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GIS techniques for Mapping highly Fragmented ecosystems- A case study on the *Myristica* swamp forests of Southern Kerala, India

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Abstract

Myristica swamps are a highly fragmented, threatened and endangered freshwater swamp forest ecosystem of Western Ghats with distribution restricted to flat bottomed valleys with sluggish streams in altitudinal range of 100 – 200 m. In southern Kerala these swamps are present in Kulthupuzha, Anchal forest ranges and Shendurney WLS. The small size of swamp patches and thick forest canopy challenge the efficacy of usual mapping techniques such as Remote sensing and GPS survey. So a combination of conventional (compass survey) and latest survey technique (GPS survey) was used for the mapping. Conversion, plotting of spatial layers, map generation and analysis was done by using customized and Open Source GIS softwares. We mapped 60 Myristica swamp patches from the study area contributing 149.75 hectare (ha) (0.01348% of Kerala forest). The area of swamps ranges from 0.22 to 16 ha Kulathupuzha Forest Range has 31 swamps (78.73 ha), Shendurney WLS has 16 (37.35ha) and Anchal has 13 (33.67ha). GIS simulation studies reveals that 148.57 km^2 area (1.34% of Kerala forest) in Kerala has potential for Myristica swamps, in which Thiruvanathapuram and Punalur forest division has maximum area to support Myristica swamps. Exact mapping proved a decisive tool for conservation and management efforts.

Keywords: *Myristica* swamps, wetlands, mapping, GIS techniques, GPS survey, swamp forests, ecosystem.

Introduction

Wetlands are transitional lands between terrestrial and aquatic ecosystems with water table at or near the surface or the land being covered by shallow water[1]. Under the Ramsar Convention on Wetlands[2] "wetlands" are defined by Articles 1.1. and 2.1. Article 1.1. states that, *"For the purpose of this Convention wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters."* Article 2.1 declares that, "wetlands *may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands."* The Ramsar classification system for wetland types has classified wetlands into Marine/Coastal wetlands, Inland wetlands and Human-made wetlands. Each have been further classifies into sub categories. *Myristica* swamps come under the category Xf (Freshwater, tree-dominated wetlands) under Inland wetlands. According to Gopal's[3] classification for the wetlands in Indian Subcontinent *Myristica* swamps come under freshwater wetlands with woody vegetation.

Myristica swamps are an endangered, endemic and highly fragmented fresh water ecosystem in Western Ghats. This ecosystem was first reported [4] from the Travancore region of South Western Ghats. These swamps are found in the flat bottomed valleys of Kulathupuzha and Anchal Forest Ranges and Shendurney WLS of Kerala part of the Western Ghats. Champion and Seth[5] classified the vegetation as Tropical fresh water swamp forests (4C/FS1). Pascal[6] described the *Myristica* swamp vegetation and Rodgers and Panwar[7,8] highlighted the vegetation as most critically needing conservation. These swamps have also been reported from Uttara Kannada district of Karnataka Western Ghats[9,10,11,12] and Satari region in Goa[13]. Major tree composition is made-up of *Myristica* trees belonging to the family Myristicaceae (figure-1). The dominant *Myristica* swamp trees are *Myristica fatua* var. *magnifica* and *Gymnacranthera farquhariana*. The other Myristicaceae members are *Myristica malabarica*, *Myristica beddomei* and *Knema attenuata.*

Only small remnants of this critically endangered ecosystem are found in the Western Ghats. Most of them were converted into paddy fields, rubber estates, arecanut orchards and teak plantations and other purposes in recent past. The existing *Myristica* swamps are in a highly disturbed condition due to anthropogenic intervention. Some of the swamps in Shendurney region were submerged under the reservoir of Thenmala dam. There is no record of distribution and area of *Myristica* swamps in Kerala part of Western Ghats. This is the first attempt to map this highly fragmented, endangered ecosystem by using GIS (Geographic Information System) techniques and to find out the

potential areas and past distribution of *Myristica* swamps by cosidering climatic and topographic factors using GIS techniques.

Figure-1
A view from *Myristica* swamp forest

Study area: The study area is located in Southern Kerala between the geo co-ordinates 8.75° to 9.0° North and 76.75° to 77.25° East. This area comes under the three revenue districts namely Thiruvananthapuram, Kollam and Pathanamthitta. The swamps are scattered in three forest ranges namely Kulathupuzha and Anchal forest ranges, and Shendurney Wildlife Sanctuary (figure-2). The drainage pattern appears dendritic to parallel. The climate within the study area is similar to that of the remaining areas of South Kerala and is generally equable.

Material and Methods

Survey and mapping: The swamps could be mapped using latitude-longitude data collected using Global Positioning System (GPS) receivers. But this had severe limitation as dense canopy was limiting GPS usage. To overcome these difficulties, a novel method using conventional survey and GPS readings was devised. To start mapping, a location such as road junction is identified in the map and on the ground. GPS readings are recorded from this point to the boundary of the swamp and mapping continued along the boundary. When the GPS is not able to provide values due to dense canopy overhead, distance and angle to the next point is measured using measuring tape and surveyor's compass. This is repeated till the GPS readings become available. Both these types of data are recorded in formats suitable for computer processing., A custom computer program converts angle – distance measurements to latitude-longitude values using the formula $x=d \cos \theta$ and $y=d \sin \theta$. Where d is the distance in meters and **θ** the angle (90- θ) from north (figure-3). The output, the lat long values of locations along boundary in Mapinfo Import Format (MIF) can be overlaid over existing layers and plotted using GIS program. For each boundary, few reference points are also collected and checked to ensure accuracy. Nearly all the swamps were mapped in this way. The baseline data is digitized from Survey of India Topo sheets using open source GIS software and reservoir and roads etc were updated from satellite imageries.

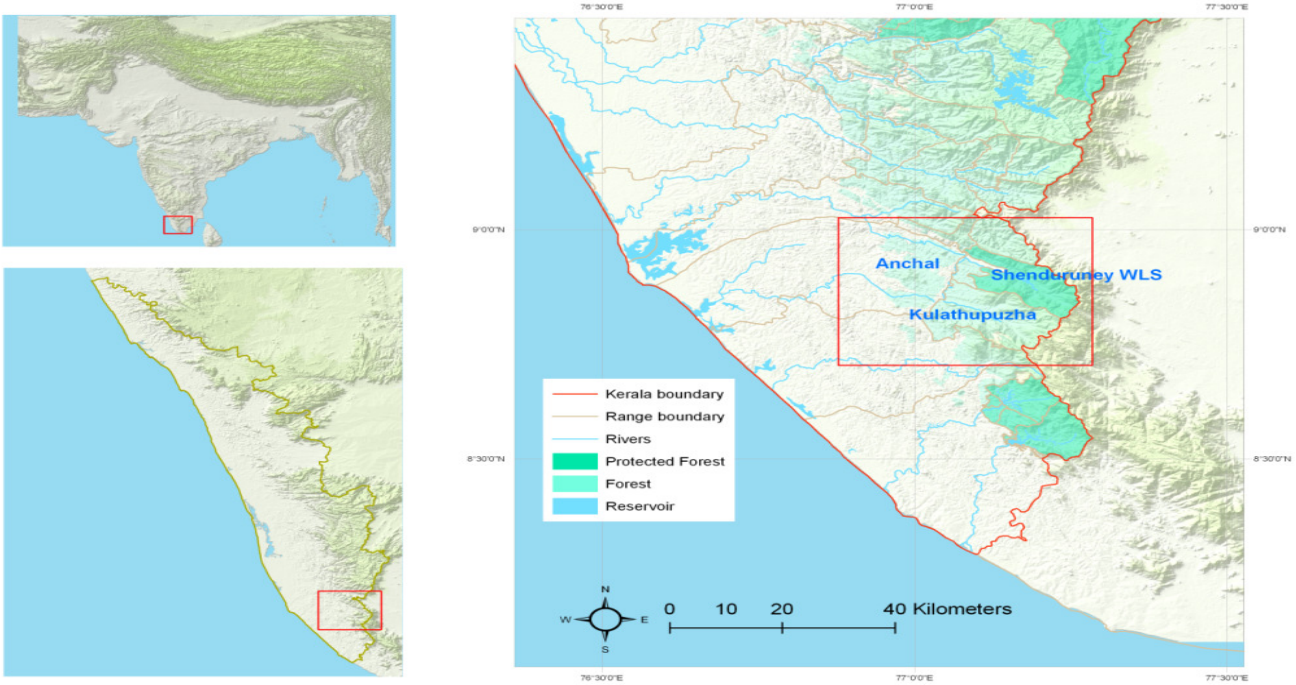

Figure-2
Study area map

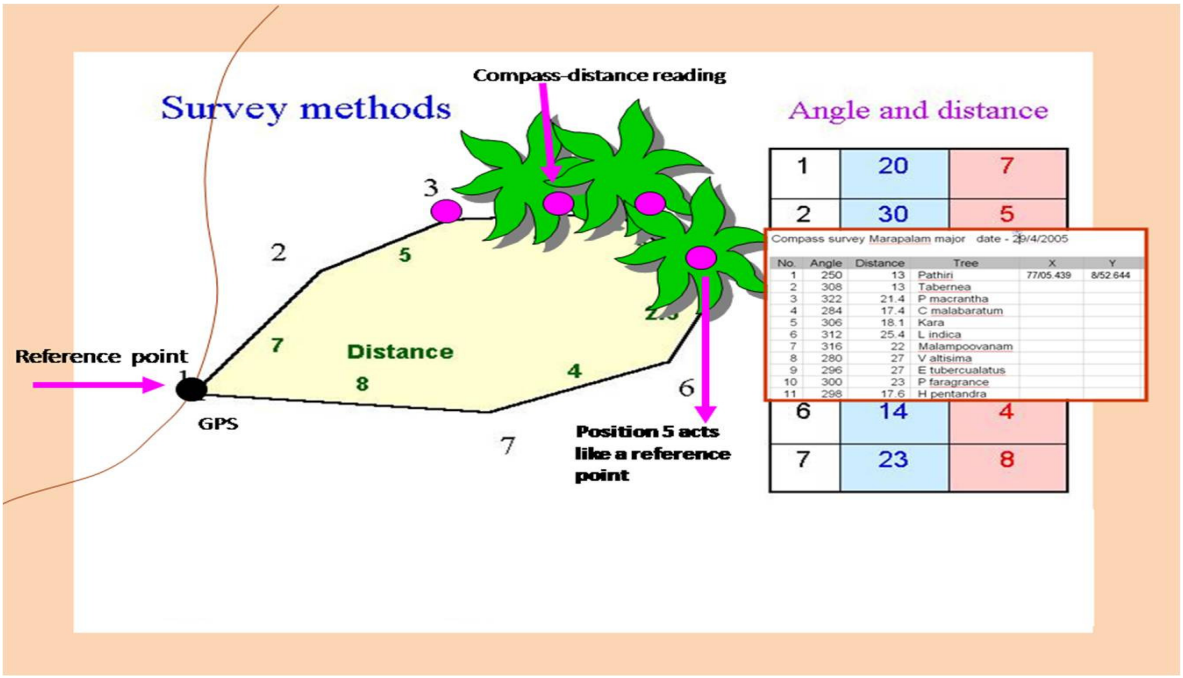

Figure-3
Details of survey method

Base layers: The study area falls in two Survey of India (SOI) topo sheets of 1:50,000 scale, 58D/13 and 58H/01. These sheets were scanned at 200 Dots Per Inch (DPI), cropped, colour and tilt adjusted in graphic softwares. The sheets were accurately registered using corner coordinates in raster GIS program Erdas and vector Geographic Information System (GIS) package Mapinfo and Open Source GIS software QGIS. Boundaries, contour lines, rivers and streams and other features were digitized using Open Source software QGIS. The contour lines were rasterised, and interpolated to make Digital Elevation Model (DEM) data of 10m resolution. In addition to the DEM data derived from Topo sheets, DEM of 90 m resolution data from Shuttle Radar Topo Mission (SRTM)[14] were downloaded from internet and used. Multispectral satellite images of 5.8m resolution were obtained from National Remote Sensing agency. These could be viewed as Red-Green-Blue (RGB) images after opening in Erdas using Generic Binary import option. The image was geo-corrected with respect to survey of India toposheets and the latest features such as dam and new roads, etc. were updated.

Identification of potential areas by using GIS: Geographic distribution of *Myristica* swamps are affected by specific climatic and topographic factor. Specific topographic and climatic parameters such as elevation, hydrology, landuse, soil type and monsoons were considered for identification of potential areas for *Myristica* swamps by using GIS software. Theses factors are follows

Elevation: The elevation of the *Myristica* swamps above sea level seems to be a critical and specific factor as all the mapped *Myristica* swamps were found between 100-200 m from sea level. In some areas, hills rise suddenly around the swamp and the vegetation becomes entirely different after 200 m limit of elevation. In Southern Western Ghats areas between 100-200 m, which are found near rivers have the ability to retain its ground water level. The ground water table here does not go below 6 m even in summer season. SRTM (Shuttle Radar Topo Mission) data set of NASA was used as material for elevation. SRTM provided digital elevation models (DEMS) for over 80% of the globe. This data is currently distributed by USGS (United States Geological Survey) and is available for download from the national map data distribution system, or USGS ftp site (*http://srtm.csi.cgiar.org*). The SRTM 90 m DEMS have a resolution of 90 m at the equator, and are provided in mosaiced 5 degree x 5 degree tiles, in geographic coordinate system-WGS-84 Datum (World Geodetic System-84). The vertical error of the DEMs is reported to be less than 16 m. These are available in both Arc info- ASCII (American Standard Code for Information Interchange) and GeoTiff format to facilitate their use in a variety of image processing and GIS applications.

Hydrology: The streams play a vital role in the functioning and formation of *Myristica* swamps. Most of the swamps are in the first order streams and in most cases the swamps are the origination point of the streamlets. To obtain data on streams, base layers from (scale 1: 1,000,000) Resource Atlas of Kerala, prepared and published by Centre for Earth Science Studies, were digitized and used.

Soil: All *Myristica* swamps mapped were found in specific soil type which indicates the influence of soils in the development of

a particular plant community. According to soil maps of Kerala (scale 1: 500,000) published by National Bureau of Soil Survey and Land Use Planning (ICAR), the soil in which the mapped *Myristica* swamps were found can be classified into two categories.

Mapping Unit-31 Very deep well drained, gravelly loam soils on steeply sloping medium hills with thick vegetation, with moderate erosion: associated with very deep, well drained soils on moderate slopes.

Mapping Unit-32 Deep well drained, loamy soils on gently sloping low hills with isolated hillocks, with moderate erosion: associated with deep, well drained, loamy soils with coherent material at 100 to 150 cm on moderate slopes, severely eroded.

These soils belong to the following taxonomic groups i. Fine – loamy, mixed, Ustic Humitropepts ii. Clayey, mixed Ustic Palehumults iii. Fine-loamy, mixed, Ustic Haplohumuits

Monsoons: Another factor influencing the development of a community or ecosystem is the water availability. Previous workers have mentioned the influence of monsoons on the survival of the *Myristica* swamps. According to the rainfall map over a period of 1902-1979 published by Centre for Earth Science Studies (CESS) and the location of mapped swamps, *Myristica* swamps come under the rainfall range of 50 cm to 150 cm in South West monsoon, 60 cm to 80 cm in North East monsoon and 30 cm to 50 cm in rainfall other than monsoon.

Land use: *Myristica* swamps are located only in the forested area in the southern part of the Kerala. Some swamps of the past are now settlements or plantations. Hence, these areas lie outside the natural forest boundary as shown in Survey of India Topo sheets. So an updated forest map[15] of Kerala prepared by Kerala Forest Research Institute (KFRI) was used for obtaining forest layers and protected area coverage of the forest.

Results and Discussion

Mapping of *Myristica* swamps: The swamps in Kulathupuzha region are located along two river systems- Kallada River and Ithikkara River. The Kallada river system is complex and a major part of it flows through forest area, mainly through Kulathupuzha, Thenmala, Arienkavu, Pathanapuram, Anchal Forest Ranges and Shendureny Wildlife Sanctuary. Kulathupuzha Ar and Chendurni Ar are the two major streams in Kallada River. Only a small part of Ithikkara River flows through the forest area (Anchal forest area). Both rivers finally fall into the Arabian Sea. All swamps in the Anchal forest range are situated in the Ithikkara River system.

A total of 60 swamp patches were mapped in the study area. A total of 47 individual swamps drain to Kallada River and 13 flows to Ithikkara River. The swamps in Ithikkara River come under Kollam District and swamps in Kallada River come under Kollam and Thiruvananthapuram Districts. Swamp patches with area less than 0.01 ha and having very few *Myristica* trees were not considered as a separate swamp patch. As the swamp patches are not marked in the Topo sheets, the names used by the local inhabitants to refer to the swamps have been used in this study. The swamps were grouped according to the river system in which they are situated (figure-4).

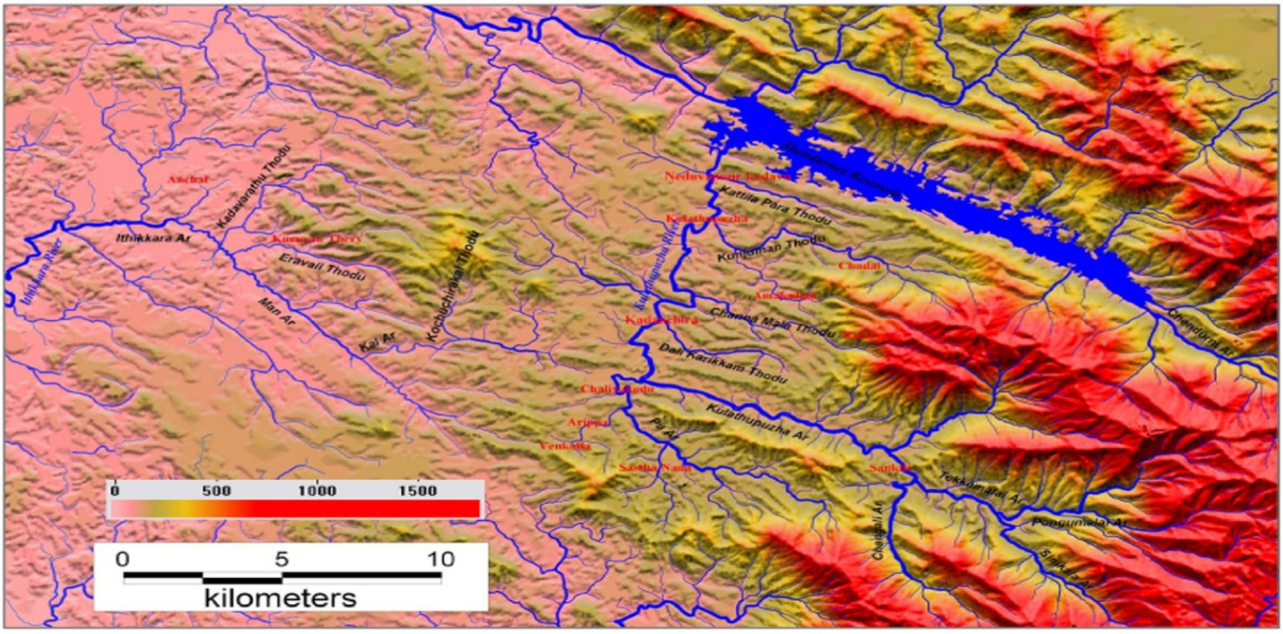

Figure-4
Map of River systems in Kulathupuzha region

Swamps in Kulathupuzha Ar of Kallada were designiatd as 'KK' with a numerical suffix indicating tributary group. Swamps in Chendureni Ar of Kallada were designiatd as 'KS' with numerical suffix. Swamps in Ithikkara River were designiatd as 'IK' with numerical suffix. Classification tree showing grouping of swamp and map showing swamp groups are shown in figure- 5 and figure- 6. There are eight groups of swamps in Kallada river system, in which seven groups comes under Kulathupuzha Ar and one under Shendurney Ar. They are Pu Ar, Tekkamalai Ar, Channa mala Thodu, Kunjuman Thodu, Kattila Para Thodu, Kulathupuzha Ar, Dali Karikkam Thodu and Chendurni Ar. Ithikkara river system has three groups of swamps they are Kochuchirakal Thodu, Eravail Thodu and Kadavarathu Thodu. The list of swamps with its river system groups and geo-coordinates is given in the table-1.

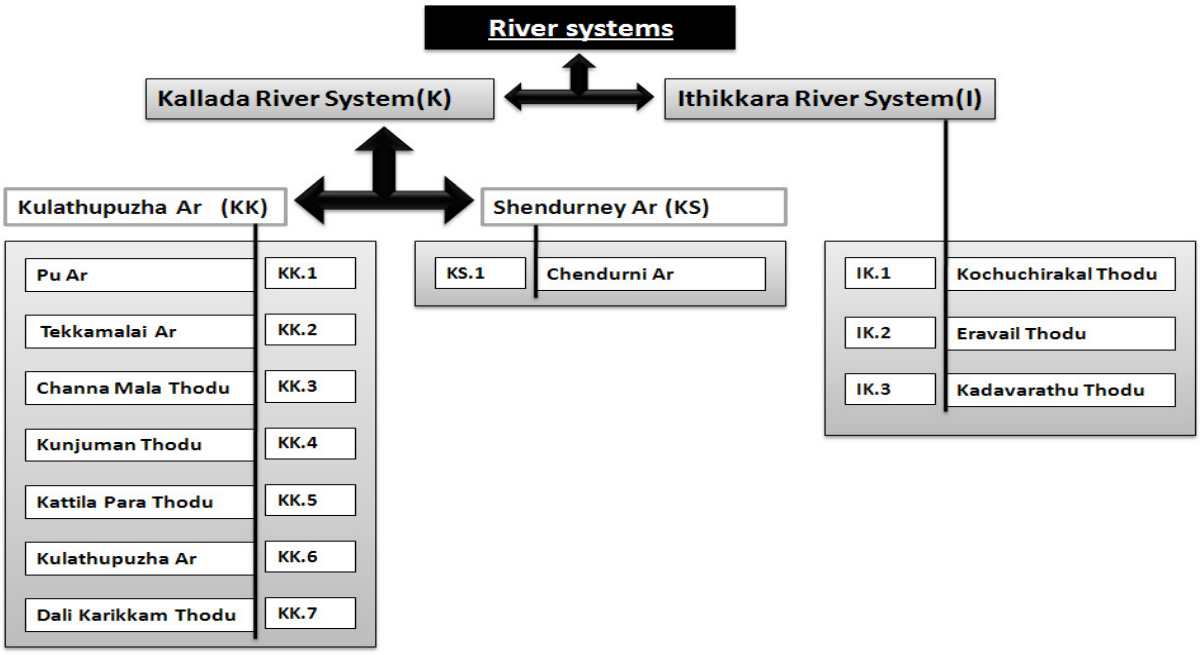

Figure-5
Classification tree showing grouping of swamps

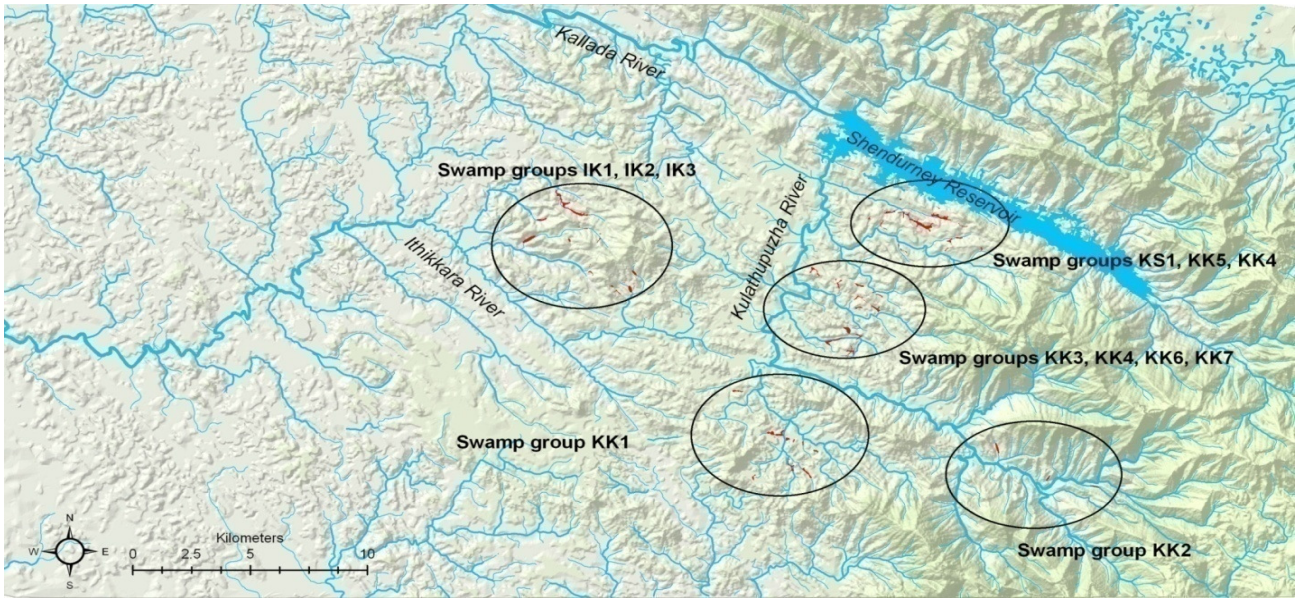

Figure-6
Hill shade map of Kulathupuzha region shows *Myristica* swamps

Table-1
The list of *Myristica* swamps

S NO	Group	Name of swamp	Forest Area	Area in Ha	Longitude (E)	Latitude (N)
1	KK.1	Chekidi Chal	Kulathupuzha	03.61	77.060921	8.802753
2	KK.1	Palli Thadam	Kulathupuzha	03.24	77.054112	8.806016
3	KK.1	Uthiran Chira	Kulathupuzha	01.45	77.040175	8.800738
4	KK.1	Karinkurinji Up	Kulathupuzha	03.29	77.046955	8.819349
5	KK.1	Karinkurinji Down	Kulathupuzha	03.95	77.051114	8.819454
6	KK.1	Sastha Nada	Kulathupuzha	01.71	77.053522	8.816829
7	KK.1	Muppathadi	Kulathupuzha	01.33	77.064307	8.811675
8	KK.1	Pillekode	Kulathupuzha	00.98	77.059372	8.815173
9	KK.1	Kochamma	Kulathupuzha	00.25	77.055901	8.816126
10	KK.1	Ammayambalam	Kulathupuzha	02.48	77.034353	8.837118
		Total		**22.29**		
11	KK.2	Choondi Para	Kulathupuzha	01.50	77.171143	8.796867
12	KK.2	Valavu Para Pacha	Kulathupuzha	05.00	77.153328	8.800395
13	KK.2	Manjalu Para	Kulathupuzha	03.00	77.133819	8.813026
		Total		**9. 50**		
14	KK.3	Poovanathu Mood 0	Kulathupuzha	03.24	77.078593	8.852787
15	KK.3	Poovanathu Mood 1	Kulathupuzha	00.51	77.078087	8.855308
16	KK.3	Poovanathu Mood 2	Kulathupuzha	00.29	77.080684	8.856648
17	KK.3	Poovanathu Mood 3	Kulathupuzha	00.76	77.080492	8.859325
18	KK.3	Poovanathu Mood 4	Kulathupuzha	01.22	77.080875	8.860595
19	KK.3	Chuvanna Karikkam	Kulathupuzha	04.00	77.076208	8.862574
20	KK.3	Munnam Chal	Kulathupuzha	10.00	77.091960	8.858014
21	KK.3	Plavu Chal	Kulathupuzha	03.58	77.087102	8.871814
22	KK.3	Pullu Mala	Kulathupuzha	01.50	77.080719	8.872284
23	KK.3	Perum Padappy	Kulathupuzha	02.17	77.082255	8.875924
24	KK.3	Channa Mala Up	Kulathupuzha	00.31	77.072784	8.882093
25	KK.3	Channa Mala Down	Kulathupuzha	02.19	77.072784	8.882094
		Total		**29.77**		
26	KK.4	Marappalam Minor	Kulathupuzha	00.26	77.086248	8.878656
27	KK.4	Mottal Mood	Kulathupuzha	02.28	77.080923	8.881830
28	KK.4	Marappalam Major	Kulathupuzha	01.31	77.089104	8.877313
29	KK.4	Chudal S	Shendureney	00.53	77.084764	8.909816
30	KK.4	Chudal SE	Shendureney	01.77	77.089126	8.907049
31	KK.4	Onnam Junda	Shendureney	01.39	77.096193	8.897516
32	KK.4	Vilakku Maraum N	Shendureney	01.67	77.115550	8.900102
33	KK.4	Vilakku Maraum S	Shendureney	00.71	77.114436	8.896808
34	KK.4	Kambaka Thottum	Shendureney	01.55	77.119234	8.901648
35	KK.4	Kurunthotti Valavu	Shendureney	00.79	77.127822	8.896965
36	KK.4	Irrikappara	Shendureney	01.04	77.119924	8.906927
		Total		**13.30**		
37	KK.5	Onnam Mile S	Shendureney	07.82	77.114645	8.910898
38	KK.5	Munkuthu	Shendureney	12.50	77.104616	8.907495
39	KK.5	Manchal	Shendureney	01.26	77.099393	8.911679
40	KK.5	Kattila Para P	Shendureney	00.40	77.096722	8.917815
41	KK.5	Kattila Para SE	Shendureney	00.22	77.100167	8.915967
42	KK.5	Kattila Para S	Shendureney	02.32	77.097829	8.911347
43	KK.5	Chudal E	Shendureney	02.90	77.092636	8.912526
		Total		**27.42**		
44	KK.6	Emponge	Kulathupuzha	03.23	77.064815	8.887532
		Total		**03.23**		

45	KK.7	Dali karikkam	Kulathupuzha	06.00	77.068595	8.857489
46	KK.7	Chithirakkala Pacha	Kulathupuzha	04.00	77.073356	8.858970
		Total		**10.00**		
47	KS.1	Onam mile N	Shendureney	00.48	77.111116	8.914470
		Total		**00.48**		
48	IK.1	Ammbalathu Pacha(1and2)	Anchal	01.75	76.988264	8.878850
49	IK.1	Chettadi(1and2)	Anchal	05.00	76.993128	8.880076
50	IK.1	Anavettanchal	Anchal	02.00	76.995824	8.878773
51	IK.1	Mottilam Pacha	Anchal	01.00	76.994654	8.886926
		Total		**09.75**		
52	IK.2	Kodukuthi Pacha	Anchal	01.16	76.978552	8.886749
53	IK.2	Eravail Pacha	Anchal	00.23	76.977566	8.889843
54	IK.2	Kalyani Up	Anchal	00.66	76.981045	8.900530
55	IK.2	Kalyani Down	Anchal	00.25	76.981544	8.903378
56	IK.2	Konju Kuzhi	Anchal	01.12	76.974602	8.905908
57	IK.2	Kuravan Thery	Anchal	2.00	76.954363	8.901118
58	IK.2	Mukkode	Anchal	01.50	76.957702	8.897911
		Total		06.92		
59	IK.3	Valiya Pacha	Anchal	01.00	76.960378	8.909507
60	IK.3	Neerattu Thadam	Anchal	16.00	76.969605	8.916449
		Total		**17.00**		

The boundaries of swamps with an area of above 0.020 ha have been mapped exactly. Previously the French Institute Pondicherry Forest Map (Forest map of South India, Thiruvananthapuram - Tirunelveli, 1997. Scale 1.250, 000) classified an area of 12.5sq km (1232 ha) from Kulathupuzha region of southern Kerala, having low elevation forests as *Myristica* swamp facies.

The present study shows that total area of *Myristica* swamps is below 1.5 km^2 (149.75 ha). In which Kulathupuzha Forest Range has 31 swamps contributing 78.73 ha area, Shendurney WLS has 16 swamps contributing 37.35 ha and Anchal Forest Range has 13 swamps covering 33.67 ha. The smallest swamp is Kattila Para SE (0.22 ha) and largest swamp is Neerattu Thadam (16.00 ha).

It is notable that maximum area of swamps and maximum number of swamps was present in Kulathupuzha Forest Range (figure- 7). Both in terms of number and area the highest values in each swamp size class are found in Kulathupuzha in all classes except in the swamp size classes 9.96 to 14.95 ha and above 14.96 ha. Shendurney had more swamps in the size class 9.96 - 14.95 than Kulathupuzha while Anchal had none. Anchal had the only one swamp Neerattu Thadam which fell in the above 14.96 category (figure- 8). The swamps in the 1-4.95 class contributed the highest both in terms of number of swamps and land area. Swamps in the below 1 ha class had the second highest value in terms of number of swamps but had the lowest contribution in terms of land area. The number of swamps in the swamp size classes with higher area was less even though the area contributed did not decrease. In terms of number of swamps and land area of swamps, Kulathupuzha

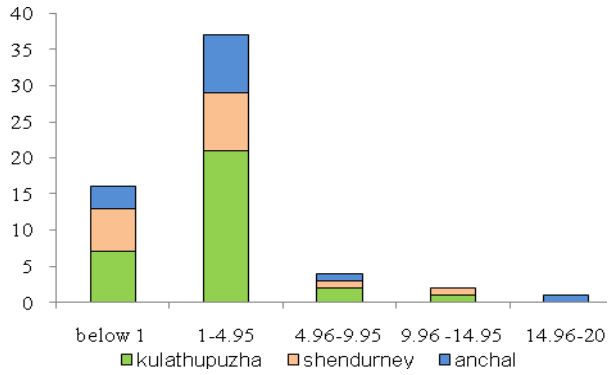

Figure-7
Distribution of number of swamps in different size classes in three forest ranges

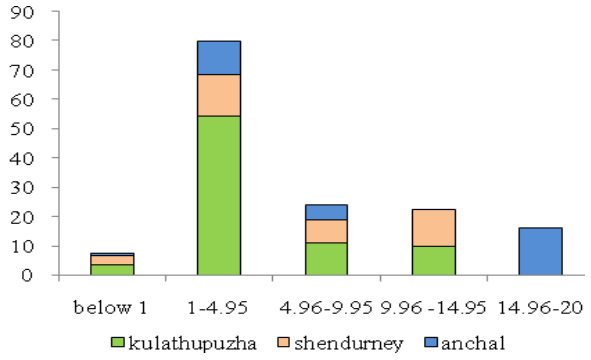

Figure-8
Distribution of swamps area in different size classes in three forest ranges

Forest Range gives the maximum contribution, which highlights the necessity of upgrading the conservation level of this area. The cumulative area of the swamps in the study area is only 149.75 ha, which is 0.01348 percent of Kerala's forested area (11,126.46 km^2) and 0.0039 percent of Kerala's total land area (38,864 km^2).

Myristica swamps have been reported from other states in the Western Ghats. Fifty one swamp patches covering a cumulative area of 9.82 ha has been reported from Uttara Kannada district. The swamp size in this area ranges from a minimum of 0.005 ha and maximum up to 1.0 ha. Most of the swamps in Uttara Kannada district come under below 0.05 ha, only three swamps fall under swamps fall under the 0.95 ha to 1.0 ha area group. The importance of the Kulathupuzha region as a habitat for *Myristica* swamps becomes more evident when one states that the cumulative land area of *Myristica* swamps in the Kuathupuzha region is 15 times the cumulative land area of *Myristica* swamps in the Uttara Kannada region. It is also notable that while the study in Uttara Kannada has included swamps less that 0.005 ha, the present study has included swamps above the 0.20 ha limit only. *Myristica* swamps have also been reported from sacred groves of Goa but exact periphery mapping has not been reported from this non mapping oriented study. Swamps other than *Myristica* swamps have been reported from India but as they were not mapping oriented studies the data obtained from these studies cannot be used for comparison with this study.

Identification of potential areas for *Myristica* swamps by using GIS: Land area which had the physical characteristics to support *Myristica* swamps were identified as follows. The total forest area of Kerala is 11,126.46 km^2. A total of 4927 km^2 area comes below the elevation of 100-200 m. In the first step of analysis the exact forest area between the elevations of 100-200 m was determined. The analysis indicated 1485 km^2 area of the forest area below 100-200 m. The next step of the analysis was to find out the presence of streams inside and within a 1.5 km proximity to the area of selected altitude criteria. A total of 884 km^2 fulfilled these criteria. In the next step of the analysis the area inside this 884 km^2 which had a specific amount of rainfall (50-150 cm for SW monsoon, 60-80 cm for NE monsoon and 30-50 cm for other monsoons) was determined. 196.6 km^2 land area fell under this specific rain fall in this area. In the final step those areas in this 196.6 km^2 which had a particular type soil (Soil type 31and32) was determined. The final analysis indicated 160.6 km^2 of land which had all these characteristics. Using Survey of India Topo sheets, forest plantation land was filtered out from this area. This led to the reduction of the total area to just 148.57 km^2 (figure-9).

An area of 148.57 km^2 has a potential for *Myristica* swamps. This includes the area which contains *Myristica* swamp patches of the present and the area which could have been previously occupied by *Myristica* swamps. The areas which have the potential to support *Myristica* swamps according to simulation are located mostly in the southern part of Kerala's Western Ghats. The areas with potential are located in Ranni, Konni, Achenkovil, Punalur, Thenmala and Trivandrum Forest Divisions; Peppara and Shendurney Wildlife Sanctuary and Agasthyavanam Biosphere Reserve. The distribution of potential area in each of these forest administrative units has been tabulated below (table 2). The total forest area of Kerala is 11,126.46 km^2 of which area land with potential to support *Myristica* swamps constitute 1.34%. Trivandrum and Punalur Forest Division show maximum potential area of *Myristica* swamps. This area includes Anchal and Kulathupuzha Forest ranges which is the present study area.

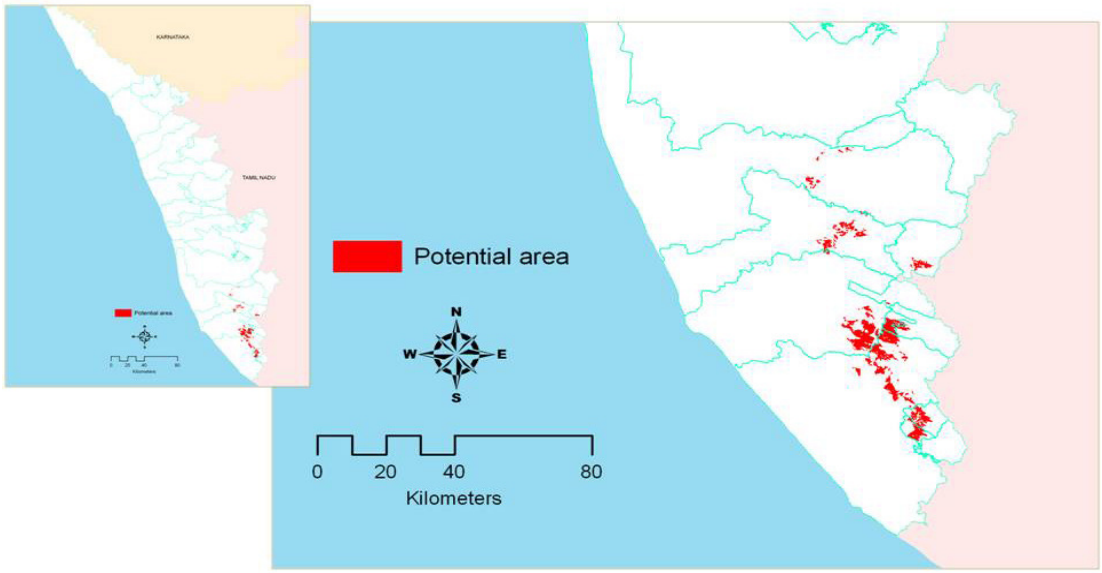

Figure-9
Potential areas of *Myristica* swamps

Table-2
Areas with potential for *Myristica* swamps in Kerala forests

S. No.	Forest Division	Potential area in km^2	Total forest area in km^2	%-potential area
1	Ranni	5.067	1059.07	0.478439
2	Konni	20.12	0331.66	6.066454
3	Achankovil	02.21	0269.00	0.821561
4	Punalur	40.29	0280.22	14.37799
5	Thenmala	04.27	0206.17	2.071106
6	Trivandrum	46.20	0369.88	12.49054
7	Shendurney WLS	04.23	0100.32	4.216507
8	Peppara WLS	14.82	0053.00	27.96226
9	Agasthyavanam BP	11.36	0031.12	36.50386
	Total	148.57	2700.44	5.501585

Kollam and Trivandrum districts are most favorable for *Myristica* swamps. As per the analysis the forest in the southern parts have more area coming under the required elevation, hydrology and rainfall and soil type for sustaining *Myristica* swamps.

The Kerala Forest Department mentions the leasing of over 9600 ha of forest land for agricultural purposes in 1943[15] and state that the practice was continued inspite of serious damage to the forest ecosystem. Since the *Myristica* swamps were first reported only in 1960 there is no data on the swamp land converted before 1960. Since Myristicaceae trees are not valued as timber specific mention of logging of these trees in the records of the Pre-Independence era is absent as forests were seen more from a utility point of view than from a conservation point of view.

Rodgers and Panwar[7,8] suggested Chirikala Wildlife Sanctuary (area of 20 km$^{2)}$ for the exclusive conservation of this ecosystem. But they failed to give the exact place and denote it along with a question mark. But they mention that Chirikala forest block in Travancore is a type locality[5] for *Myristica* swamp forest - 4C-FSI. They called for further survey to identify the best areas to be included under conservation. They placed the implementation of Chirikala Wildlife Sanctuary as first priority (National Importance- to give significant protection to endangered species or communities or regions which are poorly covered at present.). The presence of evergreen forests is a necessity for the presence of these swamps[11, 15] but Rodgers and Panwar [7, 8] state that the coastal plain had a distinctive evergreen swamp forests dominated by species of *Myristica* within a framework of drier evergreen and deciduous communities. This has virtually been cleared. They mention that remnants may remain in river valleys at the edge of the hills.

The swamp patches in the study area are situated in river valleys at the edge of the hills and almost all the swamps were surrounded by a small area of evergreen trees which soon gave way to semi evergreen, moist deciduous or plantation forests. Most of the vegetation maps show the study area as having semi evergreen and moist deciduous type of vegetation. These maps do not take into account small patches of evergreen forests which surround the even smaller patches of *Myristica* swamps. The presence of small stretches of evergreen forests is further validated by satellite images, but the resolution is not enough to work on such small patches as the *Myristica* swamps. As most of the swamps mapped in the study are located inside an evergreen forest, which in turn may be surrounded by large tracts of semi evergreen or plantation forests, it may be concluded that the presence of an evergreen forest belt is essential for the well being of a *Myristica* swamp ecosystem.

GIS and RS studies have been performed to identify the geographical setting and to assess the wetland area change occurred during the past two decades[16.] , understand the erosion accretion pattern of the island[17], generating the thematic maps and delineation of groundwater potential zones[18], quality of groundwater in hard rock areas using GIS application[19] . The overlay method for mapping an environmental unit with GIS has been successfully used[20]. Our study highlights the efficacy of GIS and RS techniques in mapping restricted and fragmented bio-geographical zones.

Conclusion

The *Myristica* swamp forests are a naturally fragmented, unique ecosystem which needs special abiotic conditions for development. The study area (Kulathupuzha region in Southern Kerala) has the largest remnants of this ecosystem. Though many studies exist on the floristic wealth and the edaphic features of these swamps, detailed mapping is lacking. Sixty swamp patches with total land area of 149.75 ha were mapped in the study area, of which 47 individual swamps drain into Kallada River system and 13 to Ithikkara River system. GIS simulation revealed that 148.57 km^2 area of Kerala's forest area has a potential to support *Myristica* swamps. Even though the results indicate a potential area of 148.57 km^2, it may be concluded that this value be taken as a baseline value only. Further understanding of the abiotic conditions needed for the development of these swamps, exact delineation of the same on maps and land use patterns may lead to increase or decrease in this baseline value. One is also aware that the environmental conditions which facilitated the development

of these forests are much changed from the climatic conditions of today. Even if the practical, logistic and economical difficulties concerning the reconversion of potential land areas to *Myristica* swamps is surmounted there will still remain the challenge of providing the optimum environmental conditions for their establishment.

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