Title of Proposal: Estimation of Water Quality Parameters for Lake Kemp Texas Derived From Remotely Sensed Data.

Statement of Critical Regional Water Problems:

Protection and maintenance of water quality is a primary objective for watershed or resource managers. Increase of chlorophyll a, turbidity, total suspended solids (TTS) and nutrients in lakes are symptomatic of eutrophic conditions (Shafique el al. 2002). Sediments also affect water quality and thus its suitability for drinking, recreation and other activities. It serves as a carrier and storage agent for nitrogen, phosphors and organic compounds that can be indicators of pollution (Jensen 2000).

Introduction

Inland water bodies are considered important ecological and sociological zones. Many lakes (natural and man-made) and rivers are the main sources for drinking water as well as for agricultural usage. According to Brooks et al. (2003) the water quality standard refers to the physical, chemical, or biological characteristics of water in relation to a specific use.

The traditional measurement of water quality requires in situ sampling, which is a costly and time-consuming laboratory effort. Because of these limitations, it is impractical to cover the whole water body or obtain frequent repeat sampling at a site. This difficulty in achieving successive water quality sampling becomes a barrier to water quality monitoring and forecasting (Senay et al. 2001). Remote sensing techniques can be used to overcome these limitations by providing an alternative means of studying and monitoring water quality over a wide range of both temporal and spatial scales. Several studies have confirmed that remote sensing can meet the demand for the large sample sizes required for water quality studies conducted on the watershed scale (Senay el al., 2001). Hence, it is not surprising that a significant amount of research has been conducted to develop remote sensing methods and indices that can aid in obtaining reliable estimates of these important hydrological variables. Several researchers have developed regression formulas to predict several lake water quality parameters from satellite data by employing spectral ratios or indices.

The purpose of this study is to estimate chlorophyll a concentration, total phosphorus concentration, and turbidity using spectral indices. Spectral indices developed by Shafique et al, 2002 for hyperspectral data will be modified in order to make them suitable for use with multispectral remote sensing, specifically the Moderate Resolution Imaging spectrometer (MODIS) onboard NASA's 'Terra' and 'Aqua' Earth observation satellites. We plan to test these modified indices to Lake Kemp, Texas. This will include determination of the optical properties of the water parameters mentioned above and selection of spectral bands that are used in the indices. Remote sensing data will be validated with field measurement to test the accuracy of the indices. The final objective is to present and provide sequential and spatial images of water quality estimates to provide decision makers with easily applicable information.

Significance:

Traditional water quality measurements require in-situ sampling that is limited to randomly selected points in a river or lake. Thus, the cost and time can lead to limitations in the sampling attempt because broad sampling of an entire large water body is not possible using these methods. A potential method to overcome these limitations and gather data from across a wide range of temporal and spatial scales is remote sensing. A major significance of this approach is

that it estimates water quality parameters that are representative of the entire water body, rather than just the sampling points in the conventional methods.

Materials and Methodology

Study area: Lake Kemp is located on Wichita River north of Seymour in Baylor County, Texas. It covers an area of 15,590 acres with a maximum depth of 53 feet, has a depth fluctuation of 6-8 feet annually and 4-6 feet depth visibility. The annual precipitation is 24 inches/year, average temperature is 63^{o} F and the elevation is 1,114 ft above mean sea level.
Data: We plan to utilize MODIS imagery from May 2001 to January 2002, covering two periods of the dry and wet seasons for Lake Kemp, for our initial model development. Five MODIS 'water bands' will be used in this study. Concurrent limnological data, collected by Dr. Gene Wilde of the RWFM department of TTU (support letter to be submitted latter), will be used. These limnological data include chlorophyll, phosphorus and turbidity measurements collected from Lake Kemp during 2001-2002. MODIS data are available on a daily basis, and are free for research use (Reference). After the initial development of 'spectral reflectance vs. limnological parameters' relationships, we also plan to collect data from the wet and dry seasons of 2006 to validate and refine our models.

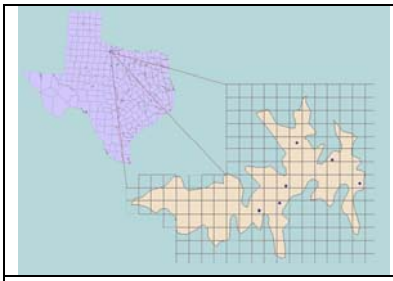

Fig.1. Map of Lake Kemp, Baylor county, Texas showing where the ground samples where taken. Each grid represent the MODIS water bands pixel size(1 km x 1km)

Work Plan and Timeline

1- Images will be downloaded from the NASA EOS Data Gateway site: http://delenn.gsfc.nasa.gov/~imswww/pub/imswelcome/ (March, 2006)
2- To represent a consistent unit in the imagery, the lake will be isolated by masking, using ERDAS Imagine software (March-May, 2006)
3- Simple linear regression will be used to determine the relationships between the MODIS derived spectral indices and water quality parameters of the pixels from where water data were collected (May-June, 2006).
4- Maps of water quality will be derived using these regression models (June-August, 2006).
5- Field data from 2006 will be used to validate the models (Sep-Dec, 2006).

Criteria of MODIS Band Selection:

The reflectance of a water body depends upon absorption and scattering of incoming radiation. This absorption and scattering is a function of the material present in the surface water (Senay et al., 2001). According to Jenson (2000), visible wavelengths between 580 – 690 nm may provide information on the type of suspended sediment in the surface water, while the near-infra red wavelength range of 714 – 880 nm can be useful for determining the amount of these materials. In addition, Gitelson (1992) and Rundquist et al. (1995) found that strong *chlorophyll a* absorption of red light is approximately at 675nm and the predominant reflectance peak is around 690 – 700nm. Thus the height of this peak above the baseline (670 – 750nm) can be used to measure chlorophyll amount (Rundquist et al., 1995). Han and Rundquist (1997) and Rundquist et al. (1996) estimated the chlorophyll pigment amount in surface water using the ratio of near-infra red (705nm)/ red (670nm) ratio when the concentration was low. On the other hand, the best result was derived from reflectance around 690nm when chlorophyll concentration was high. Regions of the spectrum at wavelengths near 450-550nm, 675-750nm and 800-1000nm were found to be good estimators of turbidity (Senay et al., 2001).

Model Development:

Based on these above-mentioned assumptions, this study proposes modification of water quality indices developed using hyperspectral remote sensing by Shafique et al., (2002) to make them useable with multispectral sensors. The indices proposed by Shafique et al., (2002) were:

$$chlorophyll\ a = 48.849(R_{705} \div R_{675}) - 34.876 \quad (1)$$

$$Total\ Phosphorus\ (TP) = 0.18081 \times \log(R_{554} \div R_{675}) - 0.0371 \quad (2)$$

$$Turbidity = 186.59(R_{710} - R_{740}) + 8.5516 \quad (3)$$

where R is the reflectance at the spectral wavelength (nm) expressed by the subscript number.

We propose to use reflectance values of MODIS bands #13 (662 – 672nm) and #14 (673 – 683nm) to estimate *chlorophyll a* concentration, #15 (743 – 753nm) and #16 (862- 877nm) to estimate turbidity, and #14 (673 – 683nm) and #12 (546 – 556nm) to estimate total phosphors (TP). Hence, the water quality indices modified for MODIS bands will be:

$$chlorophyll\ a = 48.849(b14 \div b13) - 34.876 \quad (4)$$

$$Total\ Phosphorus\ (TP) = 0.18081 \times \log(b12 \div b14) - 0.0371 \quad (5)$$

$$Turbidity = 186.59(b16 - b15) + 8.5516 \quad (6)$$

where b and the subsequent numerals stand for MODIS band numbers.

Expected Results:

Estimation of chlorophyll a concentration derived from the spectral indices must show a strong correlation with site measurements. With respect to turbidity, good correlation should be detected with MODIS bands 15 and band 16.

References

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