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RESEARCH ARTICLE

DIVERSITY ANALYSIS OF ANGIOSPERMS IN RIPARIAN SYSTEM ALONG THUPPANAD RIVER, SOUTHERN WESTERN GHATS, KERALA, INDIA.

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Abstract

Thuppanad river is a major tributary of Thutha river that drains into Bharathappuzha, the second largest river in Kerala and is draining out from north of Palghat gap of southern Western Ghats. The present inquiry summarizes the angiosperm diversity along the riparian system of Thuppanad river along with its phytogeographical affinities, percentage endemism, morphological adaptations and biological invasion. The evaluation of the angiosperm diversity revealed the presence of 270 species belonging to 70 families with higher elemental contribution by Euphorbiaceae followed by Fabaceae, Asteraceae, Rubiaceae and Acanthaceae. The riparian flora of this river basin embodies seven characteristic riparian taxa together with fifty six wetland species. Of the taxa recorded, twelve species show an extended distribution in Palakkad district of the state of Kerala. The analysis on endemism revealed that thirty four taxa are endemic to Western Ghats and at the same time, broad scale phytogeographical affinities of the riverine flora extend to African, Australian, Holarctic, Indo-Pacific and South American floristic kingdoms. The altitudinal profiling of the vegetation along the riverine belts revealed higher degree of variation in floristic elements and in the low land belts, human intervention and pollution has resulted in the gradual shift of vegetation elements into alien and invasive ones. The invading taxa in conjunction with anthropogenic disturbances pose serious threats to riparian vegetation of this area. This pioneer study on the riparian elements of this river basin indicated the need for implementing site-specific conservation plan for ecosystem management as this vegetation acts as a buffer zone between the river and cultivable lands.

Introduction:-

Riparian systems are the three-dimensional ecotones of interaction including terrestrial and aquatic ecosystems that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem and along the water course (Illhardt *et al*., 2000). They form complex assemblage of organisms and their environment existing adjacent to and near flowing water (Lowrance *et al*., 1985). As ecotones, they encompass sharp gradients of environmental factors, ecological processes and plant communities. Riparian ecosystem provides a corridor for the movement of biota and serves many important roles for humans (Kemper, 1999).

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The biotic communities living in the riparian areas, their interaction with immediate environment and their role in functioning of the river basin as a whole have gained more focus in the past two decades (Naiman and Decamps 1993; 1997). However, there is a lacuna in the riparian floristic research in India except few ecological studies (Singh and Joshua 1989., Bachan, 2003; Sreedharan, 2005; Sunil *et al.*, 2010; Nandhakumar *et al*., 2012; Vyas *et al*., 2012., Paul, 2013., Vincy *et al.*, 2014., Bhaskar and Karthik 2015., Sankhwal *et al*., 2015., Shah *et al*., 2015). As per these reports, the Western Ghats river ecotones comprise an amalgamation of evergreen, semi evergreen, deciduous, riparian, wetland and mangrove components with high species diversity and endemism. Moreover, the vegetation in the riparian area has characteristics of both aquatic and upland habitats. Plants of the riparian forest have numerous morphological and physiological adaptations which suit them for life in high-energy and wet environments (Barker *et al*., 2002; Merritt *et al*., 2010).

Thuppanad river, one of the major tributary of Thutha river originates from Kalladikkode hills, along the northern lip of Palghat gap of Southern Western Ghats. Human interventions to the river basins of Kerala, has numerous impacts on land, water and biota. Although the riverine vegetation along this river is regarded as biologically rich, it is currently threatened and no exhaustive floristic information is available. The present documentation provides a synoptic account of the riparian phanerogamic flora of Thuppanad river, Kerala, with emphasis on phytogeographical affinities and endemism.

Materials and methods:-

Study area

Thuppanad river originates from Kalladikkode hills at an elevation of 1099 m above mean sea level. Its watershed extend from 10^o 53' to 10^o 55' North Latitude and 76^o 25' to 76^o 35' East Longitude and the river draining has a length of 25km with an area of 158km^2. The study area experiences a humid tropical climate and an average rainfall of 2135mm. Though during monsoon, the river become full and floods the nearby low lying areas, there is acute shortage of water in summer. The temperature of this area ranges from 20^0 C to 45^0 C and this rain fed river turns into a dry bed in summer. The location map of Thuppanad river is summarized in Fig. 1.

Methodology:-

Intensive seasonal floristic explorations and collections were carried out in riparian zones of Thuppanadpuzha during the period of December 2015 and May 2018. Inorder to review the vegetation of Thuppanad river, 12 sample plots were selected along the riparian zone (Table 1). The specimens were identified using relevant literature and comparison with authentic specimen available at MH and CALI and enumerated as per APG IV (Chase *et al.*, 2016). The nomenclature validation has been done with IPNI (www.ipni.org) and the plant list (www.theplantlist.org). The phytogeographical affinities of the vegetation was worked out (Cox, 2001) and the RET taxa assessment was based on IUCN (2017). Wetland elements were designated as per Cook (1996).

Table 1:- Locations of sample plots in the study area

Sl. No.	Sample plots	Latitude	Longitude
1	Meenvallam	10^o.55' 28	76^o.35' 26
2	Moonnekkar	10^o 55'24	76^o34' 29
3	Moonnekkar Check dam	10^o 55' 22	76^o 33' 55
4	Aanakkallumukku	10^o 54' 59	76^o 33' 5
5	Ambalamkadavu	10^o 54' 22	76^o 32'16
6	Thuppanad	10^o 54' 22	76^o 31' 51
7	Panayampadam	10^o 54' 26	76^o 31' 20
8	Neelamkallu	10^o 54' 36	76^o 30' 20
9	Koramankadavu	10^o 54' 45	76^o 29' 23
10	Cheenikkadavu	10^o 54' 45	76^o 28'22
11	Sreekrishnapuram	10^o 54' 36	76^o 27'13
12	Kootilakkadavu	10^o 53' 10	76^o 25' 45

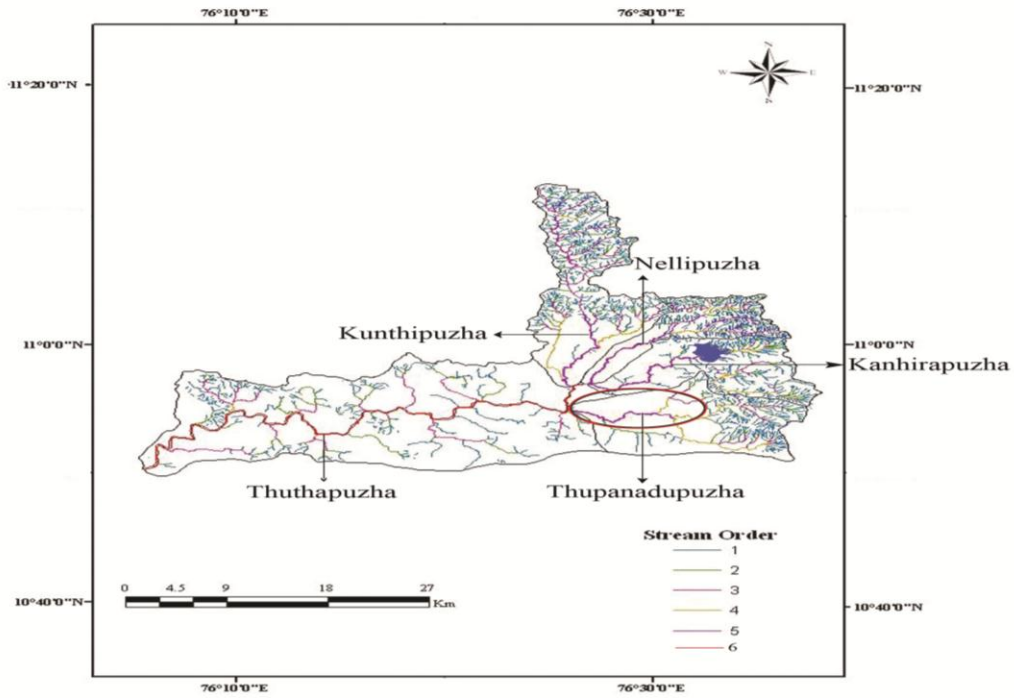

Figure 1:-Location map of the study area

Results:-

Floristic catalogue

Enumeration of the riparian flora of Thuppanad river revealed 270 taxa of flowering plants within a stretch of 25km. The floristic analysis showed the presence of 202 genera under 70 families of which, eight belong to Magnoliids, 37 to Monocots and 225 were Eudicots. The vegetation revealed the presence of aquatic, semi aquatic, wetland and riparian elements. The results showed the dominance of seven typical riparian taxa such as *Homonoia riparia* Lour., *Mallotus nudiflorus* (L.) Kulju & Welzen, *Madhuca neriifolia* (Moon) H. J. Lam, *Persicaria barbata* (L.) H. Hara, *Rotula aquatica* Lour., *Crataeva magna* G. Forst. *and Pandanus furcatus* Roxb. all along the river stretch from upper river basin to lower levels.

The angiosperm resources showed the presence of *Acmella ciliata* (Kunth) Cass., *Ceriscoides turgida* (Roxb.), *Derris trifoliata* Lour., *Dillenia indica* L., *Ficus heterophylla* L.f., *Ixora lanceolaria* Colebr., *Limnocharis flava* (L.) Buchenau, Tirveng., *Murdannia dimorpha* (Dalzell) G. Brückn., *Murdannia gigantea* (Vahl) G. Brückn., *Nelsonia canescens* (Lam.) Spreng., *Ochreinauclea missionis* (Wall. ex G. Don) Ridsdale and *Spilanthes vazhachalensis* Sheela, with extended distribution in Palakkad district with reference to flowering plants of Kerala (Sasidharan, 2011) and flora of Kerala (BSI, 2016). The present study recorded the dominance of Euphorbiaceae (19 species) followed by Fabaceae (18 species), Asteraceae (17species), Rubiaceae (17 species) and Acanthaceae (16 species) from the river basin (Fig.2). The vegetation profile of Thuppanad river include 112 herbs, 54 shrubs, 38 climbers and 66 trees. Climbers and shrubs were observed in low numbers due to seasonal clearings in the plantations and agriculture fields on the river margins and the number of herbs seems to be higher.

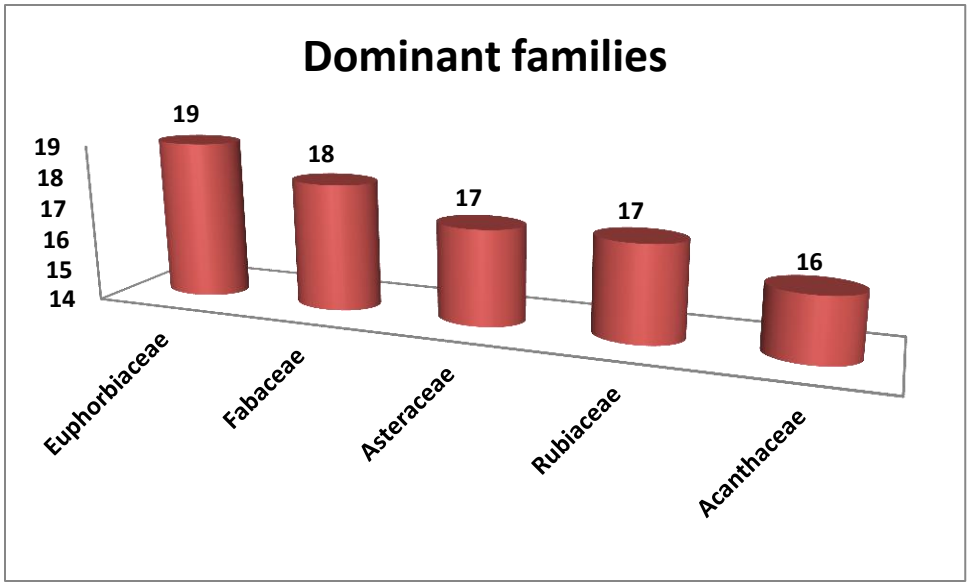

Figure 2. Dominant families of riparian vegetation along Thuppanad river

The monitoring of wetland vegetation revealed the presence of fifty six wetland taxa which contribute 20% of the total riparian flora of Thuppanad river. Systematic inquiry showed that 13% of the taxa are endemic to various geographical boundaries of India (Table 2) with a maximum share of Western Ghats. The profile of RET category taxa (IUCN, 2017) showed that 4% of the plant species belongs to endangered (2 species), vulnerable (8 species) or threatened (2 species) categories (Table 2).

Table 2:-Wetland, Endemic and RET category taxa in Thuppanad river

Sl. No	Name of species	Family	Wetland	Endemics	RET
1	*Sageraea laurina* Dalz.	Annonaceae		*	NT
2	*Uvaria narum* (Dunal) Wall.	Annonaceae			LC
3	*Cinnamomum malabatrum* (Burm. f.) Blume.	Lauraceae		*	LC
4	*Litsea coriacea* (Heyne *ex* Meisner) Hook. f.	Lauraceae		*	NT
5	*Limnocharis flava* (L.) Buchenau	Alismataceae	*		
6	*Colacassia esculenta* (L.) Schott	Araceae	*		
7	*Legenandra meeboldii* (Engl.) C.E.C. Fisch	Araceae		*	LC
8	*Arenga wightii* Griff.	Arecaceae		*	VU
9	*Commelina benghalensis* L.	Commelinaceae	*		
10	*Commelina diffusa* Burm.f.	Commelinaceae	*		
11	*Cyanotis axillaris* (L.) D.Don	Commelinaceae	*		
12	*Dictyospermum montanum* Wight	Commelinaceae		*	LC
13	*Floscopa scandens* Lour.	Commelinaceae	*		
14	*Murdannia nudiflora* (L.) Brenan	Commelinaceae	*		
15	*Cyperus cyperinus* (Retz.) Suringar	Cyperaceae	*		
16	*Cyperus diffusus* Vahl	Cyperaceae	*		
17	*Cyperus digitatus* Roxb.	Cyperaceae	*		
18	*Cyperus platystylis* R.Br.	Cyperaceae	*		
19	*Kyllinga bulbosa* P. Beauv.	Cyperaceae	*		
20	*Kyllinga nemoralis* (J.R. Forst. &G. Forst.) Dandy ex Hutch. & Dalziel	Cyperaceae	*		
21	*Globba sessiliflora* Sims	Zingiberaceae		*	LC
22	*Cynodon dactylon* (L.) Pers.	Poaceae	*		
23	*Eragrostis amabilis* (L.) Wight & Arn.	Poaceae	*		

24	*Eragrostis unioloides* (Retz.) Nees ex Steud.	Poaceae	*		
25	*Ochlandra travancorica* (Bedd.) Gamble	Poaceae		*	LC
26	*Saccharum arundinaceum* Retz.	Poaceae	*		
27	*Saccharum spontaneum* L.	Poaceae	*		
28	*Dillenia indica* L.	Dilleniaceae	*		
29	*Desmodium heterophyllum* (Willd.) DC.	Fabaceae	*		
30	*Desmodium triflorum* (L.) DC	Fabaceae	*		
31	*Senna alata* (L.) Roxb.	Fabaceae	*		
32	*Senna tora* (L.) Roxb.	Fabaceae	*		
33	*Xanthophyllum arnottianum* Wight	Polygalaceae		*	LC
34	*Ficus dalhousiae* Miq.	Moraceae		*	LC
35	*Begonia crenata* Dryand	Begoniaceae	*	*	
36	*Baccaurea courtallensis* (Wight) Müll.Arg	Phyllanthaceae		*	VU
37	*Ludwigia adscendens* (L.) H.Hara	Onagraceae	*		
38	*Ludwigia hyssopifolia* (G.Don) Exell	Onagraceae	*		
39	*Ludwigia peruviana* (L.) H.Hara	Onagraceae	*		
40	*Holigarna arnottiana* Hook.f.	Anacardiaceae		*	LC
41	*Nothopegia travancorica* Bedd. ex Hook.f.	Anacardiaceae		*	LC
42	*Naregamia alata* Wight & Arn.	Meliaceae		*	LC
43	*Vateria indica* L.	Dipterocarpaceae		*	CR
44	*Santalum album* L	Santalaceae			VU
45	*Rorippa indica* (L.) Hiern	Brassicaceae	*		
46	*Persicaria glabra* (Willd.) M.Gómez	Polygonaceae	*		
47	*Alternanthera ficoidea* (L.) Sm.	Amaranthaceae	*		
48	*Impatiens scapiflora* B.Heyne ex Roxb.	Balsaminaceae		*	VU
50	*Impatiens gardneriana* Wight	Balsaminaceae		*	VU
51	*Ixora elongata* Heyne ex G. Don	Rubiaceae		*	EN
52	*Ixora lanceolaria* Colebr. in Roxb.	Rubiaceae		*	LC
53	*Ixora malabarica* (Dennst.) Mabb.	Rubiaceae		*	VU
54	*Mussaenda frondosa* L.	Rubiaceae		*	LC
55	*Ochreinauclea missionis* (Wall. *ex* G. Don) Ridsd.	Rubiaceae		*	VU
56	*Oldenlandia auricularia* (L.) K.Schum.	Rubiaceae	*		
57	*Oldenlandia corymbosa* L.	Rubiaceae	*		
58	*Oldenlandia diffusa* (Willd.) Roxb.	Rubiaceae	*		
59	*Canscora diffusa* (Vahl) R.Br. ex Roem. & Schult.	Gentianaceae	*		
60	*Heliotropium indicum* L.	Boraginaceae	*		
61	*Heliotropium keralense* Sivar. & Manilal.	Boraginaceae	*	*	
62	*Ipomoea carnea* Jacq.	Convolvulaceae	*		
63	*Olea dioica* Roxb.	Oleaceae		*	LC
64	*Hydrolea zeylanica* (L.) Vahl	Hydroleaceae	*		
65	*Epithema carnosum* Benth.	Gesneriaceae		*	VU
66	*Scoparia dulcis* L.	Plantaginaceae	*		
67	*Lindernia anagallis* (Burm.f.) Pennell	Linderniaceae	*		
68	*Lindernia antipoda* (L.) Alston	Linderniaceae	*		
69	*Lindernia caespitosa* (Blume) Panigrahi	Linderniaceae	*		
70	*Lindernia rotundifolia* (L.) Alston	Linderniaceae	*		
71	*Torenia bicolor* Dalzell	Linderniaceae	*		
72	*Asystasia gangetica* (L.) T.Anderson	Acanthaceae	*		
73	*Barleria courtallica* Nees in DC.	Acanthaceae		*	LC
74	*Dipteracanthus prostratus* (Poir.) Nees in Wall	Acanthaceae		*	LC
75	*Gymnostachyum latifolium* (Dalz.) Anders.	Acanthaceae		*	LC
76	*Hygrophila auriculata* (Schumach.) Heine.	Acanthaceae	*		
77	*Hygrophila ringens* (L.) R. Br. ex Spreng.	Acanthaceae	*		

78	*Rungia repens* (L.) Nees	Acanthaceae	*		
79	*Strobilanthes lupulinus* Nees in Wall.	Acanthaceae		*	LC
80	*Lobelia alsinoides* Lam.	Campanulaceae	*		
81	*Acmella ciliata* (Kunth) Cass.	Asteraceae	*		
82	*Crassocephalum crepidioides* (Benth.) S. Moore	Asteraceae	*		
83	*Eclipta prostrata* (L.) L.	Asteraceae	*		
84	*Grangea maderaspatana* (L.) Poir.	Asteraceae	*		
85	*Synedrella nodiflora* (L.) Gaertn.	Asteraceae	*		
86	*Spilanthes vazhachalensis* Sheela	Asteraceae	*	*	LC
87	*Xanthium strumarium* L.	Asteraceae	*		

CR- Critically endangered, **EN**- Endangered, **LC**- Least concern, **NT**- Near threatened, **VU**- Vulnerable

The vegetation profile from upstream downwards elucidated structural transition from evergreen forest elements to the semi-evergreen – riparian – wetland – invasive taxa. The lateral zonation of floristic elements exhibited the true riparian taxa near to the water body. The small shrub species like *Homonoia riparia* Lour. are seen on the rocky river bed between different water flowing areas. Continuity of true riparian evergreen plants is followed by tropical evergreen forest trees like *Vateria, Madhuca, Hydnocarpus and Xanthophyllum*. True riparian taxa were not recorded in the lower zones due to high disturbances caused by activities like sand mining, encroachment etc. In the lower zones, along with Cyperaceae and Poaceae members, species of *Ficus, Saccharam, Pandanus* etc. occupy the marginal positions.

Taxa subjected to habitual flooding produce various types of root adaptations as in *Myristica, Holigarna, Madhuca and Pandanus. Rotula aquatica* is having riparian endemism, showed morphological variations in accessions of same habitat and locality in a riverine system, and is adapted to monsoon floods and summer drought. The broad scale phytogeographical affinities of the riverine flora of Thuppanad river extend to African, Australian, Holarctic, Indo-Pacific and South American floristic kingdoms. Majority of the vegetation include Indo-Pacific elements with four African elements (Table 3). Raunkiaer's life form spectra analysis of the vegetation (Fig. 3) revealed that the biological spectra with dominance of phanerophytes (57.03%) followed by therophytes (33.33%), chamaeophytes (5.55%) and cryptophytes (4.07%).

This study analysed the impacts of alien invasive plants on riparian ecosystem of Thuppanad river basin and ten alien elements such as *Eichhornia crassipes* (Mart.) Solms, *Monochoria vaginalis* (Burm.f.) C. Presl *ex* Kunth, *Aeschynomene americana* L., *Lantana camara* L., *Stachytarpheta jamaicensis* (L.) Vahl, *Ageratum conyzoides* (L.) L., *Chromolaena odorata* (L.) R. M. King & H. Rob, *Mikania micrantha* Kunth, *Synedrella nodiflora* (L.) Gaertn. and *Sphagneticola trilobata* (L.) Pruski were found to invade the riverine vegetation, of which five of them are categorized under 100 world's worst invasive alien species (Lowe, 2000).

Table 3:-Phytogeographical affinities of riparian flora in the Thuppanad river basin

Distributional range	**Number of species**	**%**
Indo- Pacific	114	42.22
Indo- Pacific and South American	30	11.11
Indo- Pacific, African and South American	28	10.37
Indo- Pacific and African	29	10.37
Indo- Pacific and Australian	14	5.19
Indo- Pacific and Holarctic	9	3.33
African	4	1.48
Indo- Pacific, South American and Australian	2	0.74
Indo- Pacific, African and Australian	3	1.11
Indo- Pacific, South American and Holarctic	2	0.74
Indo- Pacific, African and Holarctic	1	0.34
Endemics	34	12.96
Total	270	

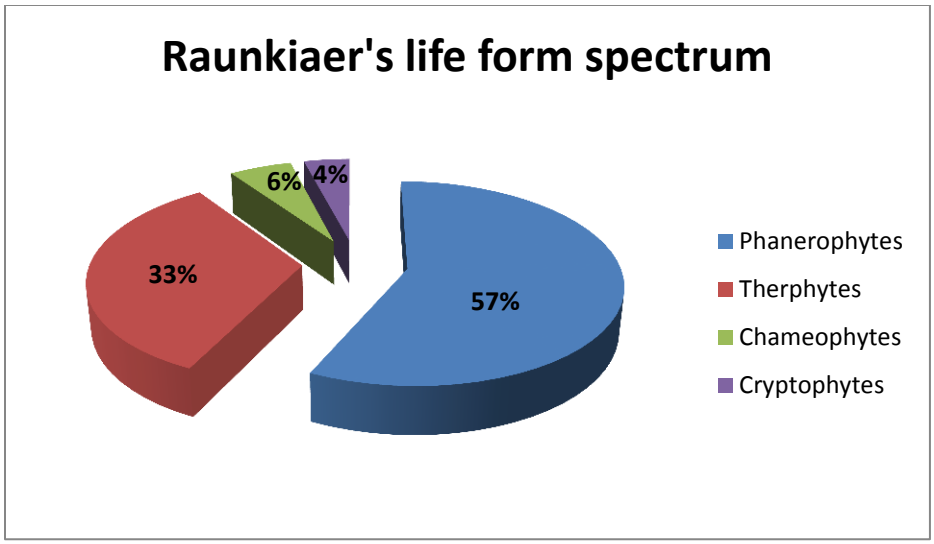

Figure 3:-Biological spectra of riparian flora of Thuppanad river

Threats to riparian vegetation

Thuppanad river occupies a unique position in the rivers of Palakkad district of Kerala and more than 1.5 lakhs people in five different panchayats living in the basin are dependent on this river. The width of this river narrows downstream due to the encroachments and reclamation of the riparian area for agriculture and other related activities. One of the significant drawbacks of conservation measures implemented by the competent authority is the absolute ignorance of local diversity of plants especially in rural and urban midland and 90% of the lands at both the banks of the stream are under private sector. Consequently, the value of riparian lands to a private landowner is measured in terms of economic benefits rather than ecological significance. Stream pollution by solid waste disposal, littering of plastics and other wastes, and biological invasion are other issues causing immense loss in economic and ecological resources. According to *bsienvis.nic.in* (2017), the analysis of the floristic elements of Thuppanad river recorded 40.83 % plant species as alien which include invasive, naturalized and cultivated plants and their spread results in native species loss, reduced species richness, diversity, evenness and decreased river flow. Anthropogenic disturbances may introduce exotic species to riparian zones and natural disturbances may facilitate their spread throughout the drainage network. Indiscriminate sand mining, riverbank erosion, clearing of riparian vegetation and the reduction in the fisheries resource have become serious. This has reduced the quality of water and caused lowering of water table and the availability of water.

Discussion and conclusion:-

The riparian forest is a unique and rich natural ecosystem which has great influence on the adjacent aquatic as well as terrestrial systems. Most of the authors have reported the dominance of family Poaceae in Western Ghats vegetation (Nayar, 1980; Parthasarathy, 1983; Nair & Daniel, 1986; Ahmedullah & Nayar 1987; Karthikeyan, 1996) and in contrast, the present study recorded the dominance of Euphorbiaceae (19 species) followed by Fabaceae (18 species), Asteraceae (17species), Rubiaceae (17 species) and Acanthaceae (16 species). This vegetation profile modification may be due to the frequent floodplain disturbances, which prevents the establishment of Poaceae and promote woody vegetation that can withstand the flood current.

Comparison of angiosperm diversity and percentage endemism between Thuppanad river basin and three main rivers of Kerala, such as Chalakkudy river (Bachan, 2003), Pamba river (Paul, 2013) and Meenachil river (Vincy *et al*., 2014) showed significant reduction in the percentage of endemics and occurrence of RET category taxa. The general observations suggest that this may be due to habitat loss, over exploitation, invasion by exotics and fragmentation of population.

In addition to stabilizing and safeguarding the riverbank from erosion, the riparian ecosystem increases the biotic productivity and the biodiversity potential of the river. They also have a major role in influencing the water quality of the river. Further documentation to reveal the longitudinal, lateral and vertical zonations in vegetation present

over here along with studies on seasonal and successional community patterns are inevitable to make any conclusions on the health of the vegetation along Thuppanad river basin.

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