Chapter

Application of Remote Sensing in Natural Sciences

Ehsan Atazadeh and Mostafa Mahdavifard

Abstract

Generally, the term biomass is used for all materials originating from photosynthesis. However, biomass can equally apply to animals. Conservation and management of biomass is very important. There are various ways and methods for biomass evaluation. One of these methods is remote sensing. Remote sensing provides information about biomass, but also about biodiversity and environmental factors estimation over a wide area. The great potential of remote sensing has received considerable attention over the last few decades in many different areas in biological sciences including nutrient status assessment, weed abundance, deforestation, glacial features in Arctic and Antarctic regions, depth sounding of coastal and ocean depths, and density mapping.

Keywords: biomass, RS, GIS, chlorophyll-a

1. Introduction

A natural resource is any kind of energy or substance that is necessary to meet the physiological, social, economic and cultural needs of humanity and to maintain all the various activities that lead to production. Natural resources such as solar energy, forests, crops, fisheries, etc. are renewable, and such as oil, coal, natural gas, etc. are not renewable (Rao). National development requires a comprehensive approach to natural resource management. Sustainable natural resource management requires long-term oversight. Periodic evaluation and monitoring of natural resources enables policymakers to be vigilant in the optimal use of resources and the development process to act promptly [1–3]. In recent years, remote sensing data has been widely used in various fields of natural resource management as it is one of the best data sources for large-scale applications [4]. In general, remote sensing is "the measurement or acquisition of information about the properties of an object or phenomenon by a recording device (sensor: satellite or aircraft) that is not studied in physical or direct contact with the phenomenon" [5]. Integrated use of remote sensing data, GPS and GIS enables consultants, natural resource managers and researchers in government agencies, conservation organizations and industry to develop management plans for a variety of natural resource management programs [6]. When natural resources are identified using remote sensing data, sampling strategies are also used to collect and evaluate field observations of the variables at the selected locations [7]. Remote sensing is a powerful tool for studying land cover, forest management, water quality parameters, etc. in remote locations. Among the studies using modern remote sensing technology to estimate the concentration of chlorophyll-A (phytoplankton pigment) in the coastal areas of Iran [8] and also in Vietnam has been used to identify and estimate the upper biodiversity of mangrove forests. In the next section, we discuss some of the applications of remote sensing in marine ecosystem management.

2. Remote sensing applications in marine ecosystems

Sea Surface temperature: Most industries use seawater as cooling water. When the water used as a coolant returns to the natural environment at a higher temperature, temperature changes reduce oxygen and affect the marine ecosystem [9]. SST information is needed in remote sensing assessment for fisheries applications [10]. Satellite SST observations help to understand regional diversity and global climate change, and allow the visualization of a wide range of ocean zones. In 1981, SST satellite infrared observations began with the launch of the AVHRR sensor on the NOAA 7 satellite, so that there are now three decades of SST satellite data [11].

Coral reef: Coral reefs are formed by living coral polyps and calcareous algae that grow at sea levels between 77 and 86 degrees Fahrenheit with normal salinity. Coral reefs act as feeding, reproductive, breeding, and aquatic habitats for many oceanic organisms, so the density and distribution of corals alter the populations of fish and other organisms [12]. The advantages of remote sensing systems in this area are the ability to survey the area on a large scale, continuous monitoring and the ability to check the system ecosystem in remote areas without direct contact

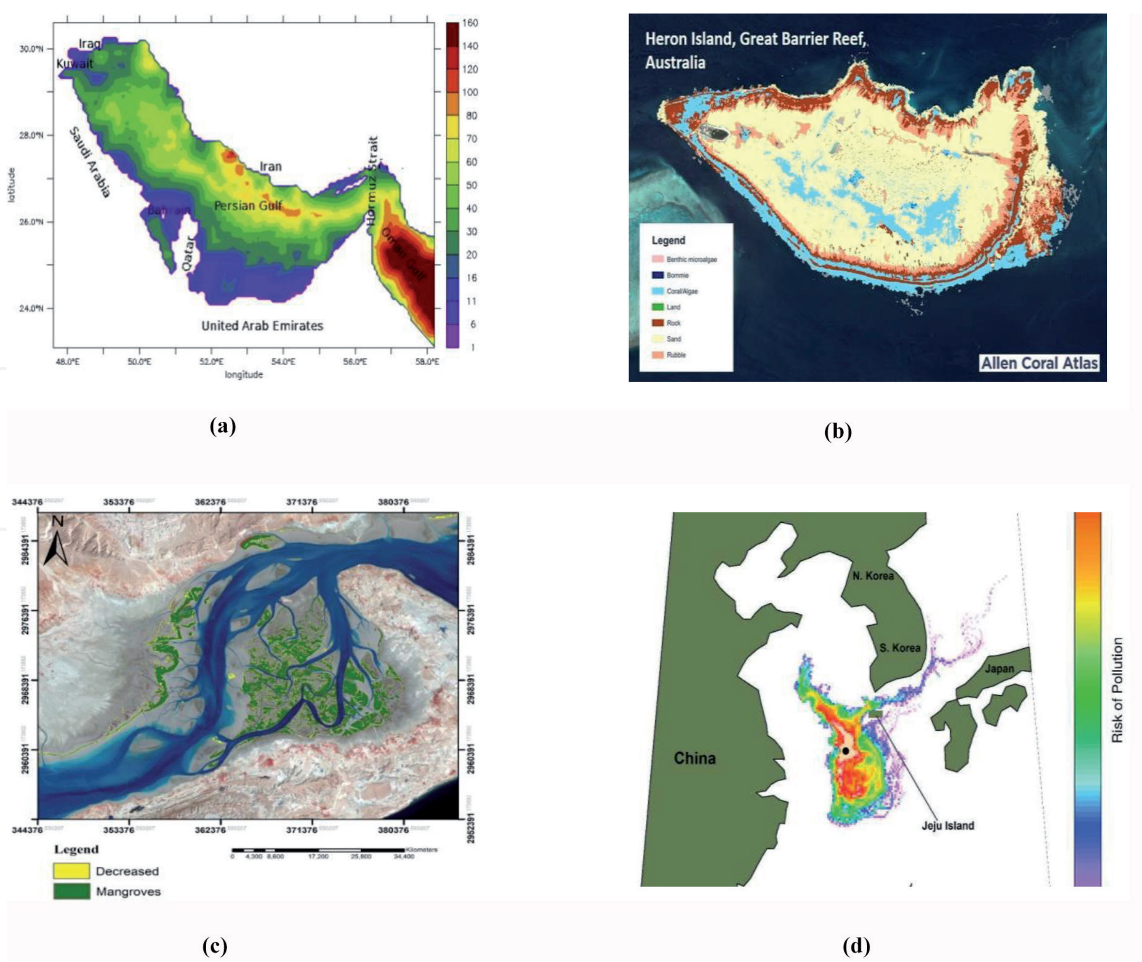

Figure 1.
Application of remote sensing: a) SST, b) coral reef, C) mangrove forest D) oil spill.

with it. Among these, optical Remote sensing systems including multispectral and hyperspectral sensors have been most used in this field [13, 14].

Mangrove forest: Mangrove forests are tropical and subtropical ecosystems that grow on the margins of two different environments, sea and land [15–17]. These forests play an essential role in ecology and are considered as carbon reserves [18–20]. Due to their location in the tropics, they are prone to hiding under clouds, so a reliable monitoring tool is essential to measure deforestation. Radar remote sensing has been shown to be useful in distinguishing mangrove cover from other ground cover due to its long wavelengths that can penetrate the cloud [21].

Ocean Color: The color of the ocean is a unique property for water. Mapping and understanding ocean color changes can help monitor water quality and identify natural and human contaminants (oil slicks and algae blooms) that are dangerous to aquaculture and even to humans [8]. Remote sensing optical data can detect targets such as suspended sediments, algal blooms, chlorophyll-A, and oil slicks at various scales [21]. In the next section, which is research-oriented, we want to examine the application of remote sensing in estimating the concentration of chlorophyll- a phytoplankton in coastal waters (**Figure 1**).

3. Materials and methods

3.1 Case study

The current research, which is the result of the authors' efforts, has been conducted on the Tiab estuary. Tiab estuary in Hormozgan province - Iran is one of the estuaries of Sirik and Kolahy basin which is located in latitudes of 27 degrees and 8 minutes and longitude of 56 degrees and 44 minutes (**Figure 1**). The climatic conditions of this region are tropical to subtropical and its climate is hot and humid. The temperature in this region reaches 45 degrees Celsius in summer. The average annual rainfall in this region is about 100 to 300 mm between November and April. Most of the vegetation of this area includes pure communities of mangroves (Avicenina marina) which is located at the mouth of the estuary and the edges of tidal waterways (**Figure 2**) [22].

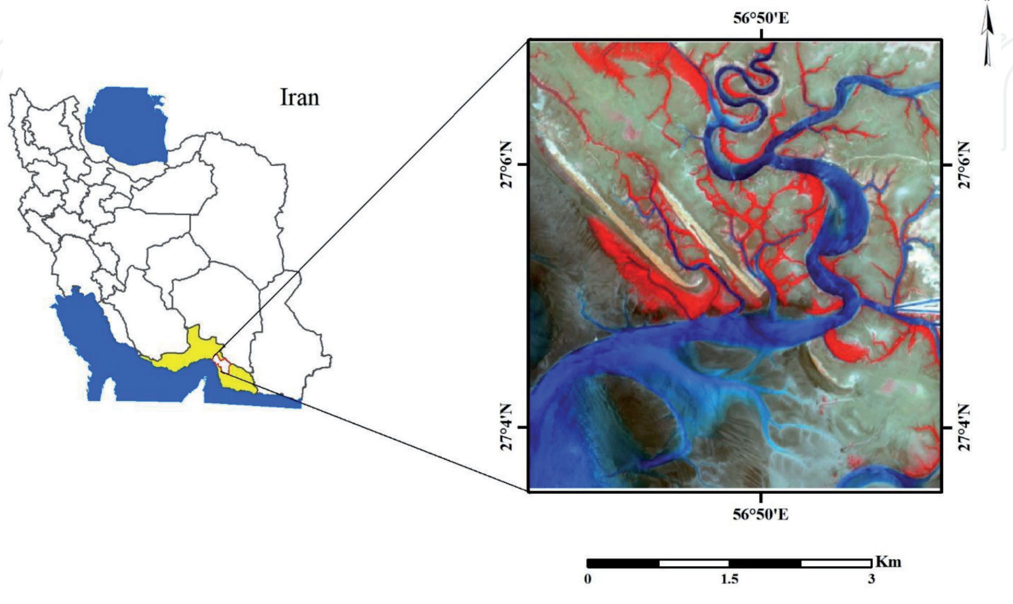

Figure 2.
Location of the study area.

3.2 Data collection

3.2.1 In-situ data

To collect field data from the study area for calibration with remote sensing data, field measurements were performed on April 7, 2019, at the same time as the Landsat-8 satellite passed the study area at 6:37 UTC. On the day of sampling, the sea level was at the highest water level and without wave turbulence. For this purpose, immediately after collecting the water sample using special bottles, the location of each station was determined using a GPS device. A total of 10 stations were located and sampled. The sampling started from the area between the entrance of the estuary and ended at the exit of the estuary leading to the high seas and lasted about 1 hour. **Figure 3** shows the field operation. In the laboratory, water samples were transferred to tubes containing 10 ml of ethanol and then centrifuged at 2500 rpm for 5 minutes and decomposed in the absorption range of 664 and 665 nm using a spectrophotometer. Finally, the field chlorophyll of each station was calculated using Eq. 1.

$$\mathrm{Chla}_{\left(mg/\mathrm{m}^3\right)} = \frac{26.7 \times \left(664_{\mathrm{b}} - 665_{\mathrm{a}}\right) \times \mathrm{V}_{ext}}{\mathrm{V}_{sam} \times \mathrm{L}} \tag{1}$$

Where 665a and 664b, respectively, before and after acidification of the samples in the spectral range, Vext amount of extraction per liter unit, Vsam amount of sample per cubic meter, L light path of the sample tube per unit centimeter and Chla chlorophyll concentration per mg unit Cubic meters.

3.2.2 Remote sensing data

In this study, Landsat-8 satellite images were used to estimate chlorophyll-A concentration. Landsat-8 is one of the newest multispectral satellites launched on February 11, 2013 to monitor natural resources. This satellite has a spatial resolution of 30 meters, 11 Multispectral bands (in the range: visible, reflective infrared and thermal infrared) and its review period from Earth is 16 days. **Table 1** shows the details of Landsat-8 time series data for estimating chlorophyll-A concentration are presented.

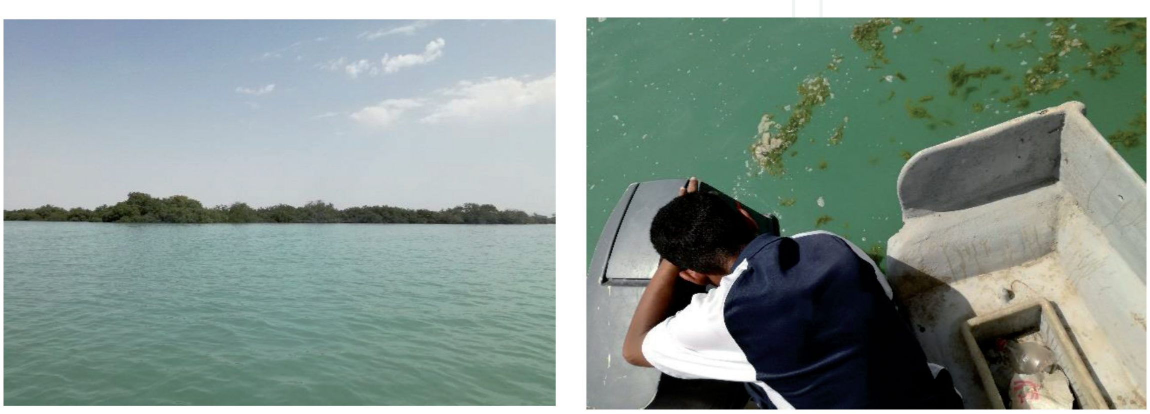

Figure 3.
Field operations in the study area.

ID-Landsat-8	Flight time	Date
LC08_L1TP_159041_20190407_20190407_01_RT.tar	6:39 (UTC)	2019/4/7
LC08_L1TP_159041_20190728_20190801_01_T1.tar		2019/7/28
LC08_L1TP_159041_20191117_20191202_01_T1.tar		2019/11/17

Table 1.
Specifications of time series data used.

3.3 Modeling of chlorophyll-A concentration

Bio-optical algorithms OC2 and OC3 were used to extract chlorophyll-A concentration from Landsat-8 data. This bio-optical model is based on nonlinear relationships between ocean reflection reflectance and field data that actually link optical measurements of reflection to qualitative parameters such as chlorophyll concentration and range-of-coastal, blue, and green weather to estimate chlorophyll concentration. Uses the following equations to calculate.

$$C = 10^{(a0+a1*R+a2*R2+a3*R3)}$$

$$R = \log\left(Rrs\,Blue \,/\, Rrs\,Green\right) \tag{2}$$

$$C = 10^{(a0+a1*R+a2*R2+a3*R3)}$$

$$R = \log\left(Rrs\,490 \,/\, Rrs\,555\right) \tag{3}$$

Where **a** are coefficients that are estimated and modeled through the relationship between field data and remote sensing. **Rrs** is a measure of distance at blue and green wavelengths, **R** is the band ratio and **C** is the concentration of chlorophyll-A in milligrams per cubic meter.

4. Results and analysis

4.1 Field measurement

The results of field sample analysis showed that the lowest concentration of chlorophyll-A was in station number 9 with 0.11 mg/m^3 and the highest level was in station number 6 with 6 mg/m^3 (due to severe algae) and in the rest of the stations. Chlorophyll content is below 1 mg/m^3. The diagram below shows the trend of chlorophyll-A changes in the stations (**Figure 4**).

4.2 Chlorophyll-A validation received from satellites with field data

The results of chlorophyll-A evaluation show that the use of OC2 bio-optical algorithm to estimate chlorophyll-A concentration using Landsat-8 data has acceptable results and has a high correlation with field data. **Table 2** shows the result of statistical parameters shows the correlation between field data and chlorophyll derived from Landsat-8 data.

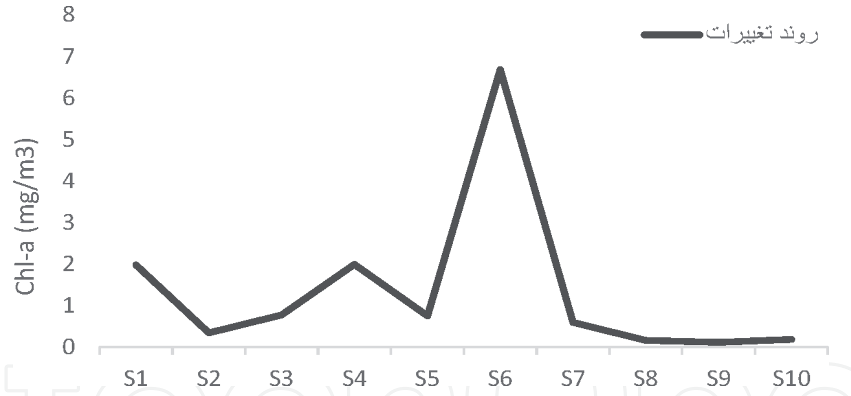

Figure 4.
The trend of field chlorophyll changes.

Algorithm	R^2	RMSE	a_x
OC2	0.91	0.13	−0.20094
			−1.3018
			0.52631
			1.4235
OC3	0.88	0.16	−0.22314
			−1.3116
			0.70002
			1.4329
			−0.16545

Table 2.
Results of RMSE, R2 and Landsat-8 modeled coefficients with field data.

4.3 Seasonal estimation of chlorophyll-A concentration with Landsat-8

After obtaining the appropriate results from the OC2 algorithm in Landsat-8 Remote Sensing data using Eq. (2) and the modeled coefficients presented in the table above, a chlorophyll-A concentration map was prepared in the seasons of 2019. The chlorophyll-A concentration estimation map is shown in **Figure 5**.

$$C = 10^{(a0+a1*R+a2*R2+a3*R3)}$$

$$R = \log\left(Rrs\,490 / Rrs\,555\right) \quad (4)$$

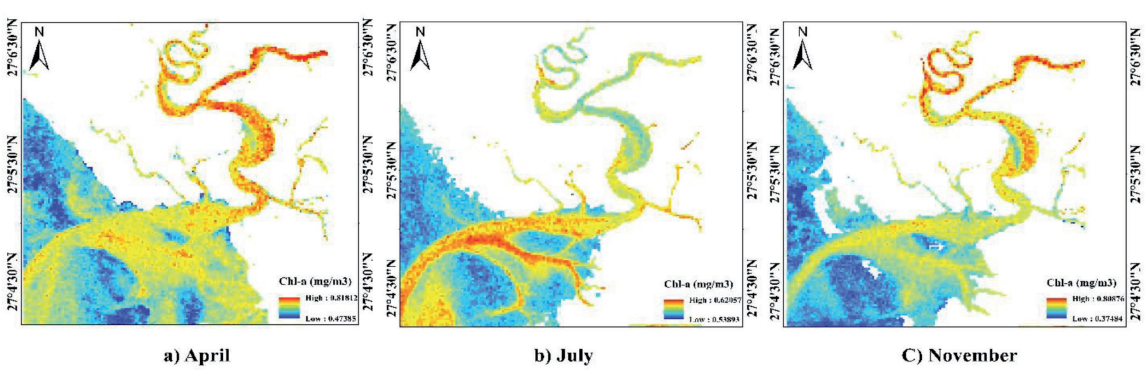

Figure 5.
Time series map of chlorophyll-A concentration in Tiab estuary prepared from Landsat-8 images [22].

The coefficients a0, a1, a2, a3, a4 were determined for Landsat OC2 algorithm −0.20094, −1.3018, 0.52631 and 1.4235, Rrs is the reflection of distance measurement at blue and green wavelengths, R is the band ratio and C, chlorophyll-A concentration to The unit is milligrams per cubic meter.

5. Discussion and conclusion

In this study, the potential of remote sensing data for modeling and estimating the time series of chlorophyll-A concentration with field data for the coastal region of Khor Tiab was evaluated.Coastal Aerosol, Blue and green band-based bio-optical models (OC2 and OC3) were applied to Landsat-8 satellite multispectral data to estimate chlorophyll-A concentrations in the coastal area. The results of this study show that OC2 and OC3 bio-optical models have a high correlation with field data sampled from the coastal waters of Tiab estuary so that the statistical parameter values R2 and RMSE in the OC2 model with field data were equal to 0.91 and 0.13, respectively. While the results of statistical parameter R2 and RMSE in the OC3 model were evaluated with field data with a slight difference of 0.88 and 0.16, respectively. Due to the good performance of the OC2 algorithm compared to the OC3 algorithm with field data, this algorithm was selected and used to estimate the time series of chlorophyll-A concentration in the Tiab estuary. As the time series map shows, the concentration of chlorophyll-A in April and November compared to July has a relatively high concentration of chlorophyll that follows the natural conditions, which is due to the fact that in April and November the sea temperature is low and cold. This has increased the concentration of chlorophyll-A in the region, while the concentration of chlorophyll-A has decreased significantly in July because the sea temperature is high this month and is completely correlated with natural conditions. In fact, there is an inverse relationship between chlorophyll-A concentration and sea surface temperature, which fully illustrates the Remote Sensing data used in this study. The end result of this study indicates that remote sensing data is a much better alternative to field operations due to its cost and time consuming nature. Finally, the participants of this study are suggested to use more field data to calibrate the Remote Sensing data in order to estimate the chlorophyll-A concentration in order to obtain better results.

Author details

Ehsan Atazadeh* and Mostafa Mahdavifard
University of Tabriz Tabriz, Iran

*Address all correspondence to: islam.atazadeh@gmail.com

References

[1] Gaur M, Pandey CB, Goyal RK. Remote Sensing for Natural Resources Management & Monitoring. Scientific Publishers; 2016

[2] http://www.felixstowedocker.com/2018/01/sanchis-sinking-raises-fears-of.html

[3] https://www.rsrc.org.au/news/2018/10/31/unprecedented-global-image-of-coral-reefs-from-allen-coral-atlas-released

[4] Kumar N, Yamaç SS, Velmurugan A. Applications of remote sensing and GIS in natural resource management. Andaman Science Association. 2015;**20**(1):1-6

[5] Colwell RN, editor. Manual of Remote Sensing, 2nd. Ed. Falls Church: ASP&RS; 1983

[6] Philipson P, Lindell T. Can coral reefs be monitored from space? Ambio. 2003;**32**:586-593

[7] Wang G, Weng Q, editors. Remote Sensing of Natural Resources. CRC Press; 2013

[8] Mahdavifard M, Valizadeh Kamran K, Atazadeh E. Estimation of chlorophyll-a concentration using ground data and Sentinel-2 and Landsat-8 satellite images processing (case study: Tiab estuary). Journal of RS and GIS for natural. Resources. 2020;**11**(1):72-83

[9] Cahyono, A. B., Saptarini, D. I. A. N., Pribadi, C. B., & Armono, H. D. (2017). Estimation of Sea Surface Temperature (SST) Using Split Window Methods for Monitoring Industrial Activity in Coastal Area. In Applied Mechanics and Materials (Vol. 862, pp. 90-95). Trans Tech Publications Ltd.

[10] Nontji, A. (1993). Laut Nusantara Penerbit Djambatan.

[11] Martin S. An Introduction to Ocean Remote Sensing. Cambridge University Press; 2014

[12] Nybakken, J. W., & Bertness, M. D. (2001). Marine Biology: An Ecological Approach 5th Edition.

[13] Andréfouët S, Kramer P. Multi-site evaluation of IKONOS data for classification of tropical coral reef environments. Remote Sensing of Environment. 2003;**88**:128-143

[14] Mumby, P.; Green, E.; Edwards, A.; Clark, C., 1997. Coral reef habitat mapping: How much detail can remote sensing provide? Marine Biology, 130: 193202.

[15] Rao, P. N. Applications of Remote Sensing and Geographical Indication System in Land Resources Management.

[16] Rezaei-Latifi A, Hosseinibalam F. An estimate of the surface heat fluxes transfer of the Persian Gulf with the overlying atmosphere. Journal of Radiation Research and Applied Sciences. 2015;*8*(3):354-361

[17] Saleh M. Assessment of mangrove vegetation on Abu Minqar Island of the red sea. Arid Envirmental. 2007;**68**:331-336

[18] Kathiresan K, Bingham BL. Biology of mangroves and mangroves ecosystems. Advances in Marine Biology. 2001;**40**:81-251

[19] Toosi NB, Soffianian AR, Fakheran S, Pourmanafi S, Ginzler C, Waser LT. Comparing different classification algorithms for monitoring mangrove cover changes in southern Iran. Global Ecology and Conservation. 2019;**19**:e00662

[20] Valiela I, Bowen JL, York JK. Mangrove forests: One of the world's

threatened major tropical environments. Bioscience. 2001;**51**:807-815

[21] CCRS, C. f. RS, (2014). Tutorial: Fundamentals of Remote Sensing.

[22] Mahdavifard M. Estimate of Chlorophyll-a Concentration Using In-Situ and Satellite Image Processing Approach: Estuary of Tiab. University of Tabriz: Master's thesis; 2020