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Assessing algae accumulation in an artificial pond using UAV-based orthophoto

Seyma Akca[*1], **Nizar Polat** [1]

[1]Harran University, Engineering Faculty, Geomatics Engineering Department, Sanliurfa, Türkiye

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Abstract

Artificial ponds serve as critical resources for various human activities, including agriculture, aquaculture, and water management. However, unchecked algae growth in these man-made water bodies can lead to eutrophication, oxygen depletion, and ecological degradation. Monitoring and managing algae accumulation in artificial ponds are essential for environmental sustainability. Traditional assessment methods have limitations in terms of spatial and temporal resolution, making them unsuitable for real-time monitoring. Recent advancements in Unmanned Aerial Vehicles (UAVs) and remote sensing technology have opened new possibilities for environmental monitoring. This study explores the application of UAV-based orthophotos and band ratios for assessing algae accumulation in artificial ponds. Structure from Motion (S*f*M) photogrammetry is used to create high-resolution orthophotos, providing detailed spatial information. Band ratios, derived from spectral information in RGB images, are employed to detect algae presence. Results show that UAV-based photogrammetry generates detailed orthophotos with a ground sampling distance of 1 cm, allowing for the identification of fine-scale features in the pond. The red/green band ratio proves effective in consistently detecting algae presence. The study demonstrates the potential of UAV-based RGB band ratios for accurate algae assessment, enabling informed decision-making and timely interventions to preserve the ecological integrity of artificial ponds. This innovative approach provides a valuable tool for safeguarding water quality and contributing to the sustainability of essential aquatic ecosystems.

1. Introduction

Artificial ponds play a pivotal role in various human activities, including agriculture, aquaculture, and water management (Niemczynowicz, 1999). These man-made bodies of water provide essential resources and services, such as irrigation, fish farming, and recreational opportunities (Popp et al., 2019). However, their ecological health and water quality can be compromised by the unchecked growth of algae, which can lead to eutrophication, oxygen depletion, and the degradation of aquatic ecosystems (Kennish, 2002; Mujere and Moyce, 2018). Monitoring and managing algae accumulation in artificial ponds is thus a critical concern for environmental sustainability.

The monitoring of algae in aquatic environments is a critical aspect of environmental science, given its implications for water quality, ecosystem health, and human activities (Glasgow et al., 2004; Altenburger et al., 2019). Traditional methods for assessing algae levels have included manual sampling, laboratory analysis, and visual inspection, all of which have inherent limitations in terms of spatial and temporal resolution (Peterson et al., 2020; Mozo et al., 2022). Manual sampling, involving the collection of water samples at specific locations and depths, is a well-established method for algae assessment. However, it is labor-intensive, time-consuming, and provides only point-in-time data, making it unsuitable for tracking algae dynamics in real-time (Simpson et al., 2005). Furthermore, manual sampling may introduce biases, especially in heterogeneous aquatic environments. Visual inspection, relying on the subjective judgment of trained observers, is often used for qualitative assessments of algae presence and abundance. While useful for rapid assessments, this method lacks the precision required for quantitative studies and may not be suitable for large-scale or continuous monitoring.

* **Corresponding Author**

*(seymakca@harran.edu.tr) ORCID ID 0000-0002-7888-5078
nizarpolat@harran.edu.tr) ORCID ID 0000-0002-6061-7796

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In recent years, advancements in Unmanned Aerial Vehicles (UAVs) and remote sensing technology have revolutionized the field of environmental monitoring (Anderson and Gaston, 2013; Karataş et al. 2022; Kanun et al. 2022). Remote sensing techniques, such as satellite and aerial imagery, offer the advantage of large-scale coverage and frequent data acquisition. Satellites can capture data at regular intervals, providing insights into long-term trends. However, their spatial resolution may limit their ability to detect algae in smaller water bodies or at fine spatial scales. UAVs, have emerged as a powerful tool in environmental science due to their versatility, affordability, and high spatial resolution capabilities. UAVs equipped with various sensors, including RGB cameras, multispectral sensors, and thermal cameras, have been deployed for a wide range of environmental monitoring tasks. In the context of water bodies, UAVs have shown promise in providing detailed and up-to-date information (Mahdavi et al., 2018). RGB cameras onboard UAVs can capture high-resolution orthophotos, which are orthorectified aerial images. These orthophotos can be used to assess water quality, including the presence and distribution of algae. Band ratios, derived from the spectral information in RGB images, have been utilized for detecting the presence of algae in water bodies (Kislik et al., 2018; Alptekin and Yakar, 2020)). Furthermore, UAVs offer the advantage of flexibility in terms of flight altitude and frequency (Karataş et al. 2023). They can be deployed on-demand to capture data at specific times or in response. Thus, it allows for the rapid collection of data on pond health, enabling timely interventions to prevent or mitigate algae-related issues. This paper presents a premise study on the utilization of UAV-based orthophotos for assessing algae accumulation in an artificial pond, focusing specifically on the capabilities of band ratios in algae detection using RGB orthophoto imagery.

2. Method

2.1. Image Processing

Structure from Motion (SfM) is a cutting-edge photogrammetric technique that has revolutionized the way we reconstruct three-dimensional (3D) environments from a series of overlapping 2D images (Calì and Ambu, 2018; Unel et al. 2020; Alptekin and Yakar, 2021). This innovative approach enables the creation of highly accurate and detailed 3D models and orthophotos from aerial photographs, such as those captured by Unmanned Aerial Vehicles (UAVs) or traditional aircraft. SfM works by identifying common features or key points in the overlapping images and then calculating their 3D positions by analyzing the variations in perspective and parallax (Kanun et al.2021; Yılmaz et al. 2022; Yakar et al. 2023). Through this process, SfM can produce a dense point cloud representation of the surveyed area, which can subsequently be used to generate digital surface models, orthophotos, and even textured 3D models (Meneely, 2023). This technology has found applications in a wide range of fields, including geospatial mapping, archaeology, environmental monitoring, and infrastructure assessment, offering a powerful tool for obtaining detailed and accurate spatial information from aerial imagery.

2.2. Band Ratios

Band ratio is a fundamental technique in remote sensing and image analysis that involves the mathematical comparison of two or more spectral bands or channels of remotely sensed data (Tucker, 1979). By dividing the reflectance values in one band by those in another, a band ratio image is created, which highlights specific features or information of interest in the scene (Liu and Mason; 2013). Band ratios are particularly valuable in tasks such as vegetation analysis, mineral identification, and land cover classification. Similarly, mineral exploration often employs band ratios to detect minerals with distinctive spectral signatures in satellite or aerial imagery. Band ratio techniques enhance the interpretability of image data, allowing for the extraction of meaningful information and the identification of specific materials or phenomena within a given area (Shebl et al., 2023).

3. Results and Discussion

In the study, the photogrammetric flight conducted utilizing a UAV at a flight altitude of 30 meters has yielded valuable insights into the artificial lake under investigation. With an 80% overlay rate and a total of 154 aerial photographs captured, our study achieved a remarkable ground sampling distance of 0.7 centimeters. The robust dataset generated during this aerial survey has allowed for the extraction of a dense point cloud comprising an impressive 4,026,467 points, with a point density of 284 points per square meter. These results reflect the effectiveness of UAV-based photogrammetry in producing high-resolution orthophotos and detailed topographic information for our study area. Figure 1 presents a high-resolution (1 cm) orthophoto of the lake under study, captured with remarkable precision during our UAV-based photogrammetric flight.

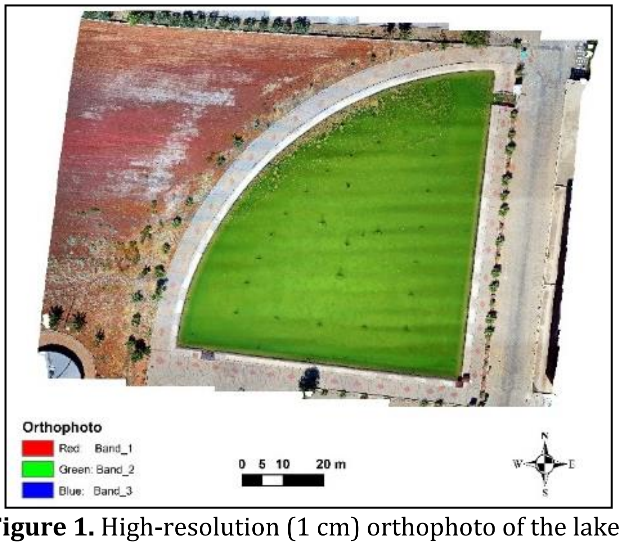

Figure 1. High-resolution (1 cm) orthophoto of the lake

The ground sampling distance of 1 cm highlights the exceptional level of detail attained in this aerial survey. Each pixel in this orthophoto represents an area of just

one square centimeter on the ground, providing a clear and vivid visual representation of the lake's features and surroundings. Notably, this orthophoto offers a wealth of spatial information, enabling the identification of fine-scale features such as shoreline characteristics, aquatic vegetation distribution, and even subtle variations in water quality. The vividness of this orthophoto underscores the utility of UAV-based photogrammetry for acquiring high-resolution geospatial data in environmental monitoring, resource management, and scientific investigations. The details depicted in Figure 1 are pivotal for our study's objectives, contributing to a comprehensive understanding of the lake's dynamics and aiding in precise analyses of various factors influencing its health and ecology.
After obtaining the high-resolution orthophoto of the lake, our study delved into further analysis to extract valuable insights regarding water quality and ecological conditions. Apart from visual inspection, the key analytical approach employed was the calculation of band ratios. These ratios serve as valuable tools for identifying specific features and phenomena within the imagery. In this context, we firstly focused on the red/green band ratio, which is known to provide critical information about water quality and the presence of algae. The results of the red/green band ratio analysis are presented in Figure 2.

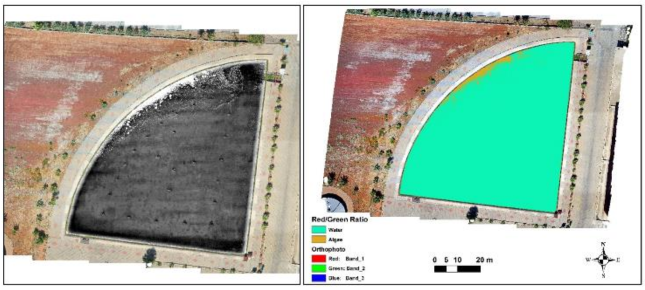

Figure 2. The result of the red/green band ratio (left) and its thematic map (right).

In Figure 2 (left), the red/green band ratio provides valuable insights into the conditions of the lake's water surface. Areas depicting a higher red/green band ratio, indicated by lighter tones in the image, correspond to regions with a greater presence of algae. This result aligns with the greenish tint observed in the water, signifying the accumulation of algae. The distinctive coloration and spatial distribution depicted in the ratio image offer a clear visual representation of the areas affected by algal growth, providing crucial information for our study's assessment of water quality and ecological dynamics (Figure 2 right). Moving beyond the red/green band ratio, we also investigated the red/blue band ratio, as illustrated in Figure 3.

This ratio reveals complementary information about the lake's water quality and the presence of algae. In the context of this ratio, areas exhibiting higher values (figure 3 left), denoted by brighter regions in the image, suggest potentially greenish water. In this case, the dark areas indicate algae accumulated on the water surface. The spatial distribution of algae can be seen in figure 3 right. Finally, Figure 4 presents the green/blue band ratio, which plays a crucial role in our assessment of the lake's water conditions.

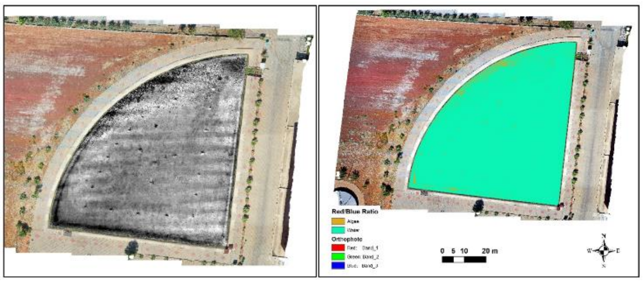

Figure 3. The result of the red/blue band ratio (left) and its thematic map (right).

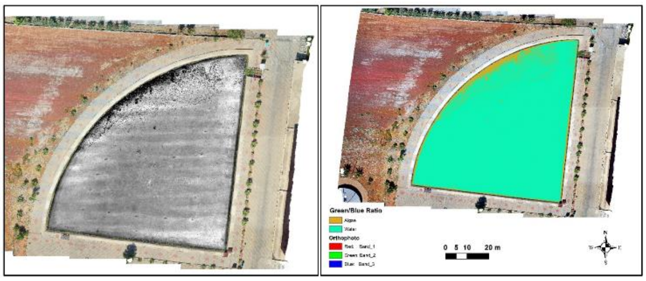

Figure 4. The result of the green/blue band ratio (left) and its thematic map (right).

In this ratio image, areas with elevated green/blue values (left), represented by lighter areas, indicate a greater likelihood of greenish water. The dark areas indicate algae accumulated on the water surface. The spatial distribution of algae can be seen in figure 4 right.
Upon reviewing the band ratio results, it is evident that the red/green ratio provides more consistent and reliable outcomes. However, it's worth noting that in the case of the other two ratios, some instances, such as the fountains within the lake, were mistakenly identified as algae. Furthermore, partial inclusion of shoreline shadows within the algae class was observed. In light of these findings, while all three ratios effectively detect algae accumulation, it is advisable to prioritize the use of the red/green ratio for a more accurate assessment of algae presence and distribution in the lake.

4. Conclusion

In Conclusion, the utilization of UAV-based RGB band ratios presents a powerful and versatile method for investigating water pollution and algae accumulation in artificial lakes. By harnessing the spectral information captured through high-resolution orthophotos, these ratios enable precise identification and mapping of areas affected by algae growth and greenish water. This approach enhances our ability to monitor and manage water quality in artificial lakes with greater efficiency and accuracy. Our study has demonstrated the potential of this innovative technique, specifically highlighting the effectiveness of the red/green band ratio in consistently detecting algae presence and distribution. While the other two ratios occasionally misidentified features such as fountains and shoreline shadows, the red/green ratio emerged as the more consistent and dependable choice for accurate algae assessment.

The integration of UAV technology and band ratio analysis not only provides valuable insights into water quality but also offers a promising pathway toward informed decision-making, timely interventions, and the preservation of the ecological integrity of these vital water bodies. As we continue to explore innovative techniques in environmental science, the UAV-based RGB band ratio approach stands as a valuable tool for safeguarding the health and sustainability of artificial lakes. It empowers us to proactively address water quality challenges and contribute to the preservation of these essential aquatic ecosystems.

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