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Remotely Sensed Data: Information for Monitoring Dynamic Wetland Systems

PURPOSE: Digital imagery (or digital data) acquired by commercial remote sensing satellites, combined with inexpensive PC-based image processing software provides an efficient and cost-effective capability/technique for monitoring changes to wetland systems. This paper describes some of the potential of this imagery as well as some of the limitations and difficulties inherent in the use of remotely sensed data. Differences between the types of imagery available are described as well as the types of techniques which may be employed to analyze/manipulate the imagery. An example application of the use of this imagery for routine change detection is described.

BACKGROUND: Since the 1972 launch of the first Landsat satellite, the earth's surface has been routinely monitored by sensors specifically designed to study the earth's natural resources. There have now been five Landsat satellites placed successfully in orbit, providing a nearly continuous archive of imagery over the United States. In 1986, the Landsat satellites were joined by the French SPOT series of satellites in their earth observing mission. As satellite imagery represents an effective way of studying large areas of the earth's surface, a great deal of attention has been directed toward using this imagery to map or monitor wetland systems. The Corps of Engineers Wetlands Research Program has published a bibliography of these efforts classifying them by wetland and sensor type (Lampman, 1992).

The use of digital imagery from space platforms has mainly been limited to research laboratories and universities due to the large amount of disk space required to handle the data, the cost of the hardware and software to manipulate the imagery, and the CPU-intensive nature of the algorithms required to extract information from the raw data. These limitations have, for the most part, been overcome by rapid advances in processor speed and the reduction in prices of computer equipment and image analysis software. A computer based on an Intel 80486 CPU, with a disk capacity of 500 megabytes or more and a tape drive or CD/ROM player is all that is required to load, display, and manipulate satellite imagery. Of course, the types of analyses conducted will depend on the software used and the level of expertise of the analyst.

Recently inexpensive software tools have become available which allow users with minimal experience in image processing techniques to load and display satellite imagery and to analyze these data in concert with data stored in a geographic information system (GIS) database. Nearly all the GIS software vendors now offer "query" software which allows users to load imagery, overlay GIS information which has been input in a full-blown GIS, and to output color hardcopy products. Also, imagery vendors have begun to provide an array of products from the raw imagery which make the data easier to use. For example, both EOSAT and SPOT have for some time provided imagery which has been geocorrected (or georeferenced) to a map projection (such as the Universal Transverse Mercator projection). This means that the data can immediately be incorporated into a GIS database and the user is relieved of this laborious task. SPOT Image Corporation has also developed a suite of products which reduce the amount and complexity of processing required of the end user and which help limit the amount of data which must be purchased to meet the needs of a project. For example, SPOT will provide data to match standard USGS map frames, including a 7.5 × 7.5 minute (Latitude/Longitude), 15 × 15 minute, or 30 × 30 minute map sheet, in any projection. Users can also opt to buy imagery by the square mile (for a project boundary) or by linear mile along a corridor (such as a river channel, highway, etc.) This means that users only have to purchase the imagery required for their specific application, and it is delivered in a format which can immediately be loaded into a GIS or "query" system. EOSAT also offers a number of options for purchasing less than a full image, including half and quarter scenes.

In the past, satellite data were usually furnished on large 9-track tapes. Nine-track tape drives are extremely expensive items, often costing more than the computers to which they are attached. Today, both SPOT and EOSAT offer data on 8mm tapes, and SPOT has recently begun distributing products on CD/ROM.

TYPES OF DATA AVAILABLE: This technical note only addresses data which are available from the Landsat and SPOT satellites. These satellites carry passive sensors which image the earth in the visible and infrared portions of the spectrum.

When discussing digital image data there are two types of resolution which must be considered: spatial and spectral. Spatial resolution deals with the size of each picture element (or pixel) in the image. The coarser the spatial resolution, the less detail will be visible in the imagery. Spectral resolution deals with the number and width of the portions of the spectrum imaged by the sensor. Most remote sensing instruments divide the spectrum into a number of sections and measure the radiation within each of these "bandwidths." By combining three of these sets of measurements it is possible to produce a true or false-color composite image. Multiple bands of image data are also useful for conducting statistical analyses using image processing software. Table 1 below lists the instruments that have flown on the Landsat and SPOT satellites and their respective characteristics.

Satellite	Sensor	Date	Spatial Resolution	Spectral Resolution
Landsat 1-5	MSS (Multispectral Scanner)	1972-Present	80 x 80 meters	4 channels (visible and near-infrared)
Landsat 4-5	TM (Thematic Mapper)	1982-Present	30 x 30 meters	7 channels (visible, near and middle infrared, and thermal
SPOT 1-3	Panchromatic	1986-Present	10 x 10 meters	1 channel (visible)
	HRV	1986-Present	20 x 20 meters	3 channels (visible, near-infrared)

TYPES OF ANALYSES WHICH CAN BE CONDUCTED: The types of analyses which can be conducted on imagery are many; essentially, they can be grouped into two types: manual interpretation (sometimes referred to as photointerpretation) or quantitative analysis. The types of analyses which are to be conducted on imagery will depend both on the capability of the software and the knowledge of the analyst. In short, information may either be extracted by manual methods or through extensive digital/image processing.

Often, a great deal of information can be gathered simply by analyzing imagery on a computer screen. For example, one can tell instantly whether or not an area has been cleared by simply "viewing" the data in black&white or as a false-color composite. For this simple type of application spatial resolution is much more important than spectral resolution and SPOT panchromatic data are probably the best choice. However, when using satellite imagery to produce a characterization of land-cover in an area, multispectral data are required and Landsat TM may be more useful (even though the spatial resolution is only 30 meters as compared to 10 meters for SPOT panchromatic data). Therefore, it is important to consider how the data will be used and what is to be extracted from the imagery.

Multispectral classification of satellite data makes use of the fact that different surface cover types reflect the sun's radiation differently within each of the portions of the spectrum which the sensors image. By analyzing the unique "signatures" of cover types with statistical analysis algorithms, it is possible to produce a land cover classification of an area. This type of analysis requires a good deal more knowledge by the analyst, as well as much more sophisticated (and expensive) software. Work under the Wetlands Research Program has shown that it is very difficult, if not impossible, to map wetlands with imagery alone, particularly when dealing with bottomland hardwood wetlands. However, land cover classifications of satellite imagery can be useful for analyzing changes in adjacent uplands. Multidate imagery (i.e. data acquired at different times) can improve the ability to discriminate between wetland cover types but it is often difficult to obtain imagery at the correct times of the year and processing of more than one data set increases the cost.

The true value of satellite imagery is recognized when the data are used in conjunction with other forms of geographic data in a GIS. Imagery data are easily integrated with GIS systems. For example, it is possible to store information related to the hydric properties of soils, National Wetlands Inventory (NWI) data, wetlands permit data and analyze these data with satellite imagery used as a backdrop. By analyzing multiple dates of satellite imagery it is possible to identify recently developed or cleared areas near potential wetlands. By overlaying hydric soils and the NWI data, it is possible to further determine the likelihood that the suspect areas were originally wetlands. The user can then overlay wetlands permit information and determine whether or not a permit was issued for development. The satellite imagery can be analyzed in a black&white mode or, if the data are multispectral, a false-color composite can be generated. This example use of satellite imagery is one which involves relatively little processing of the imagery by the end user, and can be accomplished with minimally priced software ($\approx$ \$300.00). The main effort involved in such applications is related to developing the digital databases and in purchasing the imagery data.

LIMITATIONS OF IMAGERY DATA: Although imagery data can be extremely useful for change detection and monitoring efforts, satellite data can also present a number of challenges. For example, it is often difficult to obtain an image over the area of interest during the desired timeframe. The revisit characteristics of the satellites, as well as the presence of cloud cover, can limit the availability of data. When change detection is being conducted, this is less of a problem as data from the archive is useful. However, the limitation is critical when data are required in a very specific timeframe; for example, when imagery must coincide with field data collection.

Other limitations arise from the spectral and spatial resolution of the data. The limited spatial resolution of Landsat TM and MSS data sometimes presents problems when the features studied are rather small (or narrow). Riparian wetlands often represent this type of problem. In change detection studies, it may also be difficult to detect minor intrusions into a wetland area ("nibbling"). The spectral resolution of satellite imagery often limits the ability to accurately detect more than a few wetland types and classes. However, some of these limitations are removed when the data are used with ancillary data in a GIS database. Recently the Federal Geographic Data Committee (FGDC) published a report addressing the application of satellite data for wetlands mapping and monitoring (FGDC Wetlands Subcommittee, 1992). This report outlines a number of benefits and limitations of satellite data as well as the experiences of a number of Federal agencies and other organizations in applying these data for wetland studies.

AN EXAMPLE OF A CHANGE DETECTION APPLICATION: The WES Environmental Laboratory has been involved in a major effort to characterize changes to the wetlands in the Cache River basin in Arkansas. As a part of this study, remote sensing data (Landsat) were acquired for multiple dates and these data were evaluated for monitoring the wetlands over the entire basin ($\approx$ 6 km $\times$ 20 km). Visual analysis techniques were employed as well as quantitative multispectral classification. It was often difficult to obtain data at the optimum date for classification, and frequently the best date for analyzing forest classes didn't coincide with the best date for analyzing agricultural patterns, marsh plant cover, etc. This meant that multiple dates of imagery were required to get the best results. Also, without the aid of soils information, a digital elevation model, and hydrography data it was difficult to consistently differentiate uplands forest areas from bottomland hardwood wetlands.

Some of the most exciting uses of imagery data were from simply analyzing the data in conjunction with the other in the contained data GIS. Areas of clearing, for example, were immediately identified. Figure 1 represents a portion of the NWI data for the Cache River basin. The large dark feature along the eastern portion of the basin is classified as a palustrine-forested wetland. However, in Figure 2, which is a black&white portrayal of a false-color composite, it is apparent that most of the area has been cleared. By analyzing previously acquired imagery of the area it was apparent that the area had been cleared between the time the aerial photography which was used to compile the NWI map was obtained and the time the satellite imagery data were obtained. The query software which was used to manipulate these data provided the ability to quickly overlay soils data to determine whether or not the soils in the area were hydric in nature and to display the hydrology of the area. By analyzing the basin in this manner it was possible to isolate errors both in the landcover classifications derived from the satellite imagery as well as in the NWI data. This type of quick, simple access to spatial data and the ability to get repeated, inexpensive snapshots of an area in the form of satellite imagery represents a powerful analysis and site monitoring tool.

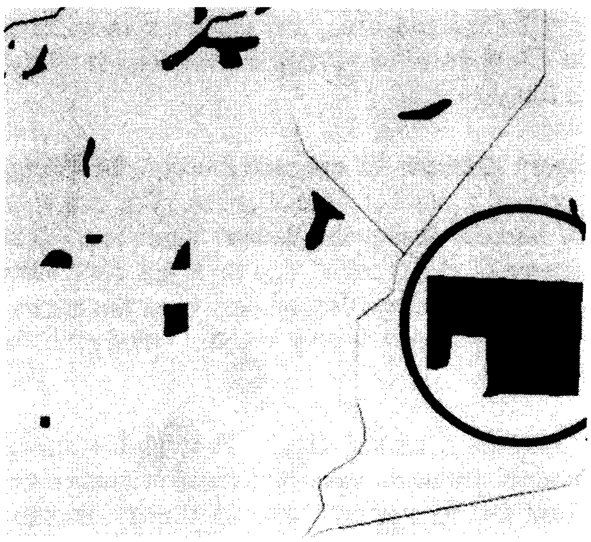

Figure 1. NWI data showing palustrine-forested wetland

Figure 2. Black and white image of false-color composite showing cleared forested area

RESULTS: Satellite imagery data together with image processing techniques represent a unique tool for monitoring wetlands. Recent developments in terms of software, hardware, and the availability of derived products have removed many of the limitations associated with effectively using remotely sensed data. Users should be cautious, however, when selecting imagery to be used for a specific application, carefully taking into account such things as the optimum date to analyze the features of interest, and the spatial and spectral characteristics of the sensors.

SOURCES FOR MORE INFORMATION: Both SPOT Image and EOSAT produce newsletters which describe the products offered as well as outline some of the applications of these data. Subscriptions to these newsletters are available free of cost and may be obtained by calling the telephone numbers listed below.

ADDRESSES AND PHONE NUMBERS OF IMAGERY SUPPLIERS:

EOSAT
4300 Forbes Boulevard
Lanham, MD 20706
(800)344-9933

SPOT Image Corporation
1897 Preston White Drive
Reston, VA 22091-4368
(703)715-3100

FOR MORE INFORMATION CONCERNING REMOTE SENSING APPLICATIONS WITHIN THE CORPS: The Corps of Engineers has establish a Remote Sensing/GIS Support Center to assist Corps district offices in the application of remote sensing technologies. The address is:

U.S. Army Cold Regions Research & Engineering Center
ATTN: Remote Sensing/GIS Support Center (CECRL-RSGISC)
72 Lyme Road
Hanover, NH 03755-1290
(603) 646-4372

REFERENCES:

Lampman, J. L. 1992. "Bibliography of remote sensing techniques used in wetlands research," Technical Report WRP-SM-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

FGDC Wetlands Subcommittee. 1992. "Application of satellite data for mapping and monitoring wetlands: Fact finding report," Technical Report 1, Federal Geographic Data Committee, Reston, VA.

POINT OF CONTACT FOR ADDITIONAL INFORMATION: Mr. Mark R. Graves, U.S. Army Engineer Waterways Experiment Station, ATTN: CEWES-EN-C, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, phone: (601)634-2557, author.