure-1). The flood severely affected the plants that grow in the riparian and adjacent land near all the rivers and other tributaries. The details and characteristics of the whole flowering plants identified from the study area are showed in the Table-1.

During the 2018 flood severe impact is observed on many herbaceous medicinal plants, including Kurunthotty (*Sida alnifolia* L. - Malvaceae), Valli-uzhinja (*Cardiospermum halicacabum* L. - Sapindaceae), Kayyonni (*Eclipta prostrate* (L.) L.-Asteraceae), Nilappana (*Curculigo orchioides* Gaertn.-Hypoxydaceae) Anachuvady (*Elephantopus scaber* L. - Asteraceae) Chakkarakolli (*Gymnema sylvestre* (Retz.) R.Br. - Apocynaceae), Mukkutti (*Biophytum sensitivum* (L.) DC. - Oxalidaceae) and Paadathaali (*Cyclea peltata* (Lam.) Hook.f. & Thom. - Menispermaceae) throughout the state[8]. Of the 40 edible plant species used by Cholanaikkans of Nilambur forest, 9 species were identified from the study area, including *Drynaria quercifolia* (L.) J. Sm., an invasive fern species whose rhizome is used for making specialised soup for their body health. Moreover, four plant species were highly considered by Arnatans tribes[17], 7 by Kattunaikkan and Muthuvan, 4 by Panyan and 3 by Kuruma tribes of Nilambur forest due to its ethnobotanical importance[18-20].

Total of 8802 individuals of 44 plant species and 5279 individuals of 52 plant species are enumerated from the five quadrants of flooded and non-flooded plots respectively. It is considerable; the number of individuals in heavy flooded soil is

much higher compared to the number of individuals in non-flooded plot. The elevated number of individuals in flooded plot, just after one year of disaster clearly indicates the flood has accelerated the growth and spread of each species in some ways. Even the number of individuals is high; the contributed species number is relatively less in flooded area. Therefore, it is assumed, the vegetation loss is fast healed by nature but biodiversity is slowly recovered. The Kerala State Biodiversity Board in their study also reported the possibility of slow regeneration of biodiversity in different parts of Kerala after the flood[8].

Invasive species: There are reports on invasive plants dissemination into Kerala after the flood time. Such wild dissemination of invasive plants becomes a major environmental threat to the state and need immediate attention[8]. From the 101 plants recorded in the study area (from two 90x15m plots in flooded and non-flooded region), 35 plants are identified as invasive species, belong to 32 genera and 14 families[15,16]. A total of 52 plant species (with 5279 individuals) are recorded from five quadrates of non-flooded region, among that 22 species (with 3433 individuals) are listed as invasive species. Similarly, 44 plant species (with 8802 individuals) are recorded from five quadrates of flooded region and 27 species (6960 individuals) are listed as invasive. Fabaceae is found to be most dominant family with 9 species, followed by Malvaceae and Asteraceae (Table-2). Majority of the invasive plants in the study plots are propagated by means of seeds, and very few are propagated through stem cuts. Also, they are pollinated by means of wind (Entomophily) or by means of animals (Zoophilous). When consider the habitat preference, majority of invasive species are moist deciduous type. Majority of the invasive plants are distributed in all the districts of Kerala[16]. It is assumed that, the new routes and pathways were formed due to the overflow of rivers and streams during flood, paved the way for dissemination of primary colonies of invasive species. As well, many invasive plant species that usually found in hilly regions are found appeared in the plain after the flood. A list of invasive species recorded from all quadrates study area (flooded and non-flooded) is shown in Table-1. The species density, frequency, abundance, relative density and relative frequency of total invasive species in five quadrants of flooded and non-flooded regions were calculated and compared in Table-3.

The relative density of invasive species is more (79.07%) in flood affected area compared to that (65.03%) in the non-affected area. That clearly states that the flood has elevated the growth and dissemination of invasive alien species. In the case of non-flooded quadrants, all recorded species including invasive ones are almost uniformly and frequently distributed. But in the case of flooded quadrants, relative density is higher in the case of invasive species but they are not frequently and uniformly distributed. Isolated patches of invasive plants are observed in flooded quadrants, which give clear idea about the influence of furry on the carrying and re-distribution of species. Also, some listed invasive species are showing limited distribution to any one or two quadrants of flooded plot.

Table-1: List of wildlife flora identified from Mathilmoola colony after the flood.

Family	Botanical Name	Common Name	Local Name	Habit	Remarks
Menispermaceae	*Tinospora cordifolia* (Willd.) Miers	Heart-leaved moonseed	*Chittamrith*	Climbing shrub	MD
	Cyclea peltata (Lam.) Hook.f. & Thomson	Indian moon seed	*Kattuvalli*	Climbing shrub	MD
Capparidaceae	*Crateva religiosa* G. Forst.	Large garlic pear	*Neermathalam*	Tree	MD
Cleomaceae	*Cleome rutidosperma* DC.	Fringed spider flower	*Neelavela/aryavela*	Annual herb	-
Malvaceae	*Corchorus capsularis* L.	White jute	*Chanam*	Annual herb	MD
	Sida cordifolia L.	Flannel weed	*Vellooram*	Perennial shrub	MD
	Sida acuta Burm.f.	Common wire weed	*Malan kurunthotti*	Under shrub	-
	Sida alnifolia L.	Sidas, fanpetals	*Vattooram, kurunthotty*	Woody shrub	MD
	Melochia corchorifolia L.	Chocolate weed	*Cheruoorakam*	Herb	MD
	Abelmoschus moschatus Medik.	Abelmosk	*Kasthoorivenda*	Herb	MD, AR
	*Hibiscus vitifolius*L.	Grape leaved mallow	*Kattuvelluram*	Herb	-

	Hibiscus furcatus Wall.	-	*Irula*	Shrub	MD
	Urena lobato L. ssp. *sinuata* (L.) Borss	Burrmellow	*Uram*	Perennial shrub	-
Tiliaceae	*Grewia asiatica* L.	Phalsa	*Chadicha*	Perennial tree	MD
	Triumfetta rhomboidei Jacq.	Burbark	*Oorppam*	Shrub	-
Oxalidaceae	*Biophytum sensitivum* L.	Little tree plant	*Mukkutty*	Shrub	MD
Rutaceae	*Naringi crenulate* (Roxb.) Nicolson	0	*Malanarakam*	Evergreen tree	MD
Rhamnaceae	*Ziziphous rugosa* Lam.	Zunna berry	*Malanthudali*	Tree	-
	Ziziphus oenoplia (L.) Miller	Jackal jujub	*Vanthudali*	Thorny shrub	MD
Anacardaceae	*Spondias pinnata* (L. f.) Kurz	Wild mango	*Ambazham*	Deciduous tree	-
Fabaceae	*Acacia mangium* Willd.	Black wattle	*Manjium*	Tree	-
	Acacia caesia (L.) Willd.	Soap bark	*Veluthaincha*	Tree	MD
	Tadehagi triquetrum (L.) H.Ohashi	Treflegros	*Adaykkapanal*	Shrub	0
	Desmodium gangeticum (L.) DC.	Shalparni	*Orila*	Shrub	MD
	Mucuna pruriens (L.) DC.	Velvet bean	*Naykurana*	Climbing shrub	MD
	Bauhaenia acuminate L.	Orchid tree	*Vella mandaram*	Perennial tree	MD
	Mimosa diplotricha Sauvalle	Giant sensitive plant	*Aanathottavadi*	Woody shrub	-
	Adenanthera pavonina L.	Coral wood	*Manchadi*	Tree	MD
	Gliricidia sepium (Jacq.) Walp	Mexican lilac	*Seema konna*	Deciduous tree	-
	Mimosa pudica L.	Sleepy plant	*Thottavadi*	Shrub	MD
	Centrosoma pubescens Sensu auct., *non Benth.*	Butterfly pea	*Poombattapayar*	Perennial herb	-
	*Calopogoniummucunoides*Desv.	Wild ground nut	-	Perennial Climber	-
	Alysicarpus vaginalis (L.) DC.	Alyce clove	*Neermuri*	Herb	AG
	Butea monosperma (Lam.) Taub.	Bastard teak	*Plashu/chamatha*	Deciduous tree	MD, TI, DY
	Cajanus lineatus (Wight &Arn.) Maesen	Wild tou	-	Perennial shrub	MD
	Cassia fistula L.	Golden shower	*Kanikkonna*	Shrub	MD
	Caesalpinia mimosoides Lam.	Hultholia	*Kuramullu*	-	-
	Rhynchosia minima (L.) DC.	-	-	-	-
	Chamaecrista fasciculate (L.) H.S. Irwin & Barneby	Patridge pea	-	Shrub	-

Rhizophoracea	*Carallia brachiate (*Lour.*)* Merr.	Carallia	*Vallabham*	Tree	MD
Combritaceae	*Calycopteris floribunda* (Roxb.) Lam. ex Poir.	Ukshi	*Pullanji*	Climbing shrub	MD
Myrtaceae	*Psidium guajava* L.	Guava	*Pera*	Tree	MD, ED
Passifloraceae	*Passiflora edulis* Sims.	Passion fruit	*Passion fruit*	Climber shrub	ED
	*Passiflora foetida*L.	Stinking pasion flower	*Poochappazham*	Perennial herb	-
Cucurbitaceae	*Mukia maderaspatana* (L.) M. Roem.	Ghugri	*Mukkapiri*	Climbing herb	-
Molluginaceae	*Glinus oppositifolius* (L.) Aug. DC.	Carpet weed	*Molugo*	Shrub	MD
	Mollugo verticillate L.	Green carpet weed	*Pulimuttuchedi*	Shrub	MD
Rubiaceae	*Mitracarpus hirtus* (L.) DC.	Gidlepod	*Thaaval*	Herb	-
	Spermacoce alata Aubl.	-	*Tharuthaval*	Herb	-
	Spermacoce exilis (L.O. Williams) C.D. Adams ex W.C. Burger & C.M. Taylor	-	-	-	-
	Oldenlandia auricularia (L.) K.Schum.	-	*Erachiketty*	Herb	-
	Mussaendafrondosa L.	Dhobi tree	*Vellila*	Annual Shrub	-
Compositae	*Chromolaena odorata* (L.) R.M. King & H. Rob.	Siam weed	*Communist pacha*	Shrub	PH
	Sphagneticola trilobata (L.) Pruski	Singapore daisy	*Amminippoo*	Perennial herb	-
	Blumea viscosa (Mill.) V. M. Badillo	Abanaadene	-	Herb	-
	Blumea axillaris (Lam.) DC.	-	*Narippacha*	Herb	OR, AR
	Mikania micrantha Kunth	Bitter vine	*Dhritharashtrapacha*	Perennial creeper shrub	MD
	Crassocephalum crepidioides (Benth.) S. Moore	Fire weed	*Appooppanthadi*	Annual herb	MD
Apocynaceae	*Ichnocarpus frutescens* (L.) W.T. Aiton	Black creeper	*Paalvalli*	Woody shrub	MD
	Alstonia scholaris (L.) R. Br.	Devil's tree	*Ezhilampala*	Evergreen Tree	MD
	Holarrhena pubescens Wall.exG.Don	-	Kudakappala	Deciduous shrub	MD
	Hemidesmus indicus (L.) R. Br. ex Schult.	Sarasaparilla	*Nannari*	Semi erect shrub	BV
Gentianaceae	*Hoppea fastigiata (*Arn. *ex* Griseb.*)*	-	-	Herb	-
Convolvulaceae	*Evolvulus nammularius* L	Round leaf bind weed	*Vishnukranthi*	Annual herb	-
	Merremia vitifolia (Burm. fil.*) Hall.* Fil	Grape leaf wood rose	*Manjavayaravalli*	Climber	-
	Hewittia malabarica L.	Malabar bind weed	*Vattappoonthani*	Perennial herb	MD, ED

Solanaceae	*Solanum torvum* Sw.	Turkey berry	*Aanachunda*	Shrub	HO
	Capsicum annuam L.	Green Chilly	*PachaMulak*	Shrub	MD
Scrophulariacae	*Scoparia dulcis* L.	Sweet broom weed	*Kallurukki*	Herb	MD
Bignoniacae	*Stereospermum chelenoides* (L.f.)	Pulila	-	Tree	MD
	Dolichondra spathacea	-	*Neerpongilium*	Deciduous tree	-
Acanthaceae	*Strobilanthus sp.*	Lesser kurinji	*Karimkurinji*	Shrub	MD
Verbenaceae	*Lantana camara* L.	Lantana	*Arippu,Poochedi*	Vigorous shrub	-
Labiatae	*Clerodendrum infortunatum* L.	Hill glory bower	*Vattapperuk*	Perennial shrub	MD
	Gmelina arborea Roxb.	Beech wood	*Kumbil*	-	-
	Tectona grandis L.f.	Teak	*Thekku*	Tree	TI
Nyctaginaceae	*Boerhavia diffusa* L.	Punarnava	*Thazhuthama*	Perennial herb	MD
Amaranthaceae	*Cyathula prostrate* (L.) Blume	Hook weed	*Cherukadakady*	Shrub	MD
	Alteranthera bettzickiana (Regel) G. Nicholson	Red calico	*Kattuponnankanni*	Perennial herb	OR, ED
Euphorbiaceae	*Flueggea leucopyrus* Willd	Bush weed	*Cherimklavu*	Perennial shrub	MD
	Mallotus philipensis Mull. Arg.	Red kamala	*Kumkumappoomaram*	Shrub	DY
	Microstachys chamelea Mull. Arg.	Creeping sebastiana	*Koduyavanakku*	Annual herb	-
	Euphorbia hirta L.	Asthma plant	*Chithirappala*	Annual herb	MD
	Macaranga peltata Roxb. Mueller	Chandada	*Vatta*	Tree	TI
	Homonia riparia Lour.	Water croton	*Aattuvanchi*	Perennial shrub	MD
	Phyllanthus urinaria L.	Gripe weed	*Chuvannakeezharnelli*	Herb	-
	Phyllanthus emblica L.	Indian gooseberry	*Nelli*	Tree	MD
	Phyllanthus niruri L	Gale of the wind	*Keezharnelli*	Herb	MD
Urticaceae	*Laportea intrrrupta* Gaudich.	Wood nettles	*Thuka*	Herb	-
Cannabaceae	*Trema orientalis* L. Blume	Charcol tree	*Amathali*	Deciduous tree	MD
Moraceae	*Ficus hispida* L.f.	Fig tree	*Parothu*	Evergreen tree	-
	Ficus beddomei King	-	*Thavittal, chela*	Evergreen tree	-
	Ficus callosa Willd.	Calloused fig	*Kadaplavu*	Evergreen tree	MD
Hypoxidaceae	*Curculigo orchioides Gaertn*	Golden eye grass	*Nilappana*	Perennial Herb	MD

Dioscoreaceae	*Dioscorea bulbifera*	-	-	-	-
Araceae	*Typhonium bulbiferum Dalzall*	-	-	Herb	-
Cyperaceae	*Kyllinga sp.* Rottb	Spikesedges	*Kyllinga*	Herb	-
	Cyperus dubious Rottb.	Umbrella plant	*Kudachedi*	Shrub	-
Poaceae	*Axonopous compressus* (Sw.) P. Beauv.	Carpet grass	*Kaalappullu*	Herb	-
	Bambusatulda Roxb.	Bamboo	*Mula*	Tree	PP
	Pennisetum polystachyon (L.) J.A. Schultes	Mission grass	-	Shrub	-

Abbreviations used: MD–Medicinal, AR-Aromatic, AG-Agrarian, TI-Timber, DY-Dye, ED-Edible, PH–Pharmacological, OR–Ornamental, ED-Edible, BV-Beverage, HO-Horticultural use, PP-Paper pulp.

Table-2: A list of total invasive species recorded from the study area.

Species	Family	Nativity	Habitat	Time		Presence in quadrants	
				flowering	fruiting	Flooded region	Non-flooded region
Acacia mangium Willd.	Fabaceae	Australia	Forest, Savanna	May	Jul-Sept		✓
Alternanthera bettzickiana (Regel) G. Nicolson	Amaranthaceae	Tropical America	Degraded deciduous forests, wastelands	Oct-Feb	Oct-Feb	✓	
Axonopus compressus (Sw.) P. Beauv.	Poaceae	Southern north America	Dry and moist deciduous forests, waste lands, paddy fields	Throughout year	Throughout year	✓	✓
*Bauhinia*sp.	Fabaceae	-	Open areas, Forest edges	-	-		✓
Caesalpinia mimosoides Lam.	Fabaceae	Indo-Malaysia	Moist forest, Degraded forest, plain	Jan-Mar	Jan-Mar	✓	✓
Calopogonium mucunoides Desv.	Fabaceae	Tropical Asia	Forest plantations	Aug-Dec	Aug-Dec	✓	✓
Centrosema pubescens Benth.	Fabaceae	Tropical America	Waste places, river banks, road sides	Apr-May, Sept-Oct	Jun-Jul, Nov-Dec	✓	✓
Chamaecrista fasciculata (Michx.) Greene	Fabaceae	America	Open woods, meadow, plains	Jun-Sept	Jun-Sept		✓
Chromolaena odorata (L.) King & Rob.	Asteraceae	Tropical America	Terrestrial weed	Nov-May	Nov-May	✓	✓

Cleome rutidosperma DC.	Capparaceae	Tropical	Degraded forest, Coastal areas	May-Nov	May-Nov	✓	
Corchorus capsularis L.	Tiliaceae	Tropical	Low lying watery places	Oct-Dec	Feb-Mar		✓
Crassocephalum crepidioides (Benth.) S.Moore	Asteraceae	Tropical Africa	Deciduous forest, plantations, plains	Aug-Dec	Aug-Dec	✓	
Cyperus dubius Rottb.	Cyperaceae	Tropical	Deciduous forest, waste lands	Aug-Dec	Aug-Dec	✓	
Dioscorea bulbifera L.	Dioscoreaceae	Asia, Tropical	Deciduous forest, plains	Sept-Oct	Sept-Oct	✓	✓
Evolvulus nummularius (L.) L.	Convolvulaceae	Tropical America	Moist deciduous forest, plains	Throughout year	Throughout year	✓	✓
Gmelina arborea Roxb.	Verbenaceae	Asia	Deciduous forest	Feb-Mar	Apr-Jul		✓
Laportea interrupta (L.) Chew	Urticaceae	Indo China	Deciduous forest	Aug-Sept	Aug-Sept	✓	
Lantana camara L.	Verbenaceae	Cental and south America	Tropical rain forest, wastelands	Throughout year	Throughout year	✓	
Melochia corchorifolia L.	Sterculiaceae	African, American	Deciduous forest, waste land	Jul-Apr	Jul-Sept	✓	✓
Mesosphaerum suaveolens (L.) Kuntze	Lamiaceae	Tropical	Degraded deciduous forest	Sept-Feb	Sept-Feb	✓	
Mikania micrantha Kunth	Asteraceae	Central America	Moist places	Dec-Apr	Dec-Apr	✓	
Mimosa diplotricha Sauvalle	Fabaceae	TA	Planes, degraded forest	Nov-Mar	Nov-Mar	✓	✓
*Mimosa pudica*L.	Fabaceae	South America	Planes	Jul-Feb	Jul-Feb	✓	✓
Mitracarpus hirtus (L.) DC.	Rubiaceae	South Asia	Moist degraded forest	Jul-Dec	Jul-Dec	✓	
Mollugo verticillata L.	Molluginaceae	Tropical America	Sandy river banks, lawns, gardens, disturbed areas.	Jun-Sept	Jun-Sept	✓	✓
Mucuna pruriens (L.) DC.	Fabaceae	South Asia	Low forest	Aug-Feb	Aug-Feb	✓	

Naringi crenulata (Roxb.) Nicolson	Rutaceae	India, Sri Lanka, Indo-China	Evergreen forest, deciduous forest, plains	Apr-May	Jul-Sept		✓
Passiflora edulis Sims	Passifloraceae	South America	Cultivated, wild distribution	Jul-Sept	Oct-Nov		✓
Passiflora foetida L.	Passifloraceae	Tropical America	Waste land, degraded forest	Jul-Dec	Jul-Dec	✓	
Pennisetum polystachyon Schult.	Poaceae	Tropical Atrica	Deciduous forest	Apr-Dec	Apr-Dec	✓	
Spermacoce latifolia Aubl.	Rubiaceae	Tropical America	Waste land	Aug-Oct	Aug-Oct	✓	✓
Sphagneticola trilobata (L.) Pruski	Asteraceae	Tropical America	Damp soil, marshy, sea beaches	Throughout year	Throughout year	✓	✓
Sida cordifolia L.	Malvaceae	AS, AF	Sea cost, wastelands	Throughout year	Throughout year	✓	✓
Sida acuta Burm.f.	Malvaceae	Central America	Wasteland, roadside, deciduous forest, plains	Aug-Oct	Aug-Oct	✓	
Spondias pinnata (L.f.) Kurz	Anacardiaceae	Indo-China	Evergreen forest, deciduous forest, plains	Mar-Apr	Jun-Dec		✓

Table-3: Species density, frequency, abundance, relative density and relative frequency of total invasive species in the quadrants of flooded and non-flooded regions.

Total invasive species	Plot	Value
Species density	Flooded plot	1,392
	Non-flooded plot	686
Frequency (%)	Flooded plot	100
	Non-flooded plot	100
Abundance	Flooded plot	1,392
	Non-flooded plot	686
Relative density	Flooded plot	79.07
	Non-flooded plot	65.03

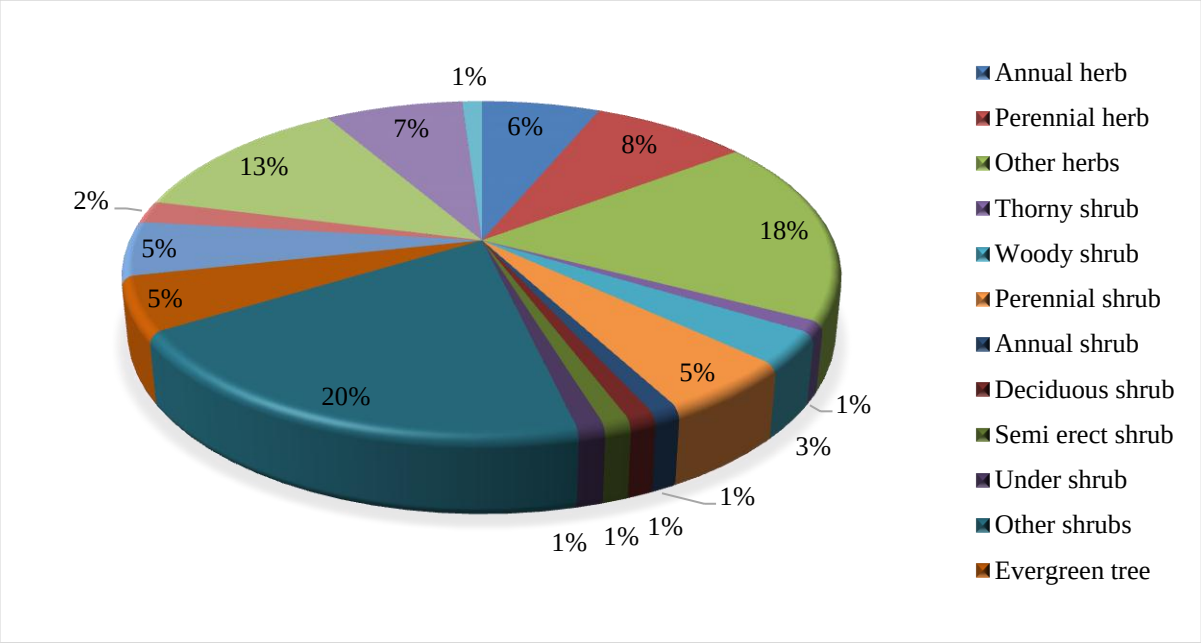

Figure-1: Pie chart showing percentage distribution of plants based on habit.

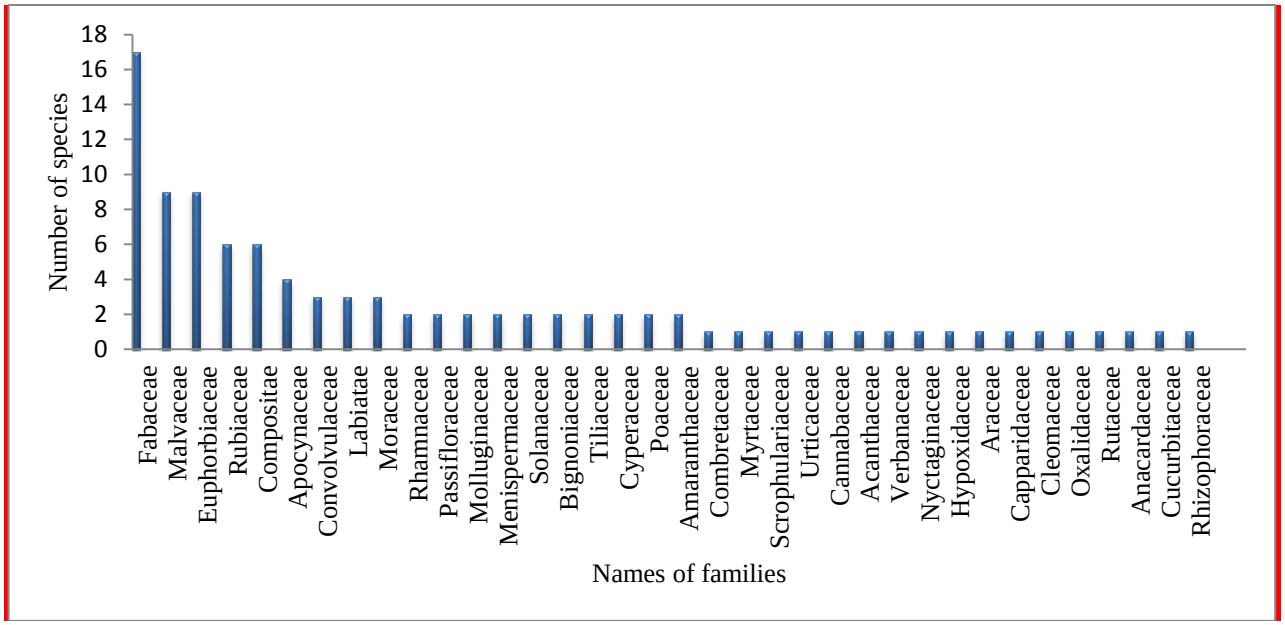

Figure-2: Distribution of the families of plants identified from Mathilmoola colony.

Conclusion

The study area was found to be rich in plant diversity, since it comes under the Nilambur forest division of the Western Ghats. The findings of the study clearly showed that 2018-flood has elevated the growth and spread of invasive species with enough potential to deplete the species density and abundance of native population. Since the study area comes under the Nilgiri ranges of Western Ghats, increases the importance of the study. The relative density of invasive species is more (79.07%) in flood affected area than non-affected area (65.03%). There were reports that, Kerala flood has caused the depletion of many indigenous species having medicinal values[8]. This, together with the unsustainable exploitation of natural resources and drastic change in land use pattern is causing continuing havoc in the state. Since 52% of Kerala is covered by different types of forests, the impact of recent floods and landslides on these forests has to be studied. The flood severely affected the plants growing in the riparian and adjacent land near all the rivers and other tributaries.

The 2018 flood has brought various changes in the highland and hilly areas of the state, which are altering in their structure, density and composition of the ecosystem. It is noteworthy that the 2018 flood has not only disturbed the environment and ecosystem but has also threatened the indigenous flora of the affected area as a number of plants are getting rare. If the dissemination of invasive plants continues to operate unchecked, the rare endemic species may become endangered and the germplasm of such plants may become sporadic or even get losted[21]. Thus, the present study suggests that strict measures should be taken to face the problem in invasive plant dissemination in the Kerala state after flood. The government should look towards a more sustainable development in the state and in future, it will surely help to reduce the impacts of similar natural incidents from happening again. Along with post flood rebuilding programs, more detailed studies should be conducted to determine the types and rate of dissemination of invasive plant species in unattended lands like forests and threat of invasive plants dissemination should also get major consideration. If governmental and non-governmental movements take initiatives to plant bamboo and other plants that can hold the soil in the mountain ranges can reduce up to a mark. Public awareness is necessary among rural, tribal and schools / college student levels in presence of Agriculturist or Botanist or Environmentalist or Officer from forest department or all of them. An organized state policy to tackle this environmental concern is needed.

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