

AQUATIC VEGETATION SURVEYS USING HIGH-RESOLUTION IKONOS IMAGERY

Leif G. Olmanson, Marvin E. Bauer, and Patrick L. Brezonik

Water Resources Center & Remote Sensing and Geospatial Analysis Laboratory

University of Minnesota - St. Paul, Minnesota, USA 55108

olman002@umn.edu, mbauer@umn.edu, brezo001@umn.edu

ABSTRACT

Aquatic plant diversity and abundance is an important indication of lake and wetland health, but accurate maps and data are difficult to acquire. IKONOS imagery with four multispectral bands similar to Landsat TM bands 1-4 and high spatial resolution (4-m multispectral and 1-m panchromatic) is potentially well suited for aquatic plant surveys in lakes and wetlands. To explore the capabilities of IKONOS imagery for aquatic plant surveys, we acquired several IKONOS images for surface water bodies, including a September 1, 2001 image for Swan Lake in Nicollet County, Minnesota. Swan Lake is a large (over 3600 ha) type-4 wetland with an abundance of aquatic vegetation. Results based on analysis and classification of a pan-sharpened multispectral IKONOS image demonstrated the potential to identify and map different aquatic plant groups throughout the image. With further research we expect to identify more specific aquatic plant types. This study indicates that the use of IKONOS imagery for aquatic plant surveys is promising. We also are conducting analyses of imagery from several other areas with a variety of landscapes and aquatic vegetation. The high spatial resolution of the IKONOS imagery enables the assessment of aquatic vegetation variation within lakes and wetlands that cannot be obtained from Landsat data and the multispectral data enable classification beyond what is commonly done with aerial photography.

INTRODUCTION

Minnesota is known for its more than 10,000 lakes, but it also has more than 4 million hectares of wetlands. Although the recreational and aesthetic value of lakes is widely accepted, wetlands traditionally have been considered a nuisance and wastelands that need to be drained. Statewide, over half of Minnesota's original wetlands (around 4.5 million ha) have been drained for agricultural and urban development, and many of the remaining wetlands have been degraded. A frequent cause of wetland degradation is increased storm water discharge resulting from changes in hydrology, such as increases in impervious surface area, installation of storm water systems in urban and suburban areas, and increased tiling and ditching systems in agricultural areas. Changes in hydrology affect water quality and quantity and may severely impact the structure and function of wetlands. For example, unimpacted wetland plant communities usually are composed of a diverse group of native species, but impacted wetlands are dominated by a less diverse group of more opportunistic native and non-native plants such as cattail, purple loosestrife and reed canary grass.

In recent decades, aquatic plants in lakes and wetlands have been recognized as important ecosystem features that should be protected. These plants are important because they help protect water quality and provide habitat for fish and wildlife while also providing economic and aesthetic benefits. With this greater appreciation for aquatic plants in wetland and lake environments, aquatic plants surveys and assessments are becoming part of routine monitoring efforts conducted by consultants, citizen groups, and state and local agencies. Aquatic plant diversity and abundance is therefore an important indication of lake or wetland health, but accurate maps and data are difficult to acquire. Because of expense and time requirements for ground-based monitoring, it is impractical to map and monitor more than a small fraction of this large resource by conventional field methods. The use of high resolution satellite-based sensing has the potential to be a cost-effective way to gather the information needed for aquatic plant assessments in many of Minnesota's lakes and wetlands. Özesmi and Bauer (2002), in their review of the methods and results on satellite remote sensing of wetlands, found that accurately mapping wetlands is a very challenging task, but their paper was written before the launch of the high-resolution IKONOS system.

The principal objective of the study reported here is to evaluate and demonstrate the capability of high-resolution satellite imagery for use by natural resource agencies to classify aquatic plant groups and thus gain a better understanding of these complex ecosystems. We investigated the use of IKONOS imagery for aquatic plant

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survey of Swan Lake in Nicollet County, Minnesota. Swan Lake is a large (over 3600 ha) type-4 wetland (i.e., a deep marsh with standing water and abundant aquatic vegetation).

METHODS

The methods used for this preliminary assessment were adapted from methods typically used for land cover classification (Lillesand et al., 1998) and methods developed for water quality assessments (Olmanson et al., 2001). The aquatic plant classification methods consist of two major procedures: separation of image features into discrete units and classification of the pixels in each unit. Procedures used for this project are preliminary and presented here as a first step to evaluate the potential of high-resolution imagery for aquatic plant surveys. We expect they will evolve as the methodology is refined with further research.

Aquatic Vegetation Reference Data

Because of the size of Swan Lake and the abundance of its aquatic plants, collection of reference data would be very difficult without the aid of modern technology. For this study we took advantage of Global Positioning System (GPS) technology and the advanced GPS tracking software available with ERDAS Imagine 8.5 software. Field reference data were collected using GPS tracking software on a Fujitsu pen-based field computer (Kerns, et. al, 2001). Different types of aquatic vegetation were identified in the field and located directly on the IKONOS image using the field computer. Being able to accurately identify location on the image while in the field was especially useful on this large wetland. Having the image available quickly after its acquisition for use in reference data collection also was a big advantage in field sampling because areas with unique spectral-radiometric responses could be identified on the image and targeted for field identification. For this preliminary assessment, emergent vegetation was targeted, but the abundance of thick submerged vegetation appearing at the surface also was noted.

Satellite Image Data

The IKONOS image of Swan Lake in Nicollet County, Minnesota was acquired on September 1, 2001. The image is of high quality with only minor cloud cover on the southern portion. The 4-m multispectral bands were "pan-sharpened" using the 1-m panchromatic band data. Fig. 1 displays the false color composite of raw data over the study area and shows distinct differences throughout Swan Lake that are caused largely by variations in aquatic vegetation.

Classification Procedures

The first step was to separate wetland features from terrestrial features. This was accomplished by digitizing the aquatic terrestrial boundary around the entire wetland and all islands. This boundary was identified using spectral-radiometric differences visible on the image. With the wetland polygon the image was subset to mask out all terrestrial features and create a wetland image.

Because Swan Lake is only two meters deep and has clear water and an abundance of aquatic vegetation, we assumed that aquatic vegetation was present throughout the wetland. Therefore, the next step was to stratify the wetland into emergent and submergent vegetation features. This was accomplished by performing an unsupervised classification. Emergent vegetation features had very different spectral characteristics than submerged vegetation features. Submerged vegetation features were masked out to create an emergent vegetation image and emergent vegetation features were masked to create a submerged vegetation map. A second unsupervised classification was performed on the emergent vegetation image specifying 100 classes. The submerged image was clustered into 10 classes to identify different variations of submergent aquatic vegetation. The next step, using the reference data, was to identify what the different classes were. For the emergent vegetation image this was performed by color-coding identified plant groups, e.g., all identified cattail classes were color-coded red. This created a map of the entire wetland identifying the locations of all cattail. This procedure was repeated for all plant types and an emergent vegetation map was created. Because of the difficulty in separating some plant types, for this preliminary study, plant groups were used to improve accuracy at the expense of categorical detail in the final map.



Figure 1. September 1, 2001 IKONOS Satellite image of Swan Lake in Nicollet County, Minnesota, USA.

For the submerged vegetation map, classes of different aquatic plant densities were identified using a graph of the spectral-radiometric signatures of the different classes and the reference data. Fig. 2 shows the signatures of the different submerged aquatic plant groups. Assuming that water clarity is similar throughout the wetland and that aquatic plants are located throughout the wetland, we attributed the differences in spectral response to differences in submerged aquatic plant depth and densities. Classes with higher radiometric response were identified as areas where the submerged vegetation was very dense and topped at the surface. Areas with lower radiometric response were identified as areas where submerged vegetation was less dense or deeper. Recoding the map into four submerged plant density classes created the submerged vegetation map. The final aquatic plant classification map was created by overlaying the submerged aquatic plant map and the emergent aquatic plant map over the multispectral image Fig. 3.

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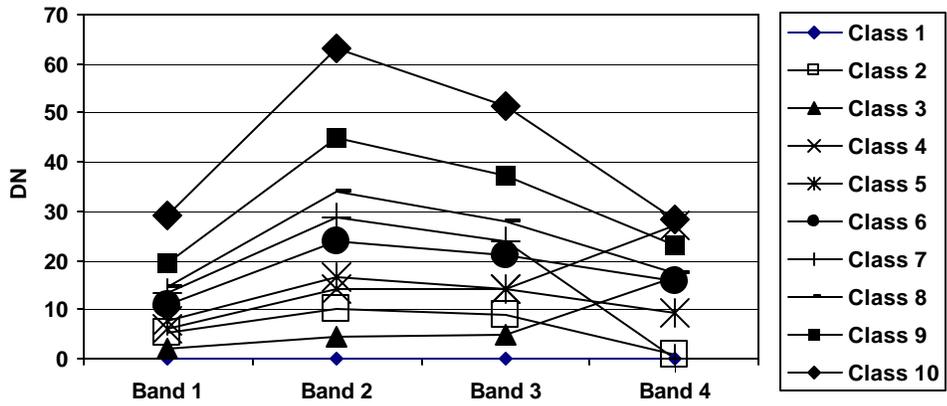


Figure 2. Swan Lake Submergent Vegetation Signatures

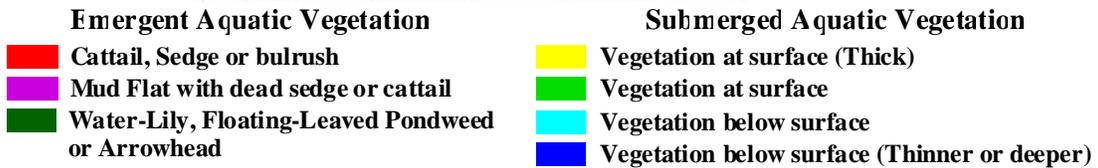
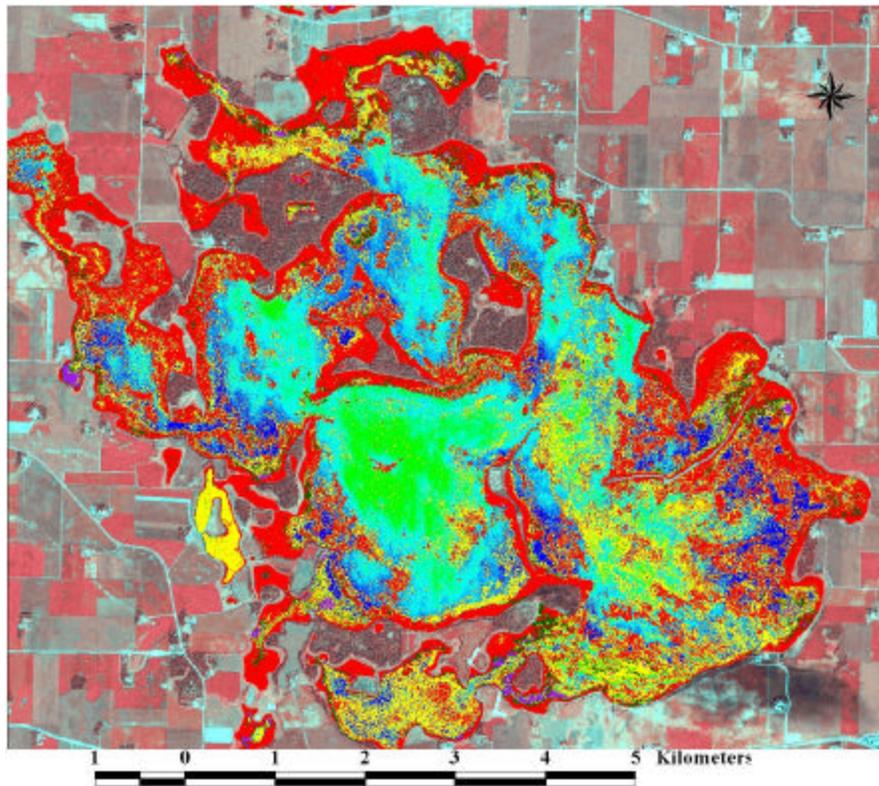


Figure 3. Aquatic Vegetation Classification of Swan Lake in Nicollet County, Minnesota, USA.

RESULTS AND DISCUSSION

Stratification and unsupervised classification of a pan-sharpened multispectral IKONOS image was able to provide a map identifying different aquatic vegetation groups throughout a large type-4 wetland. We also are conducting analyses of imagery from several other areas throughout Minnesota with a variety of landscapes and aquatic vegetation. With further research, additional field reference data, and processing we expect to identify more specific aquatic plant types. Future plans also include application of appropriate accuracy assessments techniques. This preliminary study has indicated that the use of IKONOS imagery for aquatic plant surveys is promising. The high spatial resolution of the IKONOS imagery enables the assessment of aquatic vegetation variation at a reasonably fine scale (1 meter) within lakes and wetlands that cannot be obtained from Landsat data and the multispectral data enable classification beyond what is commonly done with aerial photography.

ACKNOWLEDGEMENTS

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