

## A SATELLITE REMOTE SENSING MONITORING PROGRAM FOR SUSPENDED SEDIMENT CONCENTRATION AT OLD WOMAN CREEK

ESTUARINE RESERVE, OHO

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## ABSTRACT

Non-point source pollution due to suspended sediment loading is a major concern at Old Woman Creek (OWC) Estuary, which is the only Natural Estuarine Research Reserve (NERR) in the Great Lakes biogeographic region. In this study, near real time satellite data from Landsat5 TM was correlated with laboratory measurements of suspended sediment concentration obtained with a Malvern Mastersizer 2000. Remote sensing data of Normalized Difference Water Index (NDWI) analysis along global positioning system (GPS) referenced transects were used to calibrate sediment volume concentration. The presence of chlorophyll-a in surface water was quantified using Diffuse Spectral Reflectance spectra to evaluate the growth and decay of algal bloom in summer 2005. Red, green, and blue (RGB) composite images were used to interpret the temporal behavior of an estuarine environment between vegetation and water while the NDWI resulting images extract the apparently surface water bearing areas. The calibrated inventory was evaluated by NDWI values of water surface at selected locations along the transect in Landsat5 and Landsat7 images of past few years. This relationship is applicable only when there is sufficient open water in the estuary

between March and October.

STUDYAREA

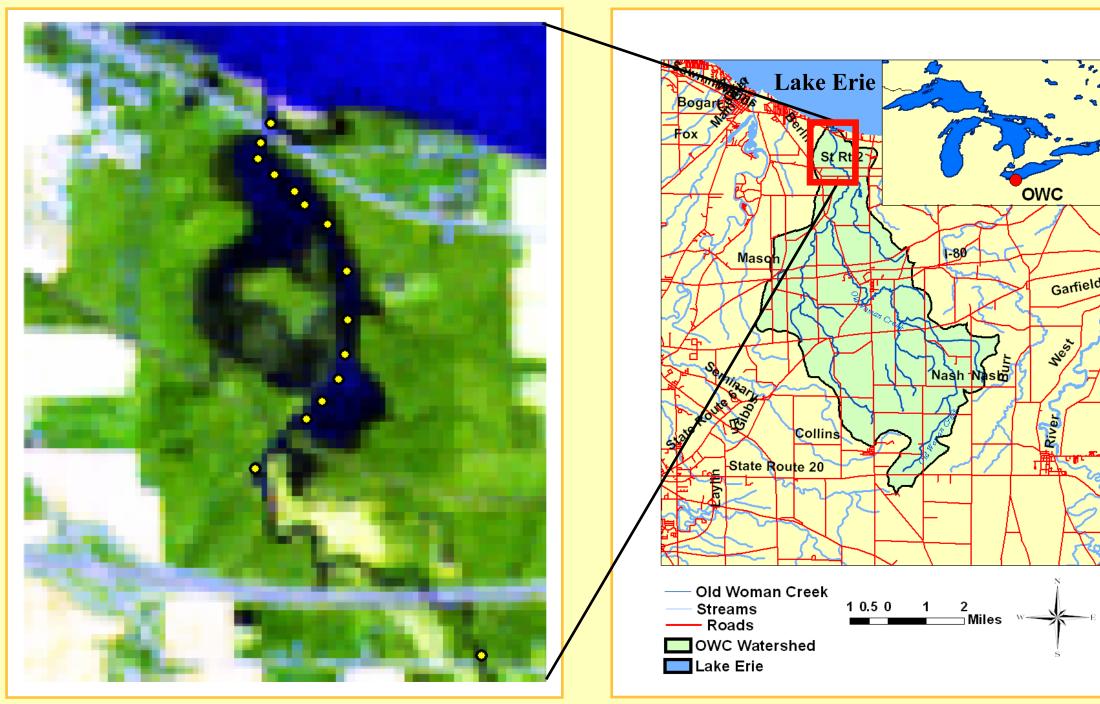


Fig.1. The estuary is located at the south central shore of Lake Erie, north central Ohio, and drains approximately 27 square miles within the Huron and Erie counties. The sampling locations are illustrated in yellow points.

### RESULTS AND DISCUSSION

Remote sensing is the process of inferring surface parameters from measurements of the upwelling electromagnetic radiation from the land surface. The color of the water in OWC estuary depends upon the optical properties of water which is caused by the materials suspended in the water column. In this study, the Landsat5 TM satellite provides the ability to measure the optical characteristics of estuarine surface water.

Assessment of water and vegetation cover of the estuary during summer 2005 is performed by analysis of Landsat5 TM bands 7, 5, and 1 in the PCI Geomatica software. At the beginning of summer, there is less aquatic vegetation cover, which progressively spreads on water in July and August. The invasion of aquatic macrophytes conceals true water surface and depicts vegetative cover, although there is a water column of 1 to 5 feet deep in areas detected as vegetation (Fig.4). In September, there is a tendency to increase the apperent water surface due to initiating the decay of these invasive plants

The NDWI of surface waters is created by the reflectance of visible and shortwave infrared (SWIR) range of the EM spectrum. The figure shows apparent surface water bearing pixels, which were extracted by pseudo-color images resulted from NDWI analysis. The black solid line indicates the real extent of Old Woman Creek estuary (Fig.5). Some of the common emergent plants found in this estuary are Fragmities, Cattail, American Lotus, and White Water Lily. The temporal variation of the apparent area of surface water was calculated based on resulting images from NDWI (Fig.6).

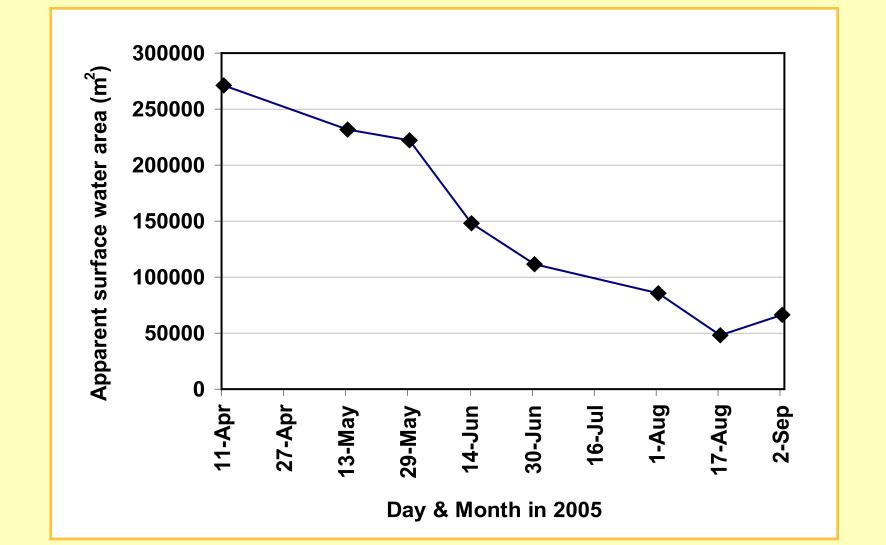
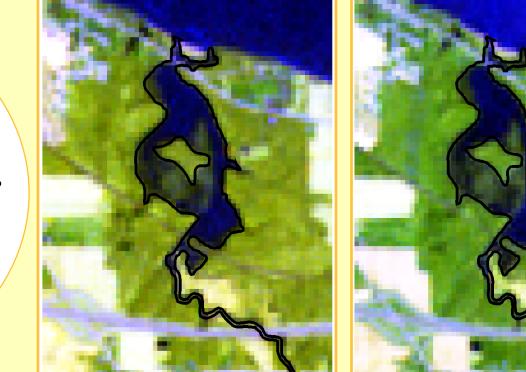


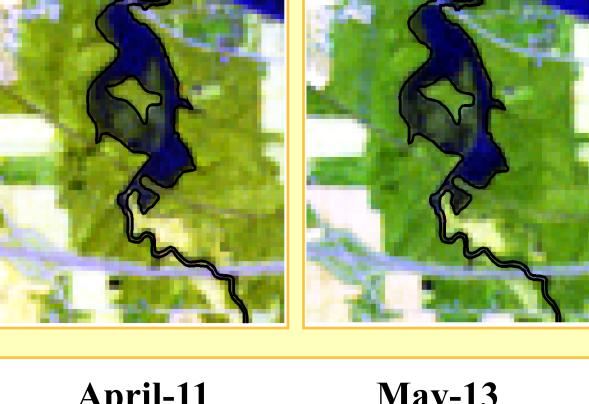
Fig. 6. The temporal variation of apparent surface water bearing area in summer 2005. The area decreases due to significant spread of aquatic emergent vegetation.

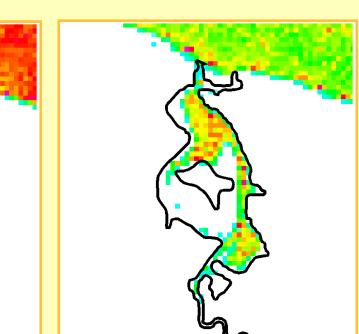
There is a high correlation between NDWI and Total Suspended Particulate Concentration of the estuary during early summer (Fig.7). Factors such as phytoplankton concentration, suspended particulates, and large scale biological activities (e.g. mating of carps) change the natural particulate balance in the system. In addition extensive spread of aquatic vegetation also influence on NDWI. Effect of cloudiness and haze also decrease the correlation between these two parameters. The calibration curve, which can be used to determine the percent volume of Total Suspended Particulate concentration during summer, was generated based on the resulted plots of high correlation (Fig.9).

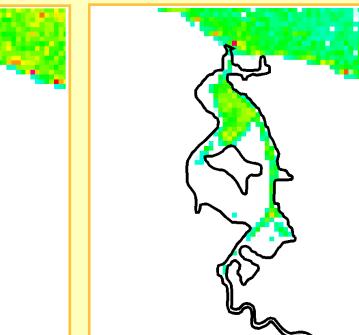


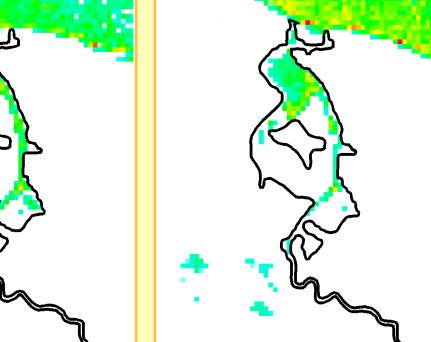
Pseudocolor NDWI images showing apparent water bearing areas of the estuary. White represents land and vegetation.

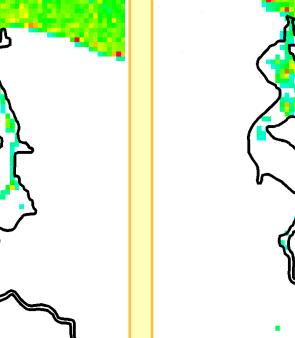


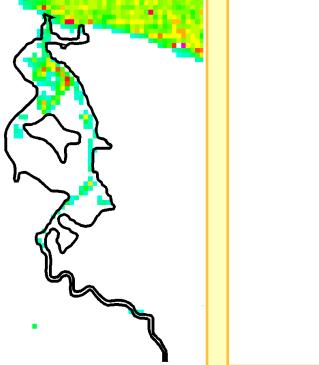




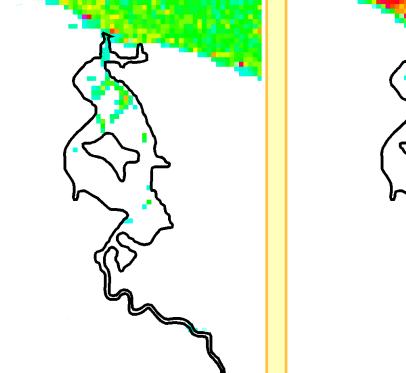








Chloroplyll-a



September-02

# -0.8 -0.6 -0.4 -0.2 June-30-2005 -0.8 -0.6 -0.4 -0.2 August-01-2005 -0.8 -0.6 -0.4 -0.2 August-17-2005 -0.8 -0.6 -0.4 -0.2 September-02-2005

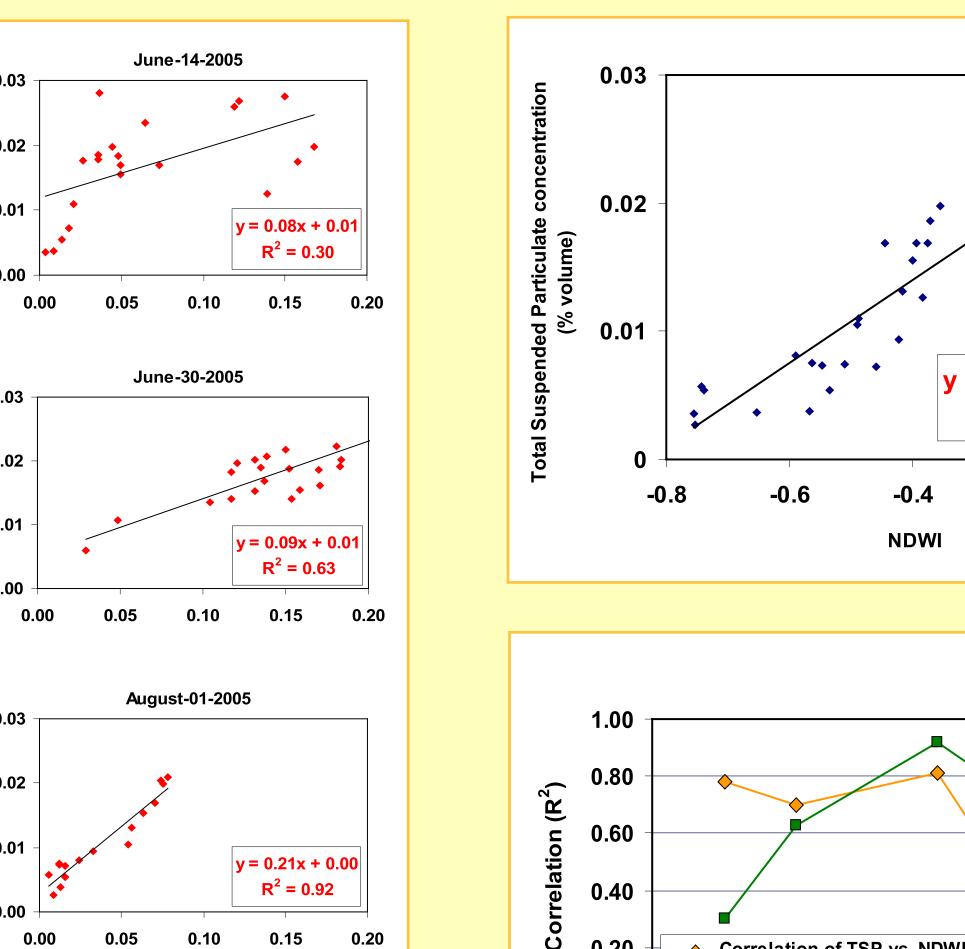
June-14-2005

Fig.7. The temporal variation of total particulate concentration as a % volume vs. NDWI

**NDWI** 

In June, there was considerable surface water exposure, and the NDWI vs. total particulate concentration exhibits a high correlation (Fig. 7 & 10). In some parts of the estuary, the signs of initial spreading of American lotus and white water lily, two dominant aquatic vegetation types, were observed. According to the Landsat5 TM images, The highest aquatic vegetation spread over the surface water is in late August (Fig.4). Therefore, the detection of many water bearing pixels as vegetation by the satellite leads to a decrease in the correlation between the parameters of interest (Fig. 7 & 10). The low spatial resolution of the Landsat5 TM images (pixel size 30 m by 30 m) leads to this problem limiting useful information to uncontaminated pixels.

In early June, the lower correlation, between the total particulate concentration and the chlorophyll absorption values, denotes a decreasing algal content in the surface water. At this time, the mouth of the estuary was open and there was a slow downward flow of the creek (Fig.8). At the end of June, the mouth was closed by a sand barrier, and there was fine warm weather for the rapid growth of phytoplankton in surface water. The highest chlorophyll absorption was recorded at the end of June, and the DSR spectra shows gradually decreasing chlorophyll peak towards September, where the presence of chlorophyll is significantly low and close to zero. The reduction of the exposed area of surface water by rapid spread of aquatic macrophytes decreases the spread of phytoplankton even during the warm climatic conditions within the closed estuarine settings. Although there is a decreasing tendency of total chlorophyll content, the high correlation between total particulates and chlorophyll is observed during the period from June to September. It indicates that about 80 % of suspended particulate is composed of phytoplankton within this period (Fig.8 & 10).



August-17-2005

0.00 0.05 0.10 0.15 0.2

September-02-2005

0.00 0.05 0.10 0.15 0.20

Chlorophyll-a absorption

**Fig.8.**The temporal variation of

total particulate concentration as

a % volume vs. Chlorophyll-a

 $R^2 = 0.75$ 

y = 0.09x + 0.09

 $R^2 = 0.01$ 

0.01

Fig.9. Calibration curve for Total Suspended Particulate concentration in estuarine surface water, measured by Malvern Mastersizer 2000, shows a high correlation (0.76) with NDWI when there is considerable surface water exposure. The curve can be used to detect the total particulate concentration in summer by determining NDWI in near real time Landsat5 TM satellite images. This user friendly tool minimizes the time and effort on field visits, sample collection, and analyzing techniques.

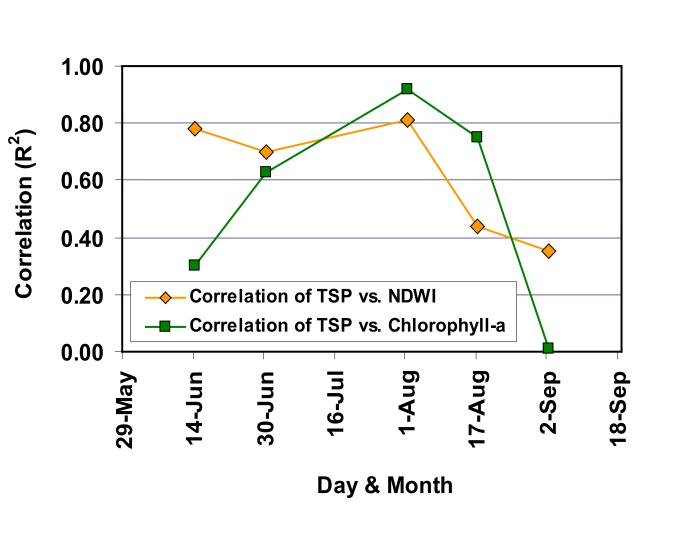


Fig.10. The graph shows trends in correlation between the three parameters; TSP concentration, Chlorophyll-a absorption, and NDWI. Almost all of the surface particulates were composed by phytoplanktons in July and August. The gradual increase of correlation between Chlorophyll-a absorption and TSP concentration indicates the initiation and growth of algal bloom in early-mid summer, where as the relationship decreases in mid-late summer due to decay of surface phytoplanktons. In June and September TSP signal dominates the

## CONCLUSIONS AND FURTHER STUDIES

Calibration of satellite images for Total Suspended Particulate concentration (TSP) in estuarine surface water is a user friendly tool in detecting estuary conditions in early or later years. Pseudocolor images resulted from NDWI analysis helps to differentiate the apparently water bearing land cover.

NDWI values analyzed from Landsat5 TM data correlates with TSP concentration in the surface water.

This relationship is applicable only when there is sufficient open water in the estuary between March and October. The highest average total particulate concentration of estuarine water recorded around April each year during past few

The spectrophotometric measurements evaluate the role of phytoplankton as a component in surface suspended particulate during summer.

Further studies on the same parameters through out several seasonal cycles will allow us to evaluate the time dependent behavior of the system.



Surface water samples were collected at 15 GPS referenced locations within the estuary during days with Landsat5 overpasses (Fig.1). The investigation period was from June to September 2005. One hundred milliliters of water was filtered onto a 47 mm Glass Fiber (GF) filters and used to quantify the algal component by Diffuse Spectral Reflectance (DSR) Spectra, using an ASD LabSpecPro FR spectrophotometer, which is a quick and efficient method of measuring chlorophyll content. The resulting reflectance spectra were corrected for background using a blank GF filter reflectance according to following equation. Corrected Reflectance = 1 - (Blank) + (Measured Reflectance)

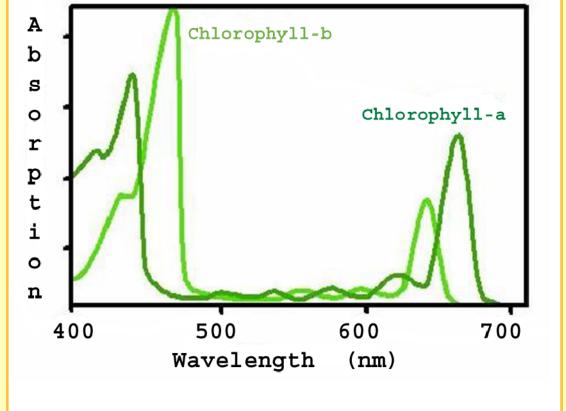
The absorption, estimated by spectra of log (1/Reflectance) was plotted against the wavelength in order to measure the peak of chlorophyll absorption at 662 nm (Fig. 2 & 3). Linear base line interpolation, a method of determination of absorption peak height, was applied to achieve a relative quantitative measure of the total chlorophyl present in surface water.

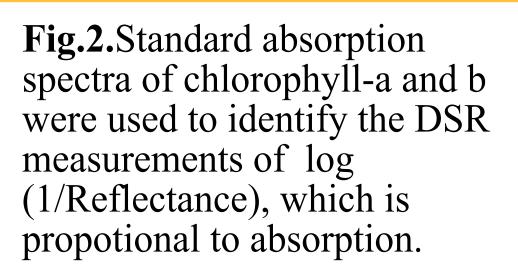
Total suspended particulate (TSP) concentration was measured directly by the Malvern Mastersizer 2000. The concentration is detected by the scatter of laser beam due to suspended particulate, passing through the sample cell.

Satellite image analysis was performed using PCI-Geomatica software, which is a convenient tool in remote sensing. Red, Green, and Blue (RGB) composites of dark object subtracted Landsat5 images were used to define the real estuarine extent. Normalized Difference Water Index (NDWI) was calculated for the series of image subsets to extract the apparently water bearing pixels of the estuarine settings. **R** stands for reflectance of a Landsat satellite data band.

$$NDWI = (Rgreen - RSWIR) / (Rgreen + RSWIR)$$

NDWI for each location was correlated with the total particulate concentration and an empirical calibration curve was generated. Chlorophyll absorption was also compared with both above parameters to evaluate the variation of algal component in suspended particulate during summer 2005. The temporal variation of TSP concentration in surface water during summers from 1999 to 2005 was interpreted based on the generated algorithm (Fig.11).





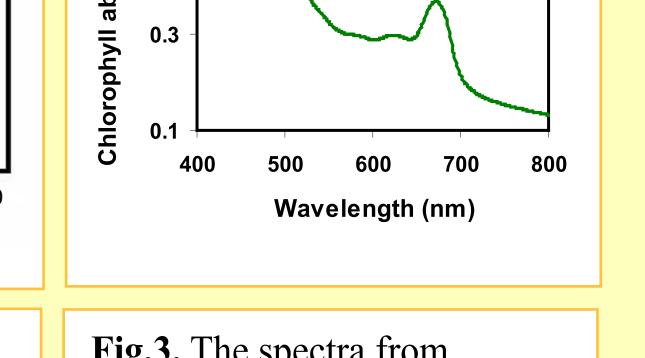
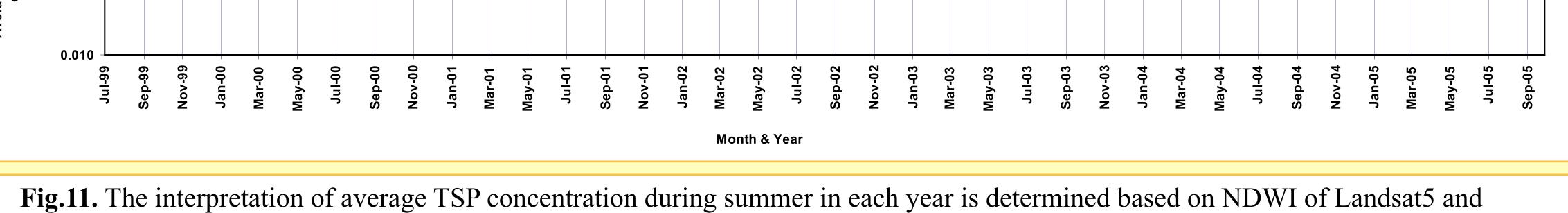


Fig.3. The spectra from LabSpecPro FR spectrophotometer dominate the presence of chlorophyll-a at 662 nm.



Landsat7 images from 1999 to 2005.

April or May records the highest TSP concentration in 2001, 2002, 2004, and 2005. According to statistics of Ohio Department of Natural Resources, 80% of the watershed is covered with agricultural lands. The dominance of agricultural activities in the watershed during this season, local precipitation, and development or breakdown of the sand barrier at the estuary mouth governs the variation of TSP in this environmental setting.

A decrease of the parameter towards September could be due to establishment of vegetation cover in farmlands minimizing soil erosion, less precipitation over the watershed, and development of the sand barrier restricting the water flow between the estuary and Lake Erie.

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