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ESTIMATING CHLOROPHYLL-A, CONCENTRATION USING SENTINEL-2 IMAGERY IN SELECTED LAKES OF KANYAKUMARI DISTRICT, TAMIL NADU, INDIA

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ABSTRACT

Water resources in India are very unpredictably distributed both spatially and temporally. Over the years, increasing population, urbanization and extension in agriculture and domestic water utilization has stressed the circumstances. Excessive algal growth due to eutrophication can have adverse effects on drinking water suppliers and end users. Monitoring of chlorophyll levels is the way to estimate the algal growth in water. Chlorophyll-a is one of the ecological indicators which is used to evaluate the status of the water bodies and its quality. Estimation of Chl-a had been carried out using in-situ data from Sentinel-2 imagery. For the present study, two lakes in Nagercoil districts - Parakkai Lake (P1, P2, and P3) and Therekal Lake (P4) were selected for the estimation of Chl-a using Sentinel-2 satellite imagery. Values of Chl-a concentration were estimated between 0.91-7.62 µg/L for P1, whereas the values of P2 0.98-5.59 µg/L and P3 the values range between 0.93-5.43 µg/L and Therekal lake (P4) is 0.97-7.01 µg/L. Use of recent techniques like remote sensing and GIS (Geographical Information System) is still limited. Though the conventional methods give accurate values of Chl-a, but these results are not very helpful in providing a complete status of the whole water body. Estimation of Chl-a in water using the remote sensing techniques in integration with GIS which is associated with conventional methods.

KEY WORDS : Algae, Image processing, Water quality, Remote sensing, GIS

INTRODUCTION

Water is a valuable natural resource essential to life forms survival, ecosystems health and its quality is a dominant factor to healthy life. Natural processes such as soil erosion and weathering; anthropogenic inputs such as industrial and municipal wastewater discharge largely determine surface water quality in a region (Kazi, 2009). Urbanization and industrialization have become major problem for disposal of sewage and waste water in cities and towns. The domestic sewage, factories effluents, and agriculture waste can lead to deterioration of surface water quality.

Under global change impacts, many surface and groundwater systems were contaminated by treated or untreated wastewater discharged with high nutrient contents which leads to cause high level of algae production in aquatic environments. Eutrophication is an ecological problem that results in visible cyanobacteria blooms that degrade the physical and chemical characteristics of water and shows an important action to control and maintain the freshwater reservoirs (Kubiak, 2016). Development and proliferation of algal blooms occurs mostly due the environmental factors which includes the available nutrients, temperature, sunlight and hydrology (river flow and water storage levels).

Algal blooms

Algae are microscopic plants occurs frequently in most of the lakes and are vital primary producers for both marine and fresh-water ecosystems. Algal blooms deplete oxygen in surface waters through excessive bacterial respiration and decomposition, while the presence of algae can cause discoloration in drinking water supplies (Sugiura *et al*., 1998). Harmful Algal Blooms (HABs), which contain toxin-producing species which is able to harm animals or humans, have increased in frequency and diversity worldwide (Sellner *et al*., 2003). Monitoring of bloom composition, frequency and intensity provides important indicators of water quality (Richardson, 1996).

Chlorophyll-a (Chl-a) is one of the ecological indicators which is used to evaluate the status of algal bloom in the water bodies and its quality. Monitoring of chlorophyll levels is the way to estimate the algal growth in water. The measuring of chlorophyll can be evaluated as an indicator of levels of nutrients. Currently, many lakes all over the world are suffering from frequent algae bloom. Their amount in surface water can be quantified by remote sensing, which overcomes the spatial and temporal limitations as well as the high costs of the conventional field-based water quality measurement (Torbick *et al.,* 2008). Monitoring and assessing the quality of surface waters are critical for managing and improving its quality.

Remote sensing

One major advantage of remote sensing observations over traditional measurements for water quality monitoring provides both spatial and temporal information of surface water characteristics (Lindell *et al*., 1999). Algorithm development for remote monitoring of water bodies such as shore waters, littoral zone waters, rivers, and lakes is difficult due to the complexity of the multilateral coastal zone designated by the complexity of biological and optical parameters that consist of spatial and temporal ecosystem dynamics. Remote sensing monitoring of algal blooms in lake water bodies has made great progress all over the world.

Currently, new satellites have signiûcantly improved and enhanced real-time monitoring and the fast detection of algae bloom. Jamadar, (2013) developed a framework (methodology comprising radiance value, wavelength ratio, band ratio, pixel rate, regression models) to monitor changes of the lake or reservoir and its surrounding environment using Multisensor satellite data - Landsat MSS, TM, ETM+, IRS LISS III and OCEANSAT-1 (IRS-P4) images. With a high spatial resolution (10-60 m) of Sentinel-2 MSI satellite image with improved spectral resolution from MODIS, the Chl-a and other water quality parameters can be effectively examined. To evaluate the Chlorophyll-a concentration in a tropical productive reservoir the OLI/Landsat-8 and MSI/Sentinel-2A sensors-based empirical algorithms were used for estimation.

Most remote sensing algorithms for Chl-a estimation in waters have been based on the principles of water absorption responding to algae pigments that match the content of Chl-a in the water, where a high content of Chl-a leads to an increase of water absorption at 443 nm and near 675 nm. In this study, S2A has two bands within the blue region, which are centered at 443 nm (band 1) and 490 nm (band 2); one band within the green region (band 3, centered at 560 nm); one band within the red region (band 4, centered at 665 nm) and five bands within NIR regions (bands 5, 6, 7, 8a, and 8, centered at 705 nm, 740 nm, 783 nm, 856 nm, and 842 nm, respectively). Consequently, all available band ratios commonly used for Chl-a estimation were evaluated in this study, including two green-blue band ratios (B3/B1 and B3/B2, respectively) one green-red band ratio (B3/B4), five NIR-red band ratios (B5/B4, B6/B4, B7/B4, B8a/B4, and B8/B4), and one three-band ratio ((B5 + B6)/B4). Therefore, innovative remote sensing methods for algae blooms monitoring and early prediction are proposed, which are definitely more accurate.

MATERIALS AND METHODS

Study area

Kanyakumari district is one of the 38 districts in Tamil Nadu and the southern most district in India. The district is located in between latitudes of 8º-03′ to 8º-35′ ºN and longitudes 77º-15′ to 77º-36, ºS. The district population 1,539,802 people lives in urban areas of which males are 761,407 and females are 778,395. Sex ratio in urban region of Kanyakumari district is 1022 as per 2011 census data which includes 8, 32, 269 males and 8, 43,765 females spreading in an area of 1672 km. Most of the inhabitants are using hand pumps water, and rest are using well water and municipality tap water for their domestic purpose (Subramanian, 2011).

Nearest city is Thiruvananthapuram (85 km), Kerala and the nearest town is Nagercoil, the administrative headquarters of Kanyakumari District. Nagercoil is the 12th largest town in south Indian state of Tamil Nadu. The district is surrounded by the ocean on 3 directions and the

Western Ghats bordering the northern side. In present study, selected Parakkai lake (P1, P2, P3) and Therekal lake (P4) located in Nagercoil. It lies between 8º 11′13.6" N and 77º 27′06.3" E for Therekal lake and 8º 08′ 42.8" E and 77º 27′15.0" N which lies in the Parakkai lake. The map of the study area is shown in Fig. 1.

Methodology

- **Delineation of Lake Boundary:** Sentinel-2 satellite imagery data is used to digitize the delineation of Lake Boundary using FCC (False Composite Color) image.
- **Image Pre-Processing:** Sentinel-2 satellite image is used for the present study to estimate the amount of chlorophyll-a. Sentinel-2 image carries an improved instrument radiometric digitization (12 bits) that is helpful for low-radiance aquatic environment applications. Spatial resolution is 10 m in four bands (Table 1) is used for the present study and the revisit period is 5 days when the Sentinel-2 operation system is in working order.

Pre-processing of Sentinel 2 satellite image, to convert Spectral bands to Top of Reflectance using Q GIS (3.4). The algorithm used for the Conversation of pixel to Top of Atmospheric reflectance is,

$$\rho\lambda=(M\ \rho * Q\ cal + A\rho)/\mathrm{Sin}(\varnothing) \quad .. (1)$$

Where $\rho\lambda$ = Top of atmospheric reflectance, $M\ \rho$ = band specific multiplication rescalar factor, $A\tilde{n}$ = band specific additive rescalar factor, Q_{cal} = digital number i.e., digital image, $\varnothing$ = sun angle of elevation.

Chlorophyll-a Estimation: Equation (2) is used to estimate the Chl-a value

$$\text{Chl.-a } \mu g/L = ((B5+B6)/B4) \quad .. (2)$$

Where B4 (red), B5 and B6 are the bands produced from the satellite image.

Work flow : The overall workflow of the study is revealed in the Fig. 2.

RESULTS AND DISCUSSION

According to the sentinel 2 imagery processing, the values of Chl-a concentration for February 2019

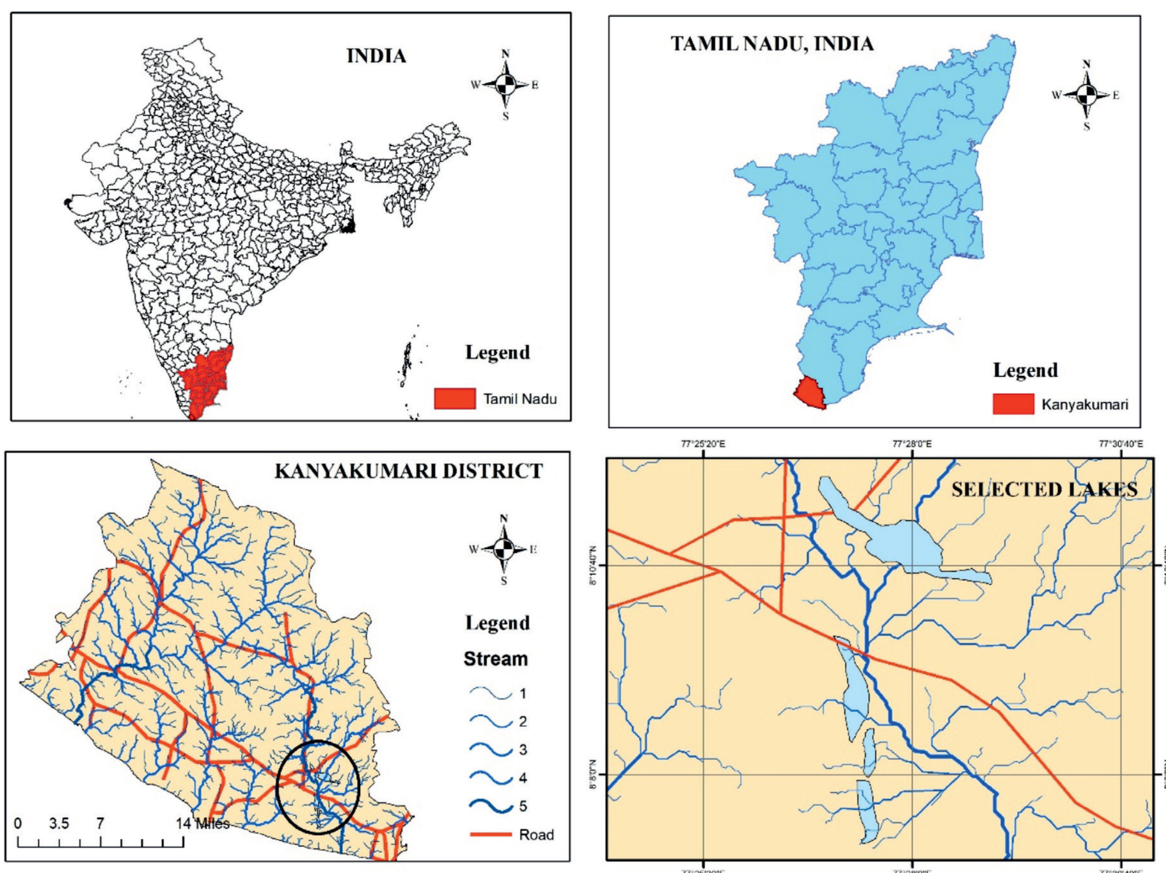

Fig. 1. Study area

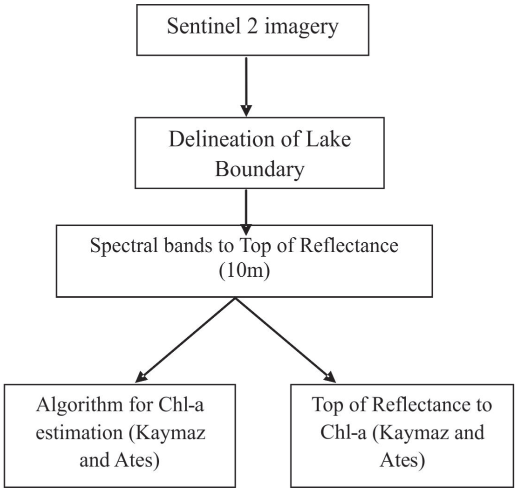

Fig. 2. Workflow of the study

were estimated and the cause for variation in chlorophyll distribution in ground was viewed for human settlements, agricultural lands, waste discharge etc., using Google Earth. Values of Chl-a concentration were estimated between 0.91-7.62 µg/L for P1. In the segment of P1 the level of Chl-a were seen in the Northern part and middle region of the lake Fig 3(a) and 4(b). Due to the presence of agricultural activities and in certain areas human settlements were seen in and around the lake which causes water contamination in the lake. In the segment of P2 the values of Chl-a concentration were estimated between 0.98-5.59 µg/L, the level is seen in the boundary of the lake Fig. 4(a) and 4(b). The activity of agricultural and its waste discharge which leads to the flow of nutrients increases the nutrient load in the water that increases the presence of Chl-a in the water of the lake.

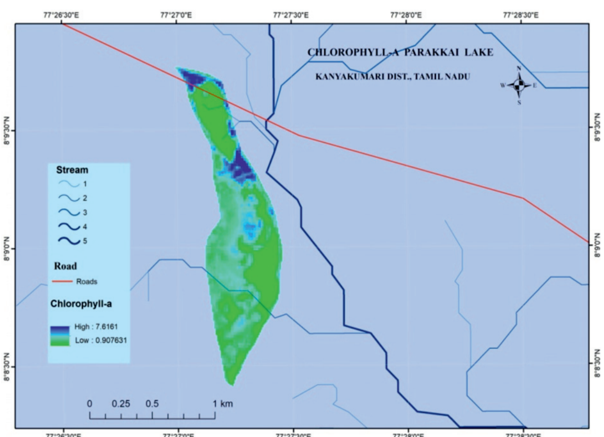

Fig. 3(a). Estimation of Chl-a in (P1)

Fig. 3(b). Estimation of Chl-a in (P1)

Table 1. The band, resolution wavelength and central wavelength of Sentinel-2 satellite image

Band	Resolution (m)	Wavelength (nm)	Central Wavelength (nm)
1	60	412-456	442.7
2	10	439-533	492.4
3	10	538- 583	559.8
4	10	646-684	664.6
5	20	695-714	704.1
6	20	731-749	740.5
7	20	769-797	782.8
8	10	760-907	832.8
9	60	932-958	945.1
10	60	1337-1412	1373.5
11	20	1539-1682	1613.7
12	20	2078-2320	2204.4

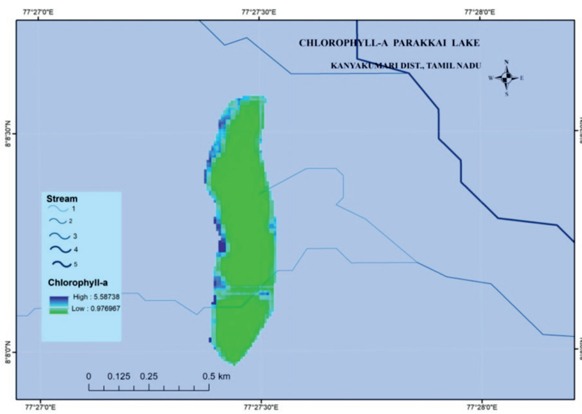

Fig. 4(a). Estimation of Chl-a in (P2)

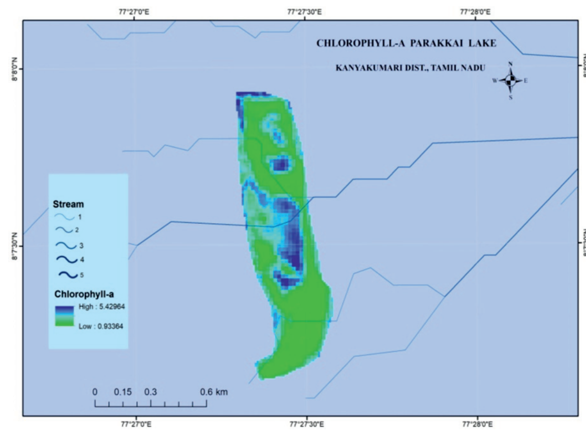

Fig. 5(a). Estimation of Chl-a in (P3)

Fig. 4(b). Estimation of Chl-a in (P2)

Fig. 5(b). Estimation of Chl-a in (P4)

The values of Chl-a concentration of P3 were estimated between 0.93-5.43 μg/L, the level of Chl-a in the segment of P3 is high in the boundary region and middle of the lake. In this segment the presence of Chl-a were occurred due to the presence of agricultural lands in and around the lake region Fig 5(a) and 5(b). In the segment of P4 the values of Chl-a concentration were estimated between 0.97-7.01 μg/L and the level is higher in the boundary when compared to the middle region of the lake Fig. 6(a) and 6(b). The presence of Chl-a were seen throughout the boundary area due to the presence of agricultural land and human activities and its waste discharge which leads to the water pollution in the lake. When compared to P1, P2, and P3 segments P4 segment shows the maximum level of Chl-a due to the increase impact of human activity on the environment, agricultural activities discharges leads to the contamination of water in the lake. The above-mentioned activities lead to water contamination which in turn leads to the increase of algal blooms that reveals the status of water quality.

The graphical representation of lake segment P1, P2, P3 and P4 were shown in Fig 7 (a, b, c and d). In

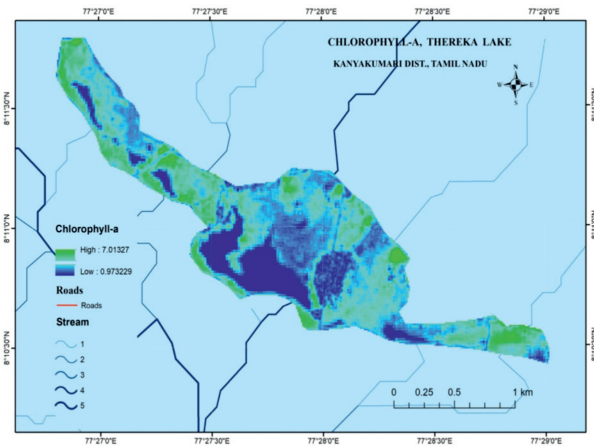

Fig. 6(a). Estimation of Chl-a in (P3)

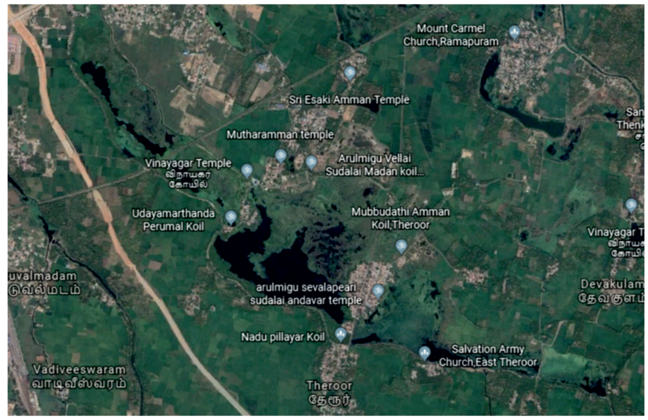

Fig. 6(b). Estimation of Chl- a in (P4)

P1 segment the presence of Chl-a gradually increases when compared to P2 segment of the lake which is represented in the graph in the form of peaks. Whereas P4 segment shows presence of high amount of Chl-a when compared to P3 segment. Among all four segments P4 segment has the high amount of Chl-a content in the water of the lake.

Algae are an important component of biological monitoring programs for evaluating water quality. They are used for assessing the degree of pollution in different water bodies. Monitoring chlorophyll levels is a direct way of tracking algal growth.

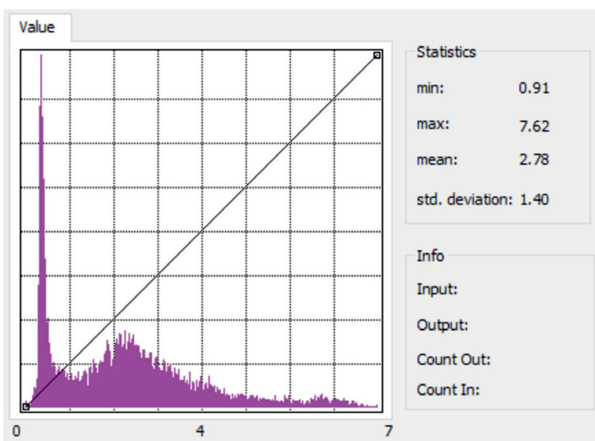

Fig.7 (a) Representation of (P1)

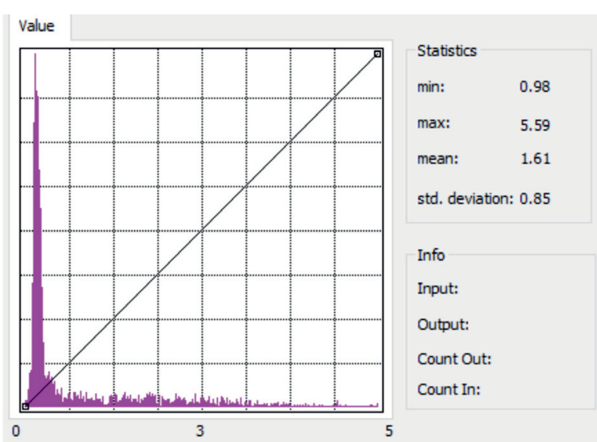

Fig.7 (b) Representation of (P2)

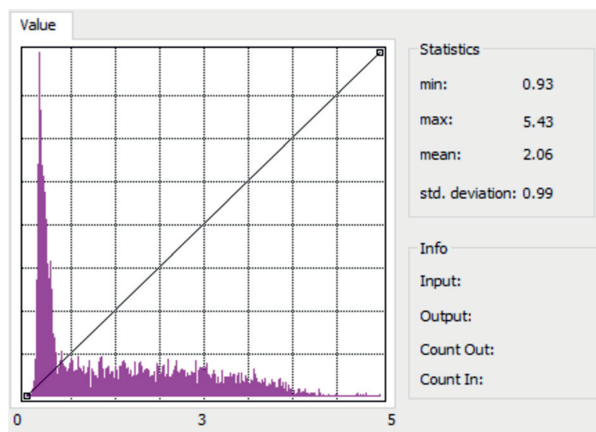

Fig. 7(c). Representation of (P3)

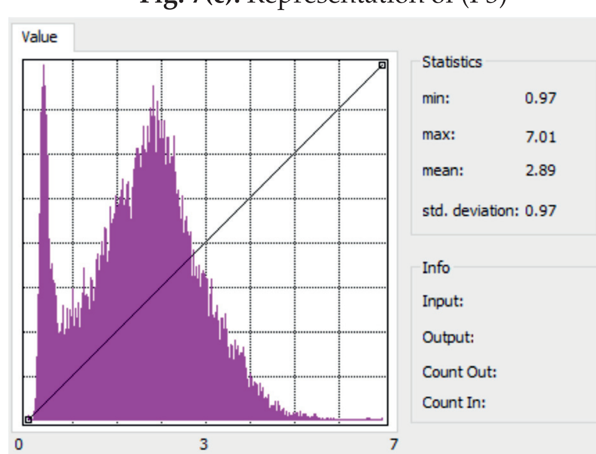

Fig. 7 (d). Representation of (P4)

Surface waters that have high chlorophyll content are typically high in nutrients. These nutrients cause the algae to grow or bloom. High levels of algae blooms can be an indicator of pollution from man-made sources, such as septic system leakage, poorly functioning wastewater treatment plants, or fertilizer runoff. So that, Chl-a measurement can be utilized as an indirect indicator of nutrient levels. From this study, concluded that the monitoring programs using remote sensing and GIS are needed to threats all contamination occurs and provides the effective action at all levels. Remote sensing can be used to generate water quality maps of algae blooms that enable drinking water managers to quickly assess water quality and allow for better monitoring of water quality status. Hence, the lake should be protected from the contaminations occurred by the man-made sources.

CONCLUSION

Algae are used for assessing the degree of pollution or as indicator of water pollution of different water bodies.

Using improved spectral and spatial resolution sensors and geospatial modelling techniques, water quality parameters such as chlorophyll-a, algae bloom and turbidity in water bodies are being monitored at low cost and with greater accuracy. Traditional methods for monitoring water quality consist of field sample collection; laboratory analysis and identification of phytoplankton are time consuming, expensive unless a special sampling method is used. In addition, predicting the location and timing of algal blooms using traditional field sampling methods is extremely difficult. So, recent advancements in the field of remote sensing and GIS have made it possible to conduct large scale water monitoring studies mainly in estimating the algal blooms in surface water of lake reservoir, oceans etc., Satellite images are increasingly common in all kinds of applications on environmental monitoring, however, they are still expensive and difficult to access.

The innovation of remote-sensing monitoring technology lies in providing a more accurate, flexible, cheaper, and faster monitoring method of detecting and predicting eutrophication. Algorithms developed for remote satellite monitoring of algae blooms in sea water are well described but are not accurate for inland waters such as shore waters, littoral zone waters, rivers, reservoirs and lakes. The developed algorithms can provide a new compressive analysis of water quality parameters and in order to monitor algae bloom and produce data for an early warning system application. The presence and growth rate of this algal bloom community could be used as supporting information for early warning systems about the toxic bloom.

REFERENCES

Jamadar, B. and Purandara, B. 2013. Review on Study of Lake Water Using Multi Sensor Remote Sensing Data. *IOSR Journal of Mechanical and Civil Engineering.* 6 (5) : 50-52.

Kazi, T. G., Arain, M. B., Jamali, M. K., Jalbani, N., Afridi, H. I., Sarfraz, R. A., Baig, J.A. and Shah, A.Q. 2009. Assessment of water quality of polluted lake using multi variate statistical techniques: a case study, *Ecotoxicology and Environmental Safety*. 72 : 301-309.

Kubiak, K.A., Kotlarz, J. and Mazur, A.M. 2016. Monitoring Cyanobacteria Blooms in Freshwater Lakes using Remote Sensing Methods. *Journal of Environmental Studies*. 25 (1) : 27-35.

Lindell, T., Pierson, D., Premazzi, G. and Zilioli, E. 1999. *Manual for Monitoring European Lakes Using Remote Sensing Techniques*, (EUR 18665 EN, Ofcial Publications of the European Communities, Luxembourg. 161.

Richardson, L. 1996. Remote Sensing of Algal Bloom Dynamics. *Bio Science*. 46 (7) : 492-501.

Sugiura, N., Iwami, N., Inamori, Y., Nishimura, O. and Sudo, R. 1998. Significance of attached cyanobacteria relevant to the occurrence of musty odor in Lake Kasumigaura. *Water Research*. 32 (12) : 3549-3554.

Sellner, K.G., Doucette, G.J. and Kirkpatrick, G.J. 2003. Harmful algal blooms: causes, impacts and detection. *Journal of Industrial Microbiology and Biotechnology*. 30 : 383-406.

Subramanian, A. 2011. Ground Water Quality Assessment of Nagercoil Town (Hand Pumps) *Journal of Environment and Earth Science*. 1 (1) : 1-6.

Torbicketal, N. 2008. Mapping chlorophyll-a concentrations in West Lake, China using Landsat 7 ETM+. *J. Great Lakes Res*. 34 (3) : 559-565.

Thi Thu Ha, N. Phuong Thao N. T. Koike, K. and Nhuan, M.Y. 2017. Selecting the Best Band Ratio to Estimate Chlorophyll-a Concentration in a Tropical Freshwater Lake Using Sentinel 2A Images from a Case Study of Lake Ba Be (Northern Vietnam). *ISPRS Int. J. Geo-Inf*. 6 (290) : 1-15.