Indian Journal of Geo Marine Sciences
Vol. 49 (06), June 2020, pp. 1025-1030

A remote sensing approach to monitor potential fishing zone associated with sea surface temperature and chlorophyll concentration

S Karuppasamy*[,a], T P Ashitha[b], R Padmanaban[c], M Shamsudeen[d] & J M N Silva[c]

[a]SRM Institute of Science and Technology Mahatma Gandhi Road, Potheri, SRM Nagar, Kattankulathur, Tamil Nadu – 603 203, India
[b]Anna University Chennai - Regional Office, Tirunelveli Region, Nagercoil Road, Tirunelveli, Tamil Nadu – 627 007, India
[c]Centre for Forest Studies (CEF), Instituto Superior de Agronomia (ISA), Universidade de Lisboa, Tapada da Ajuda, Lisbon – 1349-017, Portugal
[d]University V.O.C. College of Engineering, Anna University Campus, 7[th] Street West, Bryant Nagar Main Road, Tamil Nadu – 628 008, India
*[E-mail: karuppasamys@yahoo.com]

Received 20 November 2018; revised 18 June 2019

India is the biggest seafood producing country in the world, and its economy relies, to a large extent, on fish production. Recent technologies in the remote sensing field enabled the gathering of information about the Sea Surface Temperature (SST) and Chlorophyll Concentration (CC) are used for analyzing the Potential Fishing Zone (PFZ). We used Landsat 8 images to create the base map of the Thoothukudi coastline. MODIS-AQUA satellite data were used to derive the SST and Chlorophyll-*a* for the Thoothukudi coast (Bay of Bengal) for the years 2013 to 2017, for the month of June. PFZ was classified into three classes: High PFZ, Medium PFZ, and Low PFZ. Results shows 2015 has highest PFZ found in the region of Sippikulam and Vembar. During 2016, PFZ identified at Kayalpattinam, Tiruchendur, and Manapad regions. The PFZ level was low during 2017 compared to the previous years. The PFZ has increased in the international maritime boundary line, which forced the fishermen to cross the territorial boundary. This study provides valuable information about fish catching areas to the fishermen and local populations, by reducing fish search time by 30 to 70 %, and consequently the fuel cost and human efforts. Additionally, also reduces the need of crossing the international maritime boundary line.

[**Keywords**: Coastal, Fishery, GIS, Landsat, MODIS-AQUA, Remote Sensing, Thoothukudi]

Introduction

Sea fishing in India is a large income generating industry, employing nearly 14 million people across country[1,2]. Based on the statistics from the Food and Agriculture Organization (FAO), sea production has doubled in India between 1990 and 2010[1]. In Tamil Nadu, an annual fishing ban is practiced between April 15 and May 31[3,4]. Therefore, the June and July months are best time for fish catching along the region but there is a decline in fish export in India[5]. Marine fish production has drastically decreased from 32,472 tons to 23,957 tons which is nearly 10 % of the exports[2] due to anthropogenic and climatic factors[6]. The changes in Sea Surface Temperature (SST) and Sea Surface Chlorophyll (SSC) are the two most important parameters that affect the growth of fishes[7] and are also used to identify fish availability and PFZ. Turbidity, chlorophyll, and SST obtained from satellite data are also considered as parameters to estimate PFZ[8]. SST is the water temperature closer to the ocean surface, between 1 mm and 20 meters below the surface of sea[7]. All these factors have a synergistic effect on the biota ranging from microscopic plankton to large fishes and marine mammals[9,10]. Satellite-derived SST and chlorophyll information over the ocean are key inputs to identify the PFZ[11,12]. SST is one of the essential parameters that play a significant role in the earth's atmosphere. An increase in mean SST over the years is one of the primary indicators of global warming[13]. Temperature affects ocean parameters such as salinity, pH, and dissolved oxygen[14]. Chlorophyll (*a*, *b*, *c*) and *Phaeophytin* are considered to be the pigments in seawater[15]. Chlorophyll-*a* is one of the predominant photosynthetic pigment of marine phytoplankton that has been used as an indication of biomass or primary productivity in the oceans[14]. Chlorophyll data is also used very effectively for fisheries research. The data is used to define marine habitats of fishery resources. Traditionally, the in-situ SST observations were made by drifting/moored buoys and ships. An integrated approach of Remote Sensing (RS) and Geospatial system has been widely adopted in various coastal studies as they are economical, minimizes human error, and are also useful especially in the absence of field investigations[16–20]. In recent years, mapping of CC and SST derived from satellite RS as a tool to explore the distribution of fishery wealth, has been gaining momentum[21,22]. Now a days the SST and CC can be usually derived from NOAA-AVHRR satellite data or MODIS-AQUA Satellite data[23]. In present study analyzed the impacts of SST and identified PFZ along the study area using MODIS-AQUA imageries of June from 2013-17.

Materials and Methods

Study area

Thoothukudi also known as Tuticorin is basically a port and industrial city that belongs to the municipal corporation of the southern state of India, Tamil Nadu[24]. The city lies in the Coromandel coast of Bay of Bengal. The district coast extends from Vembar to the south of Manapad having a length of 163.5 km. Coastline geographically lies between 8°9'00"-9°7'30" N latitude and 78°2'30"-78°25'00" E longitude (Fig. 1). covering an area of 4,621 sq.km[ref. 3].

The major activity of this district is salt production and fisheries[18]. The commonly occurring fishes are Horse mackeral, Bluefin trevally, Barracuda, Sardines, and Tuna. According to United Nations Convention based upon the law of the sea, territorial sea extends up to 12 nautical miles from its baseline that is nearly 22.2 km[ref. 1].

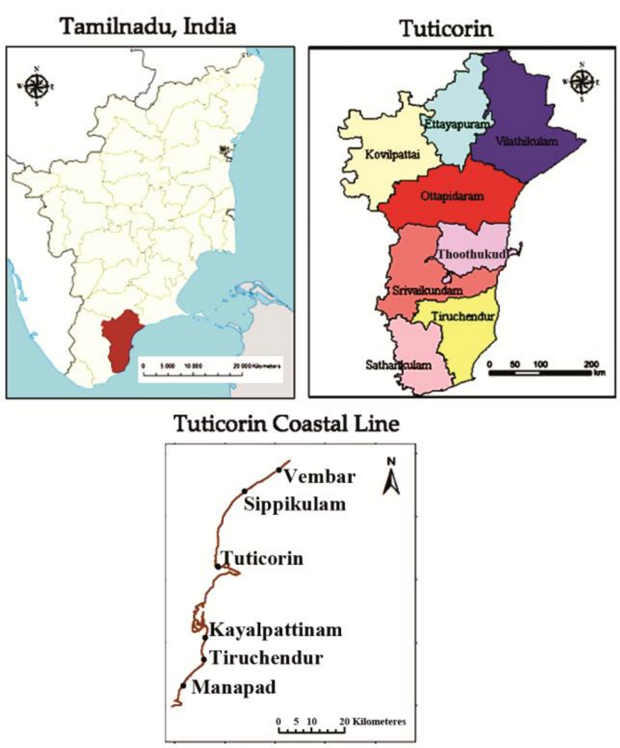

Fig. 1 — Geographic location and coastal line of Thoothukudi

Data used

The study utilized Landsat Enhanced Thematic Mapper 8 (ETM+) with 30 m spatial resolution and Moderate Resolution Imaging Spectroradiometer (MODIS) images with 250 m (bands 1–2), 500 m (bands 3–7) and 1000 m (bands 8–36) resolution from June 2013 to June 2017. The Landsat 8 images were downloaded from the United States Geological Survey (USGS) in GeoTiff format[24,25]. Later on, Landsat bands 3, 4, and 5, were extracted for the study area. We collected SST and chlorophyll data MODIS-AQUA for five years from 2013-17, which were downloaded from the Indian National Centre for Ocean Information Services (INCOIS)[24].

Methodology

Image pre-processing

Pre-processing is employed to reduce the geometrical distortion and noise from the satellite data to enhance for subsequent processing. The layer-stacking method in R was used to combine separate image bands into single multispectral image files. The bands 3-5 from Landsat satellite images were combined using R[26,27]. After pre-processing, the base map was prepared for Thoothukudi coastline using ArcGIS 10.2.1 software by digitizing the coastal area using a line layer[28].

Coastal line creation

The buffer function in R was used to determine the area covered within the specific features. Buffering was created from the linear coastal line of Thoothukudi. Since the study area required a demarcated coastal line for 12 nautical miles[28], the linear features were used as input in the R.

Adding surface information

We identified minimum and maximum z values (Height) from a terrain within the spatial extent of a polygon using min and max function available in raster and rgdal R package. Initially, we computed the SST and CC for each individual pixel of the study area. The pixel values from the images were used for the derivation. Within the buffer area, the points were marked using a point layer to derive the SST. For SST, the point layer and SST data has to be given as input and have to select the values to be assigned in Z. For CC, the point layer and CC data has to be given as input and have to select the values to be assigned in Z. The Z value column was multiplied by 0.005 for the °C conversion for SST. Thereafter, the values of SST and the CC on the buffer area have been derived. The flow chart of methodology adopted for the estimation of PFZ is shown in Figure 2.

Inverse distance weighted in R

In this study, the IDW was created by using the raster values derived from various raster data, and eventually the map was created using IDW of Interpolation function in R[29,30].

Assigning the rank for SST and chlorophyll

For low SST and high CC, the rank assigned is 1 which means PFZ is high, the high SST and low CC is assigned as rank 3 which means PFZ is low. The medium values of SST and CC are assigned to be rank 2, which mean the PFZ is medium. After assessing the rank for SST and CC, the PFZ was mapped for the years 2013 -17.

Results and Discussion

Sea Surface Temperature

The SST map from June of 2013 to 2017 was produced and analyzed. The SST map for June 2013 is presented in Figure 3(a) showing a low SST of about 24 to 27 °C, which is highly suitable in PFZ with rank one. The area with SST values ranging between 30 to 31 °C being a high temperature zone considered as a low suitability area for PFZ.

During the years 2014-17, the regions with low SST values ranging between 24 to 27 °C, were found to be highly suitable for Potential Fishing Zone with rank one; whereas, the regions with temperature range between 30 to 31 °C showed low suitability for PFZ (Fig. 3). The remaining regions along the study area showed medium suitability as PFZ (Fig. 3).

Chlorophyll concentration

The CC map from June of 2013-17 was produced and analyzed. As illustrated in Figure 4, the regions

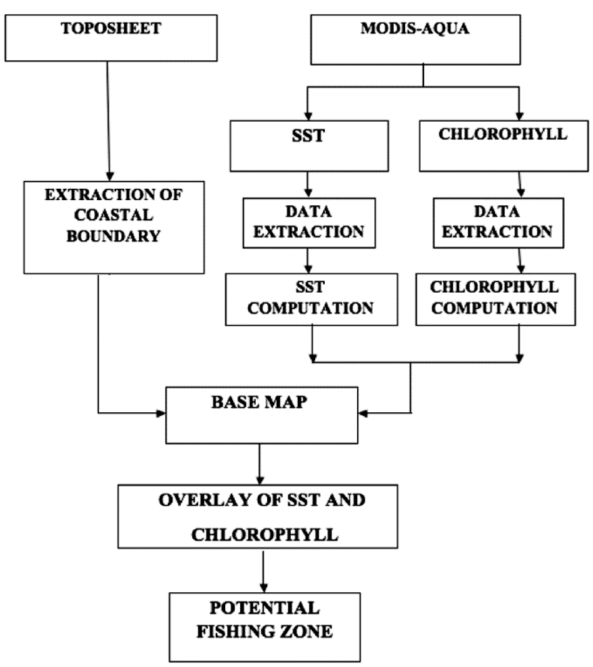

Fig. 2 — Methodology flow chart for the estimation of Potential Fishing Zone

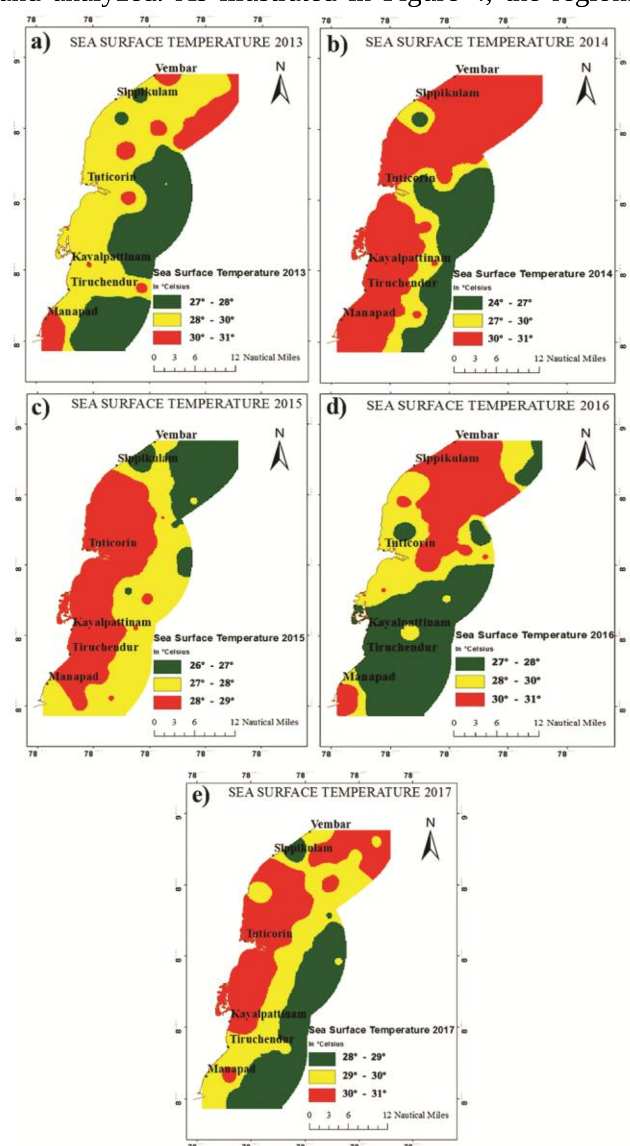

Fig. 3 — Sea Surface Temperature in: a) June 2013; b) June 2014; c) June 2015; d) June 2016; and e) June 2017

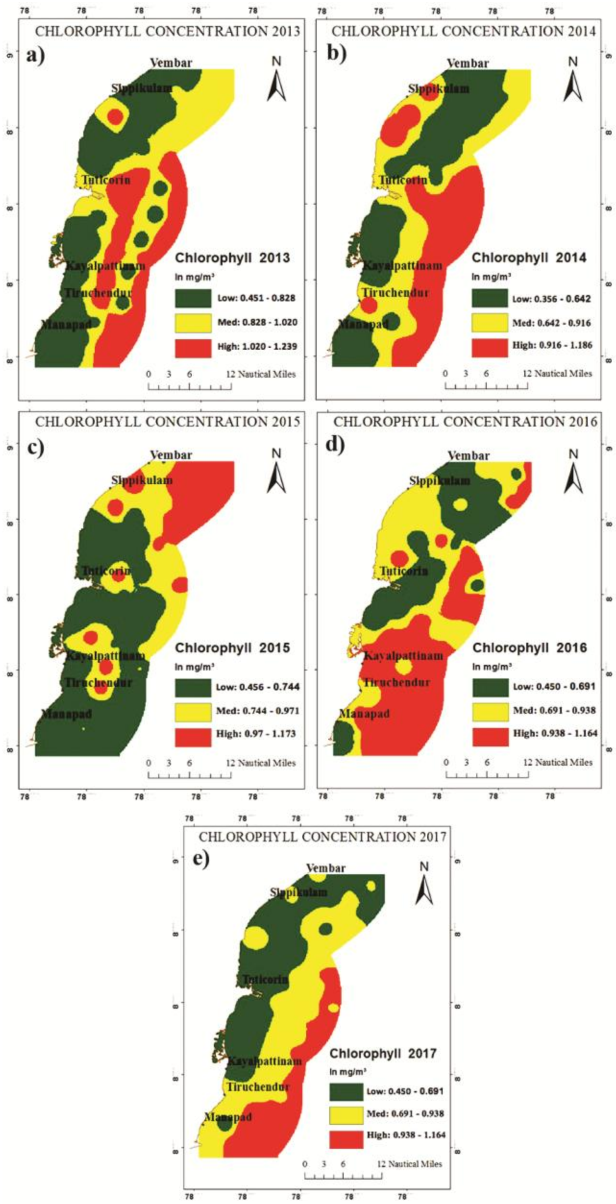

Fig. 4 — Chlorophyll Concentration in: a) June 2013; b) June 2014; c) June 2015; d) June 2016; and e) June 2017

with CC 1.02 mg/m³ to 1.23 mg/m³ were highly suitable for PFZ areas. Further, the regions with low CC range between 0.45 mg/m³ to 0.82 mg/m³ were considered as a low suitability area for PFZ; whereas, the remaining areas showed medium suitability as PFZ with CC range 0.82 mg/m³ to 1.02 mg/m³ (Fig. 4).

PFZ mapping

The study shows SST and chlorophyll are an important oceanographic parameters for identifying PFZ along the coast. The PFZ maps are created from 2013 to 2017 by assigning a rank value as shown in Table 1. Low SST and high chlorophyll concentration

Table 1 — PFZ Rank

SST	CC	Rank	PFZ
Low	High	1	HIGH
Medium	Medium	2	MEDIUM
High	Low	3	LOW

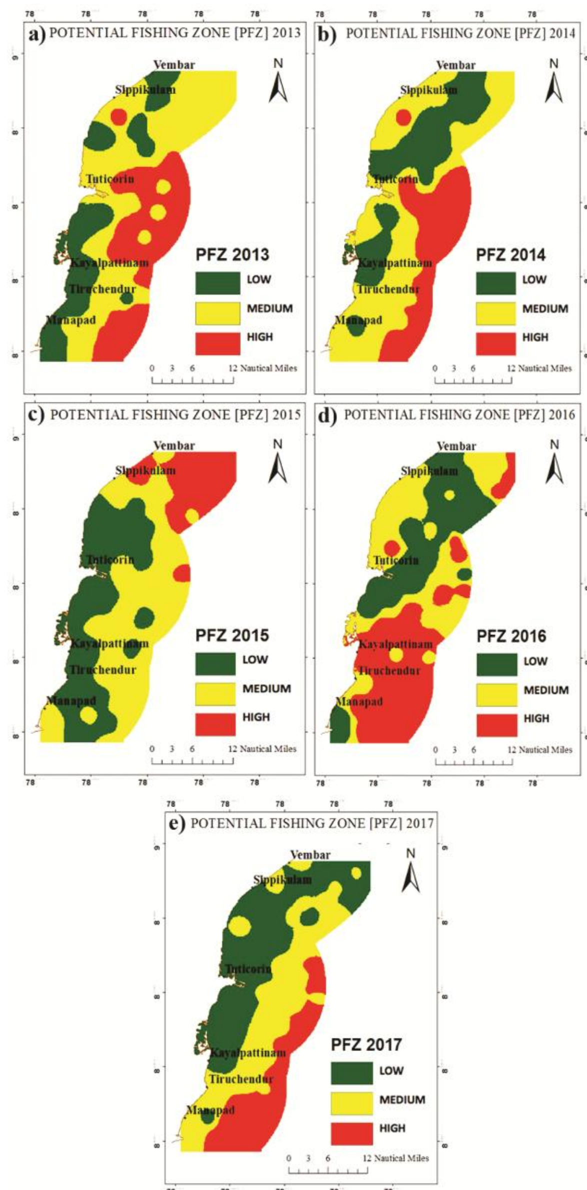

Fig. 5 — Potential Fishing Zone in: a) June 2013; b) June 2014; c) June 2015; d) June 2016; and e) June 2017

is assigned as rank one i.e. high PFZ. The intermediate values of SST and CC are consigned to be rank two as Medium PFZ. The high SST and low CC is allotted as rank three as low PFZ.

The SST and the CC values were used to extract the PFZ map. On the basis of SST and CC data, June 2013 showed a medium PFZ (Fig. 5). Similarly, June

2014 showed high PFZ near Sippikulam (Fig. 5b), June 2015 showed high PFZ near Vembar coast (Fig. 5c), June 2016 showed high PFZ near Kayalpattinam and Tiruchendur region (Fig. 5d), whereas June 2017 showed low PFZ compared to the previous years (Fig. 5e).

Conclusion

In the present study, the PFZs were determined based on SST and CC data using R programming. The MODIS_AQUA satellite was used to derive SST and CC data. The PFZs were further classified into three classes as high, medium, and low PFZ. The favourable range of SST and CC for the pelagic fishes was 24 to 29 °C and 0.90 to 1.20 mg/m^3, respectively. The SST was medium (27 – 30 °C) in the year 2013 whereas it was increased to 30 – 31 °C during 2014. Likewise, the CC was high (0.945 – 1.193 mg/m^3) during the year 2016. However, in the recent year i.e. 2017, the chlorophyll level was decreased to 0.432 – 0.691 mg/m^3. The reported data on SST and CC suggests that the PFZ is changing every year probably due to climate changes and anthropogenic activities near coastal areas. In the year 2015, the PFZ was at Sippikulam and Vembar. Meanwhile, in 2016 the PFZ was close to Kayalpattinam, Tiruchendur, and Manapad. During the year 2017, the PFZ was entirely low. The PFZ mostly increase in the boundary line which force the fishermen to cross the territorial boundary to catch fishes. Global warming has also contributed to changes in SST. If the SST rises, the CC slightly decreases. Further, the present study can help the fishermen to enhance the fish catch and to reduce the search time by 30 to 70 %, and can also help to reduce fuel cost, manpower, fishing duration.

Acknowledgments

The research was conducted as part of the master programme in Remote Sensing at Anna University, Regional Campus, Tirunelveli. We thank three anonymous reviewers for their comments that have helped to substantially improve the paper.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

TPA and SK conceived the study and wrote the paper. TPA, RP and MS conducted image processing, classification, and other calculations under the supervision of MNS and SK. RP, MS and MNS revised the paper.

References

1 Padmanaban R & Sudalaimuthu K, Marine Fishery Information System and Aquaculture Site Selection Using Remote Sensing and GIS, *Int J Adv Remote Sens GIS*, 1 (1) (2012) 20-33.

2 FAO, FAO Fisheries and Aquaculture Department, Mangrove forest management guidelines, *FAO For Pap FAO Fish Aquac Dep Rome*, 2004.

3 Visalatchi A & Padmanaban R, Land use and land cover mapping and shore line changes studies in Tuticorin coastal area using remote sensing, *Int J Adv Earth Sci Eng*, 1 (1) (2012) pp. 12.

4 Ar I, Federation I, Cross R, *et al*., Risk Assessment of Indian Coastal Cities to Sea Level Rise A Development Planning Perspective, *Propos Risk Assesment Indian Coast cities to Sea-level Rise*, 2009.

5 Jayaprakash M, Senthil Kumar R, Giridharan L, Sujitha S B, Sarkar S K, *et al.*, Bioaccumulation of metals in fish species from water and sediments in macrotidal Ennore creek, Chennai, SE coast of India: A metropolitan city effect, *Ecotoxicol Environ Saf*, 120 (2015) 243-255.

6 Kathiresan K & Bingham B L, Biology of mangroves and mangrove Ecosystems, *Adv Mar Biol*, 40 (2001) 81-251.

7 Trenberth K E & Shea D J, Relationships between precipitation and surface temperature, *Geophys Res Lett*, 32 (14) (2005) 1-4.

8 Guidetti P, Bussotti S, Pizzolante F & Ciccolella A, Assessing the potential of an artisanal fishing co-management in the Marine Protected Area of Torre Guaceto (southern Adriatic Sea, SE Italy), *Fish Res*, 101 (3) (2010) 180-187.

9 Rajagopal T, Thangamani A, Sevarkodiyone S P, Sekar M & Archunan G, Zooplankton diversity and physico-chemical conditions in three perennial ponds of Virudhunagar district, Tamilnadu, *J Environ Biol*, 31 (3) (2010) 265-272.

10 Blaber S J M, Cyrus D P, Albaret J J, Ching C V, Day J W, *et al*., Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems, *ICES J Mar Sci*, 57 (2000) 590-602.

11 ISRO, Indian Space Research Organization, ISRO, Governement of India.

12 Minnett P J, Sea surface temperature, In: *Encyclopedia of Earth Sciences Series*, 2014, pp. 754-759.

13 McCarthy M P, Best M J & Betts R A, Climate change in cities due to global warming and urban effects, *Geophys Res Lett*, 37 (9) (2010) 5 pp.

14 O'Reilly J E, Maritorena S, Mitchell B G, Siegel D A, Kendall L, *et al*., Ocean color chlorophyll algorithms for SeaWiFS, *J Geophys Res Ocean*, 103 (C11) (1998) 24937-24953.

15 Rogers A D, The biology of Lophelia pertusa (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities, *Int Rev Hydrobiol*, 84 (4) (1999) 315-406.

16 Padmanaban R, Bhowmik A K, Cabral P, Zamyatin A, Almegdadi O, *et al.*, Modelling urban sprawl using remotely sensed data: A case study of Chennai city, Tamilnadu, *Entropy*, 19 (163) (2017) 14 pp.

17 Padmanaban R, Bhowmik A K & Cabral P, A remote sensing approach to environmental monitoring in a reclaimed mine area, *ISPRS Int J Geo-Information*, 6 (12) (2017) 14 pp.
18 Monishiya B G & Padmanaban R, Mapping and change detection analysis of marine resources in Tuicorin and Vembar group of Islands using remote sensing, *Int J Adv For Sci Manag*, 1 (1) (2012) 1-16.
19 Fakhruddin B, Mahalingam R & Padmanaban R, Sustainable development goals for reducing the impact of sea level rise on mangrove forests, *Indian J Geo-Mar Sci*, 47 (10) (2018) 1947-1958.
20 Padmanaban R, Karuppasamy S & Narayanan R, Assessment of pollutant level and forecasting water pollution of Chennai coastal, Tamil Nadu using R, *Indian J Geo-Mar Sci*, 47 (7) (2018) 1420-1429.
21 Meza Diaz B & Blackburn G A, Remote sensing of mangrove biophysical properties: evidence from a laboratory simulation of the possible effects of background variation on spectral vegetation indices, *Int J Remote Sen*s, 24 (01) (2003) 53-73.
22 Kerr A M, Baird A H, Bhalla R S & Srinivas V, Reply to Using remote sensing to assess the protective role of coastal woody vegetation against tsunami waves, *Int J Remote Sens*, 30 (14) (2009) 3817-3820.
23 Zhengming W, *MODIS Land-Surface Temperature*, China, 1999.
24 Padmanaban R & Kumar R, Mapping and Analysis of Marine Pollution in Tuticorin Coastal Area Using Remote Sensing and GIS, *Int J Adv Remote Sens GIS*, 1 (1) (2012) 34-48.
25 Center U Geological SERO & S. USGS, USGS, available online: http://earthexplorer.usgs.gov/.
26 Huang X, Zhang L & Wang L, Evaluation of morphological texture features for mangrove forest mapping and species discrimination using multispectral IKONOS imagery, *IEEE Geosci Remote Sens Lett*, 6 (3) (2009) 393-397.
27 Padmanaban R, Jerome J, Smitha A V, Dasgupta P & Painho M, Urban Agent Based Model of Urban Slum Dharavi, Mumbai, India, *J Earth Syst Sci Eng*, 2 (2017) 1110-1117.
28 ESRI, ArcGIS, November 2017.
29 Tugrul B, Polat H, Privacy-Preserving Inverse Distance Weighted Interpolation, *Arab J Sci Eng*, 39 (4) (2014) 2773-2781.
30 Mueller T G, Pusuluri N B, Mathias K K, Cornelius P L, Barnhisel R I, *et al.*, Map Quality for Ordinary Kriging and Inverse Distance Weighted Interpolation, *Soil Sci Soc Am J*, 68 (6) (2004) 2042-2047.