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Index-based mapping of floating algae blooms observed on Lake Iznik using Landsat-8 imagery

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Abstract

As one of the most important members of the freshwater ecosystem, lakes have been under pressure in recent years, mainly due to climate change, population growth and anthropogenic activities, which adversely affect water quality and cause several environmental disasters such as harmful algal blooms. Remote sensing technologies have been widely used for their advantages in monitoring rapid changes in freshwater resources at global and local scales. The main goal of this study is to detect and map the dense floating algae formations observed in Lake Iznik, the largest freshwater source of the Marmara region, in 2022. For this purpose, Automatic Mucilage Extraction Index (AMEI), initially proposed for mucilage detection, and the well-known Normalized Difference Water Index (NDWI) were utilized, and their performances were compared in mapping algal formations using the Landsat-8 image. The results showed that the floating algae formations covered 12.1% (about 36.35 km^2) of Lake Iznik on June 5, 2022. In addition, the high-density algal formations were detected with 99% accuracy, while high- and low-algae formations were detected with 77% accuracy in the AMEI index map produced with appropriate threshold values. As a result, it can be concluded that the AMEI, initially formulated by considering the spectral bands of Sentinel-2, can be easily adapted to Landsat imagery to extract floating algal blooms.

1. Introduction

Lakes are one of the most important members of the inland water ecosystem, playing an essential role in many aspects, such as agricultural activities, biodiversity, and meeting drinking water needs. Pressure on freshwater resources has increased in recent years due to rapid global climate change and impacts from anthropogenic activities, resulting in a significant decline in the surface water quality of the aquatic environment. Pressure on the aquatic environment leads to significant changes in the physicochemical parameters of lakes, resulting in significant environmental problems such as harmful algal blooms (Moss et al. 2011; Zhang et al. 2023).

Remotely sensed images are the most important data source for monitoring water resources and detecting changes over time. Recently, considerable literature has grown around the monitoring and mapping of floating algae formations observed on inland waters using remotely sensed imagery at different spatial and spectral resolutions (Sun et al. 2022; Laneve et al. 2022; Rodríguez-López et al. 2023).

Water indices have been widely used in mapping algae formation using satellite datasets. For example, the Floating Algae Index (FAI) was applied by Hu (2009) to detect floating algae in the open ocean using the Moderate Resolution Imaging Spectroradiometer (MODIS) imagery. Furthermore, Rodríguez-López et al. (2023) investigated Chlorophyll-a concentration in Andean Lake using the FAI and surface algal bloom index (SABI) calculated from multitemporal Landsat imagery. More recently, Colkesen et al. (2023) introduced and applied an Automatic Mucilage Extraction Index (AMEI) for mapping massive mucilage formations observed on the Sea of Marmara using Sentinel-2 imagery.

In this study, the performance of the mucilage-specific AMEI index in mapping floating algal blooms observed intensively in Lake Iznik in June 2022 was analyzed, and its performance was compared with the Normalized Difference Water Index (NDWI), which is commonly used in algae detection. A Landsat-8 satellite image captured on June 5, 2022 was used as the primary

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data source in the application, and the results were compared thoroughly.

2. Material and Methods

2.1. Study area and dataset

Lake Iznik, also known as Lake Nicaea, is a freshwater lake located in the Bursa Province of Turkey (Fig 1.) It is characterized by specific physicochemical properties that play a crucial role in its ecosystem dynamics. Oktem et al. (2012) stated that rapid population growth, regional urbanization, and agricultural activities in the basin negatively impact the lake's ecosystem. It was also underlined that the lake shows a eutrophic characteristic due to the large amounts of nitrogen and phosphorus returned to the lake. Yağcı and Ustaoğlu (2012) highlighted that the lake has a mesotrophic-eutrophic character regarding zooplankton and is extremely sensitive to eutrophication. Derin et al. (2013) underlined that the lake has switched from mesotrophic to eutrophic in the past thirty years.

In this study, the Landsat-8 (Collection 2 level-2) image captured on June 5, 2022 was the primary data source for mapping floating algae formations. Seven bands of Landsat-8 at 30 m spatial resolution, consisting of coastal aerosol, blue, green, red, near-infrared (NIR), shortwave infrared-1 (SWIR-1), and shortwave infrared-2 (SWIR-2), were used for index-based extraction of algal formations.

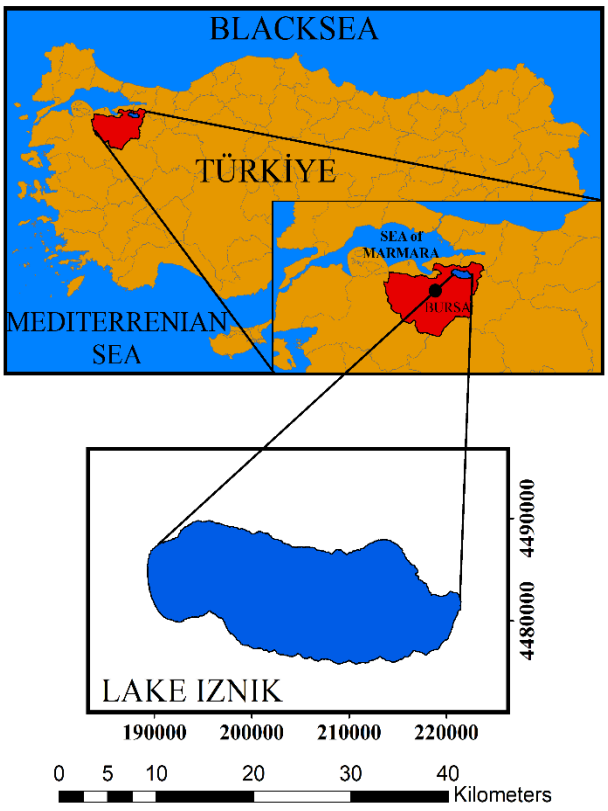

Figure 1. The location of the study area

2.2. Method

Index-based feature extraction methodology based on the utilization of AMEI and NDVI indices was followed to extract floating algal formations observed on the Landsat-8 image dated June 5, 2022. For this purpose, a ground truth dataset consisting of 1500 pixels (i.e., 500 pixels for each class) representing water and algae formations (i.e., high-density and low-density) was selected from the image. The mean spectral curves of these samples are given in Fig. 2 to analyze the spectral characteristics of water and the algae formation observed on the lake surface. As shown in the figure, high-density algal formations could be identified with the NIR band, whereas the difference between the DNs of low-density algae and water pixels was relatively lower in this band. On the other hand, it can be stated that algae and water pixels have similar spectral characteristics in the other bands of the Landsat image (except for the green and red bands). Therefore, it is not easy to distinguish pixels containing low-density algae from water pixels.

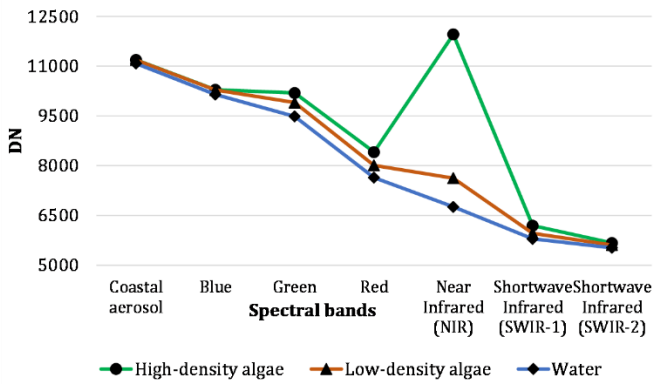

Figure 2. Spectral signatures of algae and water pixels

Considering the above-mentioned spectral features, the AMEI and NDVI indices based on the use of green (B3), red (B4), NIR (B5), and SWIR-1(B6) bands of the Landsat-8 image were used in this study. The basic formulations of the indices are given in Table 1 with references. The AMEI and NDWI indices were calculated to perform an index-based approach and derived grey-level images were used as the primary data sources for mapping algal formations.

Table 1. Formulas of NDWI and AMEI indices used in this study

Index	Formula	Reference
NDWI	$\frac{B5-B6}{B5+B6}$	Gao, 1996
AMEI	$\frac{(2\times B4)+B5-(2\times B6)}{B3+(0.25\times B6)}$	Colkesen et al. 2023

3. Results

In order to achieve the ultimate goal of the study, grey-level AMEI and NDWI index maps were produced. The resulting index maps and the false-colour Landsat image captured on June 5 2022, are given in Fig. 3. As shown in the false-colour image, high- and low-intensity floating algal formations, which appeared in green colour on the image, are mainly located in the middle and northern-east part of the Lake Iznik. Furthermore, cumulus cloud formations are observed in the eastern

and western parts of the lake. On the grey-level index maps, the highest index values indicate a high level of alg concentration, whereas the lowest index values depict a water surface. In addition, it was seen that the effects of cumulus clouds were reduced by applying AMEI and NDWI indices, and algae formations with high- and low-density can be easily identified on the maps.

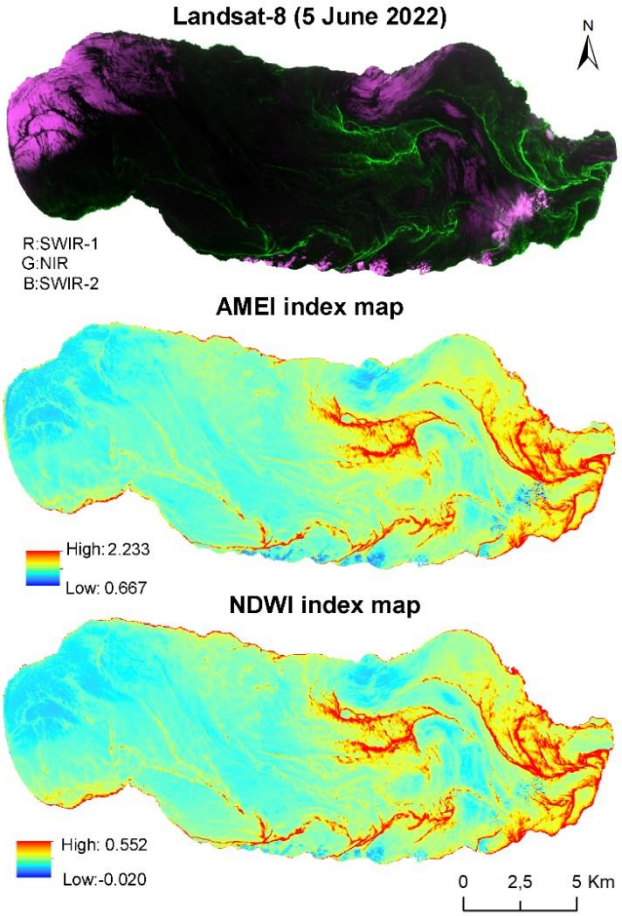

Figure 3. Index maps produced with AMEI and NDWI

The grey-level index maps were classified into two-class using multiple threshold values to investigate the spatial distributions of the algal formations and calculate algae-covered areas on the lake. Based on the natural break thresholding algorithm, four threshold values ensuring appropriate differentiation between algae and water pixels were determined for the AMEI index map, whereas two threshold values were optimal for classifying the NDWI index map. It should be noted that the class defined on the left side of the histogram, consisting of pixels having low index values, was named as water class in both index maps. On the other hand, the remaining classes on the histograms (i.e., three classes on the AMEI histogram and two classes on the NDWI histogram) were merged into one class and named as algae class. The resulting two-class index maps are given in Figure 4. According to the two-class AMEI map, the floating algae formations covered 36.35 km^2 (12.1% of the total area) of Lake Iznik on June 5, 2022. On the other hand, the algae-covered area was calculated as 27.63 km^2 corresponding to 9.21% of the total lake area on the classified NDWI map. The ground truth dataset representing water and floating algae formation was also used to assess the accuracy of the two-class index maps.

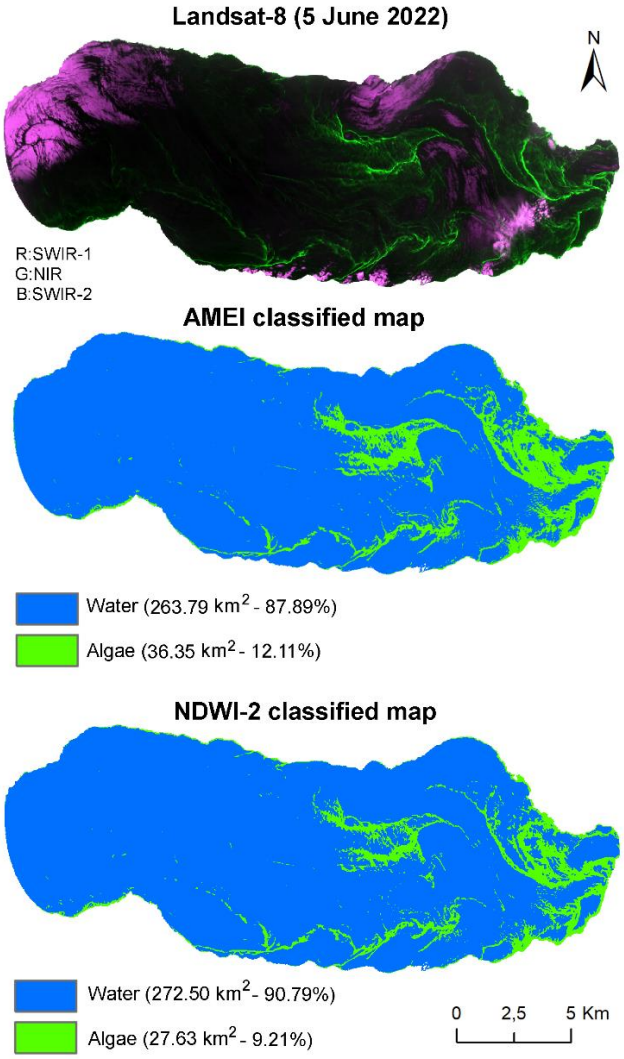

Figure 4. Classified index maps of Lake Iznik representing water and floating algae formations

The overall accuracy (OA) value, derived from the standard confusion matrix, was used as a map accuracy measure. When the accuracy analysis was performed based on water and high-density algae samples, it was seen that the classification accuracies calculated for the AMEI and NDWI maps were 99.9% and 99.5%, respectively. On the other hand, when the accuracy analysis was performed considering the whole algae samples, consisting of high- and low-density algae pixels, it was observed that the classification accuracies decreased significantly and calculated as 76.7% and 69.7% for AMEI and NDWI, respectively. This finding indicates that high-density algae formations can be accurately detected with an index-based approach, while the accuracy is relatively low in distinguishing pixels containing low-density algae formations from water pixels. On the other hand, the mucilage-specific index, AMEI, was superior to the popular NDWI index, especially in extracting low-density floating algal formations.

4. Conclusion

This study evaluated the performance of AMEI and NDWI indices in mapping the algal blooms observed in Iznik Lake with the help of Landsat 8 images. More specifically, the performance of the AMEI index, initially proposed for detecting mucilage-covered areas from Sentinel-2 imagery, was evaluated in terms of the extraction of floating algal blooms and its applicability to Landsat-8 satellite imagery. The results showed the effectiveness of the AMEI index map produced with appropriate threshold values in mapping algal blooms observed in inland waters using Landsat-8 imagery. The estimated map accuracy was 99% for the AMEI map, indicating algae formations covered 12.1% (about 36.35 km^2) of Lake Iznik on June 5, 2022. Results also indicated that distinguishing pixels containing low-density algae from water pixels was challenging due to their spectral similarity. However, it should be noted that the effectiveness of the index should be assessed in different fields and with different data sets.

References

Colkesen, I., Kavzoglu, T., Sefercik, U. G., & Ozturk, M. Y. (2023). Automated mucilage extraction index (AMEI): a novel spectral water index for identifying marine mucilage formations from Sentinel-2 imagery. International Journal of Remote Sensing, 44(1), 105-141, https://doi.org/ 10.1080/01431161.2022.2158049

Derin, Y., Milewski, A., Fryar, A. E., & Schroeder, P. (2013). An integrated approach for understanding anthropogenic and climatic impacts on lakes: a case study from Lake Iznik, Turkey. American Geophysical Union, Fall Meeting 2013, abstract #H31H1320

Gao, B. (1996). NDWI—A Normalized Difference Water Index for Remote Sensing of Vegetation Liquid Water from Space. Remote Sensing of Environment 58(3), 257–266. https://doi.org/10.1016/S0034-4257(96)00067-3.

Hu, C. (2009). A Novel Ocean Color Index to Detect Floating Algae in the Global Oceans. Remote Sensing of Environment 113(10), 2118–2129. https://doi.org/ 10.1016/j.rse.2009.05.012

Laneve, G., Bruno, M., Mukherjee, A., Messineo, V., Giuseppetti, R., De Pace, R., Magurano, F., & D'Ugo, E.. (2022). Remote Sensing Detection of Algal Blooms in a Lake Impacted by Petroleum Hydrocarbons. Remote Sensing 14(1), 121. https://doi.org/10.3390/rs14010121

Moss, B., Kosten, S., Meerhoff, M., Battarbee, R. W., Jeppesen, E., Mazzeo, N., Havens, K., Lacerot, G., Liu, Z., De Meester, L., Paerl, H., & Scheffer, M. (2011). Allied attack: climate change and eutrophication. Inland waters, 1(2), 101-105. https://doi.org/10.5268/IW-1.2.359

Oktem, Y. A., Gumus, M., & Yilmaz, G. B. (2012). The potential sources of pollution affecting the water quality of Lake Iznik. International Journal of Electronics Mechanical and Mechatronics Engineering, 2(3), 225-233.

Rodríguez-López, L., Duran-Llacer, I., Bravo Alvarez, L., Lami, A. & Urrutia, R. (2023). Recovery of Water Quality and Detection of Algal Blooms in Lake Villarrica through Landsat Satellite Images and Monitoring Data. Remote Sensing 15(7), 1929. https://doi.org/10.3390/rs15071929

Sun, Z., Chang, N. B., Chen, C. F., & Gao, W. (2022). Lake Algal Bloom Monitoring via Remote Sensing with Biomimetic and Computational Intelligence. International Journal of Applied Earth Observation and Geoinformation 113, 102991. https://doi.org/ 10.1016/j.jag.2022.102991

Yağci, M. A., & Ustaoğlu, M. R. (2012). Zooplankton fauna of Lake İznik (Bursa, Turkey). Turkish Journal of Zoology, 36(3), 341-350. https://doi.org/10.3906/zoo-1001-36

Zhang, C., Kong, X., Xue, B., Zhao, C., McGowan, S., Lin, Q., Zhang, K., & Shen, J. (2023). Double-edged effects of anthropogenic activities on lake ecological dynamics in northern China: Evidence from palaeolimnology and ecosystem modelling. Freshwater Biology, 68(6), 940-955. https://doi.org/10.1111/fwb.14077