MAPPING SPATIAL AND TEMPORAL VARIABILITY IN A DYNAMIC ESTUARY USING SATELLITE IMAGERY

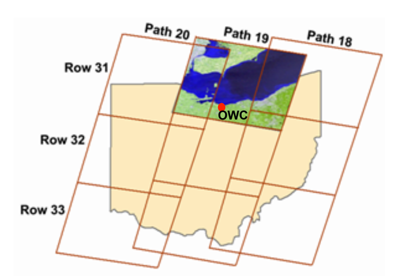
Wijekoon, N (nwijekoo@kent.edu), Ortiz, J.D., Witter, D.L., Munro-Stasiuk*, M.J.

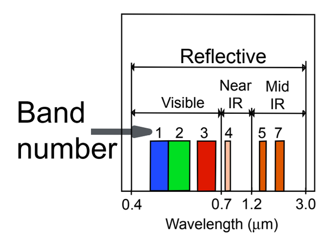
Department of Geology, Department of Geography, Kent State University*

ABSTRACT

Estuaries are highly dynamic environments, shifting between terrestrial and aquatic habitats in response to climatic and seasonal variations. The importance of frequent monitoring, identification and mapping of surface reflectors is a key element in estuarine investigation. Therefore, the current study focused on spatial and temporal mapping of Old Woman Creek (OWC) estuary, which is the smallest among the National Estuarine Research Reserve (NERR) system, using satellite imagery.
In this study, Landsat-5 TM reflectance data from summer 2005 was used to identify the spatial and temporal distribution patterns of dominant land covers at OWC based on end-member scattergrams and principal component analysis (PCA). The scattergrams were segmented using normalized difference vegetation index (NDVI), normalized difference water index (NDWI), and normalized difference ground index (NDGI) in order to identify the critical value for land cover variability. PCA is a data reduction method which we applied to identify the underlying patterns of surface reflectance variability. During the investigation, it was observed that photosynthetic macrophytes, open water, and exposed ground/ non-photosynthetic macrophytes are the prominent surface cover types of the area. Interpretation of the end-members as well as principal components was perfomed by the comparison of their spectral patterns with spectrophotometric spectra generated from field samples. Finally, we re-constructed the spatial and temporal distribution patterns of surface land covers by spatial interpolation of NDVI, NDWI, NDGI and factor score value from PCA using geographic information system (GIS). The techniques described in this study can be applied to other estuaries to identify the dominant land covers and map their distribution in space and time.

LANDSAT-5 TM IMAGERY





Landsat-5 TM data from path19 row 31 are freely available in www.ohioview.org.
All images were clipped and radiometrically corrected. The spatial resolution of a pixel is 30 m. The temporal variability is updated by the re-visit of Landsat-5 TM every 16 days.

Reflectance data were collected by thematic mapper sensor through six spectral bands located within visible, NIR, and MIR wavelengths of EM spectrum.The satellite data are in digital format and relatively easy to integrate into statistical analysis as well as GIS applications.

SEASONAL VARIABILITY IN 2005

The observed dominant surface reflectors at Old Woman Creek estuary in summer 2005

The variation of surface cover types in responce to seasonal, climatic, and other environmental factors is a unique evidence for dynamism in this natural laboratory. During mid-summer, mainly American lotus and water lily invaded the water body masking the reflectance of surface water.

REFERENCES

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Ozesmi, S. L., and Bauer, M. E., 2002. Satellite remote sensing of wetlands, *Wetlands Ecology and Management* **10** 381-402.

END-MEMBER SELECTION BY SCATTERGRAMS

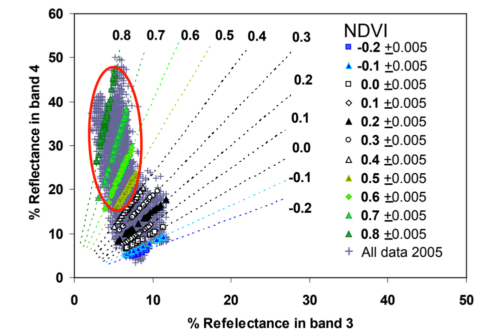
End-members

In this study, the basic land cover classes were called end-members and they were identified using reflectance properties.

Image scattergrams, which are the scatter plots of two spectral bands were used to categarize end-members.

The three end-member land cover types in this area were;
(1) photosynthetic vegetation,
(2) estuarine open water, and
(3) exposed ground or non-photosynthetic vegetation.

Normalized Difference Vegetation Index

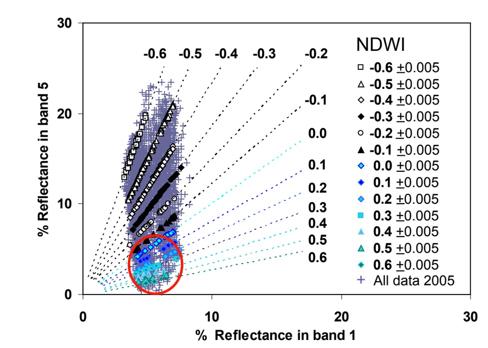


$$NDVI = \frac{(R_{Band\,4} - R_{Band\,3})}{(R_{Band\,4} + R_{Band\,3})}$$

R= % Reflectance

The pixels of NDVI > 0.4 was identified as **photosynthetic vegetation.**

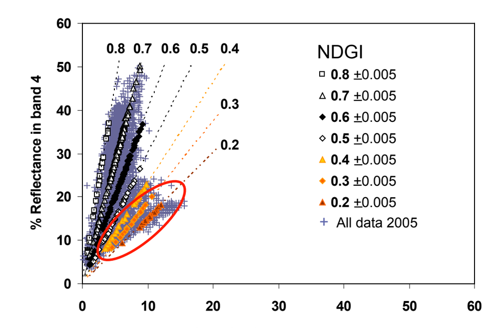
Normalized Difference Water Index



$$NDWI = \frac{(R_{Band\,1} - R_{Band\,5})}{(R_{Band\,1} + R_{Band\,5})}$$

The pixel of NDWI > 0.0 was identified as **open surface water.**

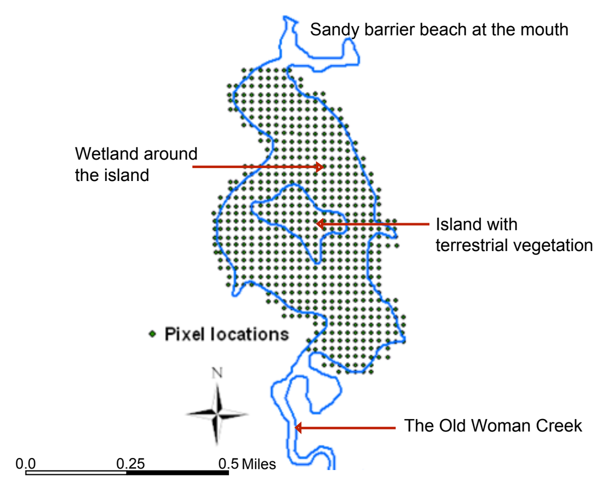
Normalized Difference Ground Index



$$NDGI = \frac{(R_{Band\,4} - R_{Band\,7})}{(R_{Band\,4} + R_{Band\,7})}$$

The pixels of NDGI < 0.4 was identified as **exposed ground or non-photosynthetic vegetation**

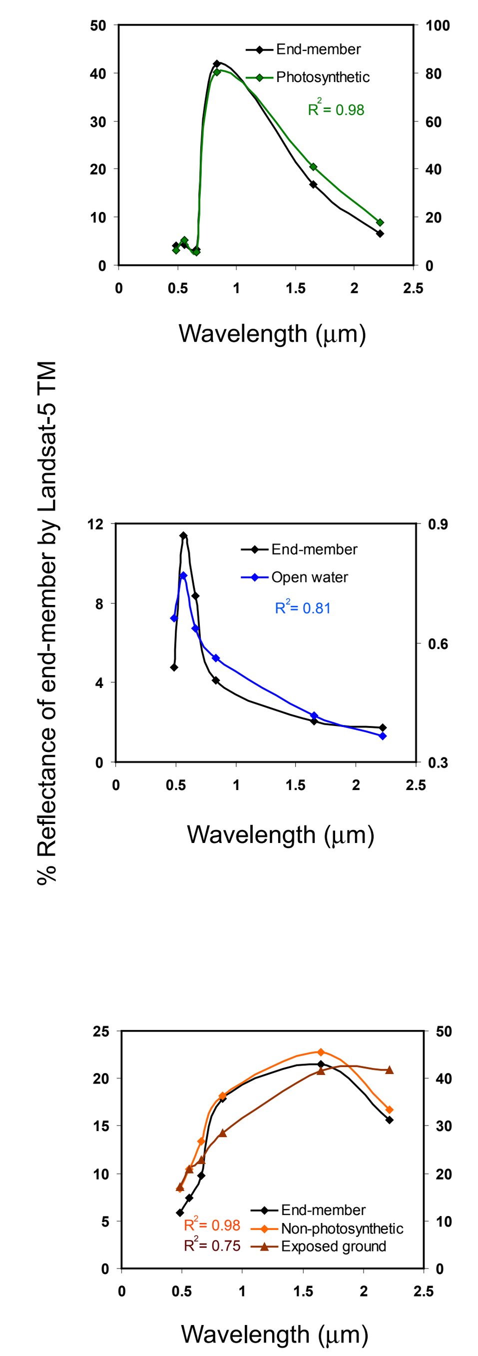
SATELLITE DATA COLLECTION



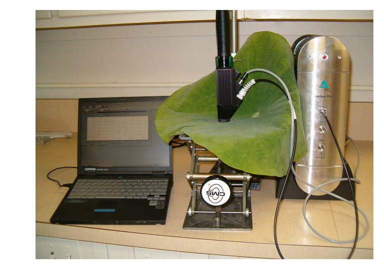
The circles indicate the locations of the pixels. We collected reflectance data from eight imagery in 2005 using PCI Geomatica 10.0. From each image 611 pixels were considered.

Evaluate end-members by spectrophotometric spectra

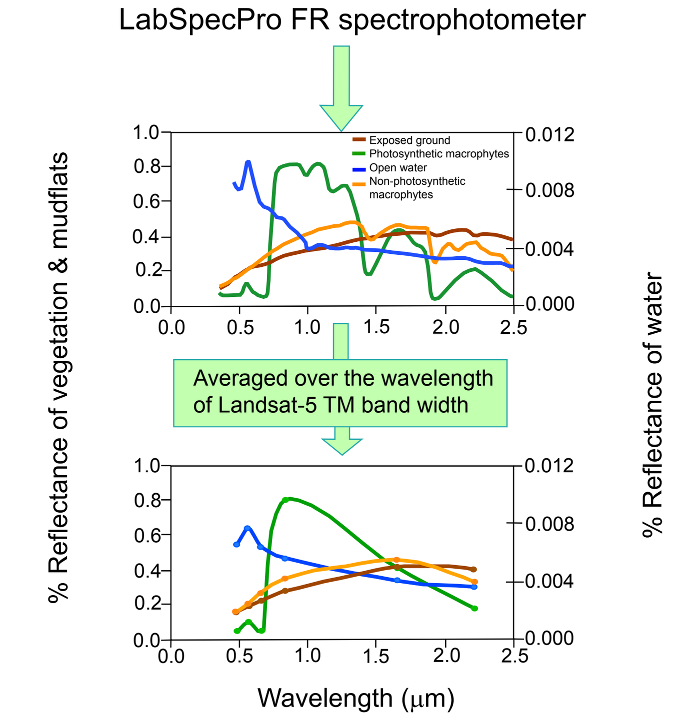
Spectra Comparison



We collected samples of surface water, emergent aquatic and terrestrial macrophytes, and exposed mudflats every 16 days coincidence with the Landsat-5 TM overpassings from June to October in 2005. The reflectance spectra were measured using a LabSpecPro FR spectrophotometer. The mean spectrophotmetric spectrum for each dominant surface reflector was generated by averaging 15 measurements with 100 sub samples each.



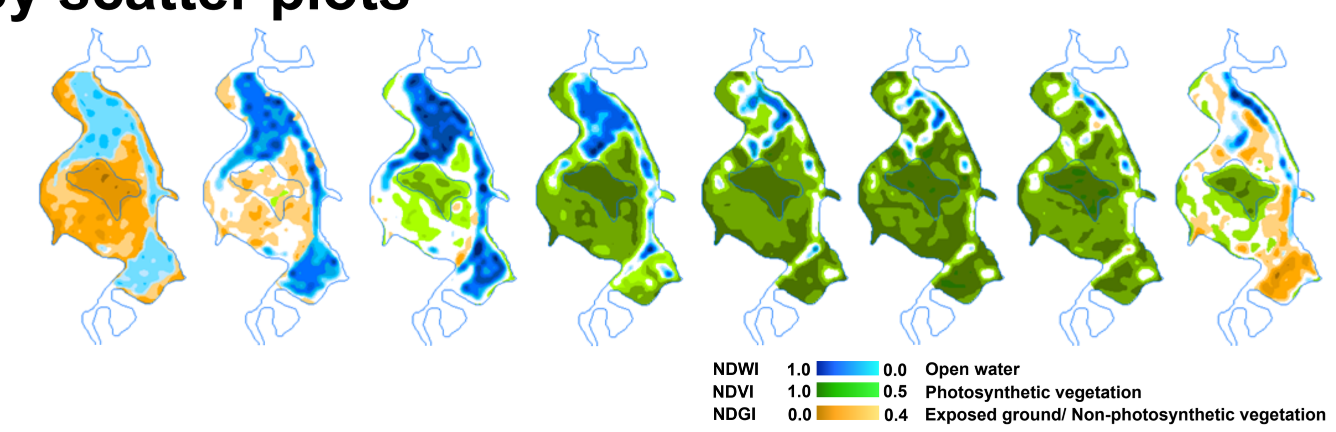
LabSpecPro FR spectrophotometer



The mean reflectance spectra of each land cover class were averaged over the wavelengths corresponding to Landsat-5 TM band widths and compared with the spectra resulted from the end-members and the factor loading values of PCA.

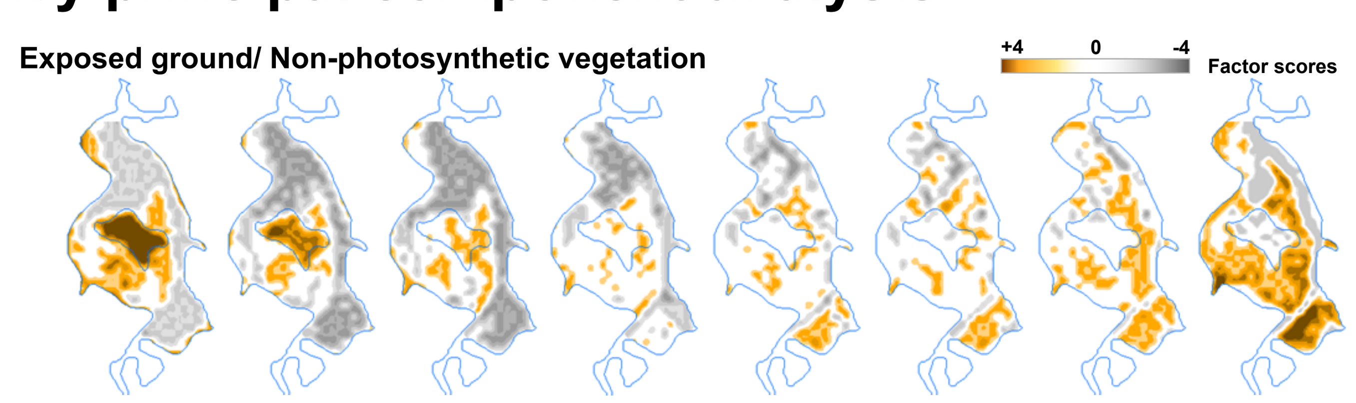
SPATIAL AND TEMPORAL VARIABILITY

By scatter plots

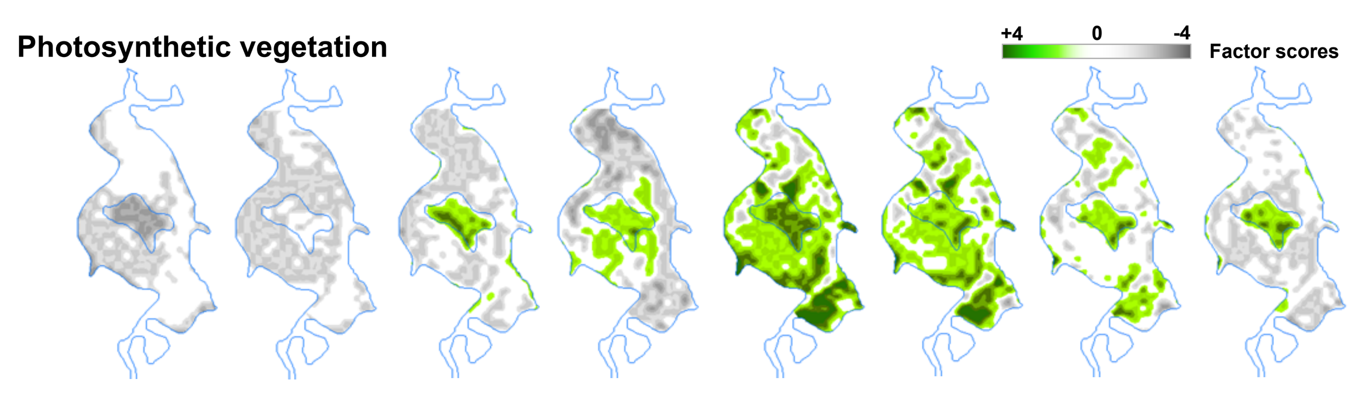


By principal component analysis

Exposed ground/ Non-photosynthetic vegetation



Photosynthetic vegetation

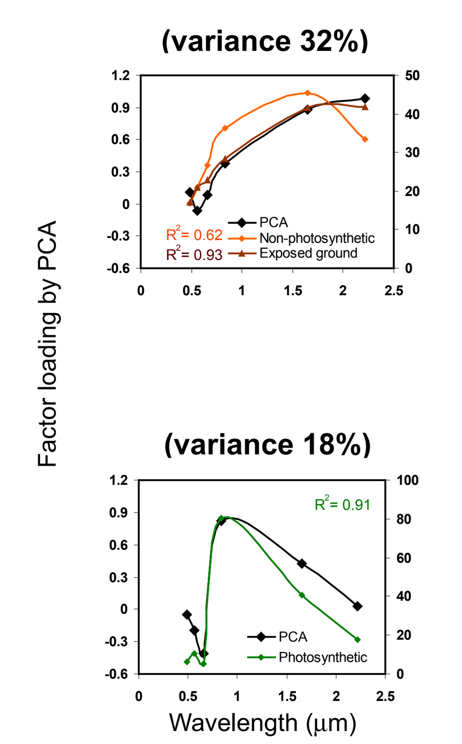


PRINCIPAL COMPONENT ANALYSIS (PCA)

PCA is a data reduction method that was applied to identify the underlying components of reflectance data. "Varimax-rotated PCA" technique was used to maximize the variance between resulting factors to make them as distinctive as possible.

Value	Definition	Usage
% variance	% of entire dataset related to each specific component	Identified the dominant components in entire dataset
Factor loadings	Derived from the correlation matrix between original variables and the newly derived components	Generated spectral patterns of resulting components to identify their reflectance properties
Factor scores	Projections of the factor loadings onto each pixel	Interpolated the point data to raster images by spatial interpolation using ArcGIS 9.2

Evaluate principal components by spectrophotometric spectra



The identification of newly derived components was based on the correlation (R_2) between the PCA resulted Landsat specta and the mean spectrophotometric spectra from the field data. Two components that exhibit highest correlations of 0.93 and 0.91 with exposed ground and photosynthetic vegetation were identified and mapped.

SUMMARY

The distribution patterns of dominant land cover types from two mapping techniques, end-member selection and principal component analysis, displayed overall similarity.The spread of aquatic macrophytes in mid-summer on surface water was effectively mapped by the end-member method where as the PCA detected only dense aquatic macrophyte communities as photosynthetic vegetation. The seasonal land cover variability in the island at the middle of the estuary was remarkably mapped by both methods. The spatial and temporal variation of open surface water extracted using NDWI in end-member method was identical to the distribution pattern of high negetive factor scores of exposed ground resulted by PCA. It was an indication of submerged areas because high positive factor scores represented exposed ground. Although we used 30 m and 16 day spatial and temporal resolution Landsat-5 TM data, the reflectance data from other satellites having finer spatial, spectral, and temporal resolutions will provide more detailed information on surface cover.

ACKNOWLEDGEMENT

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