Using Landsat Thematic Mapper and SPOT Satellite Imagery to Inventory Wetland Plants of the Coeur d'Alene Floodplain

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Abstract.—Landsat Thematic Mapper (TM) and SPOT Satellite Imagery were used to map wetland plant species in the Coeur d'Alene floodplain in northern Idaho. This paper discusses the methodology used to create a wetland plant species map for the floodplain. Species mapped included common cattail (*Typha latifolia*); water horse-tail (*Equisetum fluviatile*); water potato/arrowhead (*Sagittaria* spp.); and wild rice (*Zizania aquatica*). Useful classifications were derived and lessons were learned about the timing of image acquisition and field data collection. This will guide improved classifications in the future.

Remote sensing technology and GIS are powerful tools useful in analyzing complex ecosystem problems. The objective of this research work was to use these tools to map and quantify a part of the wetland plant components of the Coeur d'Alene floodplain ecosystem, specifically common cattail (*Typha latifolia*), water horsetail (*Equisetum fluviatile*), water potato/arrowhead (*Sagittaria* spp.), and wild rice (*Zizania aquatica*). These four plant species have been identified by the U.S. Fish and Wildlife Service (FWS) as waterfowl food items in the ecosystem. The Coeur d'Alene River floodplain was the area chosen for the research (fig. 1).

During the past 100 years, much of the Coeur d'Alene River floodplain became contaminated with heavy metals such as zinc, lead, and cadmium from mining activities. Since the 1880's, mining and smelting activities in the Kellogg, Smelterville, Wallace, and adjacent areas have released an estimated 75 million tons of tailings into the South Fork of the Coeur d'Alene River (Horowitz *et al.* 1993). Contaminants from these tailings have washed into the lower Coeur d'Alene River and lake system (Keely *et al.* 1976, Horowitz *et al.* 1993). Waterfowl mortality related to heavy metal poisoning, particularly among tundra swans, was reported in the lower Coeur d'Alene River valley as early as 1924 (Chupp 1956). Other reports by Benson *et al.* (1976), Neufeld (1987), and Blus *et al.* (1991) document more recent waterfowl mortality due to heavy metal poisoning. By quantifying the four wetland plant species, we can learn more about how the ecosystem of the Coeur d'Alene floodplain functions.

METHODS

Three different techniques were used to enhance digital imagery for classification and mapping of the wetland plants. First, image merging of a Landsat TM scene with a SPOT Panchromatic scene of the same date was completed to create an image with higher spectral and spatial resolution. Second, FWS National Wetlands Inventory (NWI) maps (Cowardin 1979) were incorporated as ancillary data. The third technique involved the use of NWI polygons to mask out the upland areas to focus more specifically on the spectral response patterns in the floodplain.

Image Merging

The merge of the SPOT and TM scenes was processed on a Sun Sparc 10 Model 30 workstation with 138 megabytes of swap space and 64 megabytes of RAM. The software used to merge the images was ERDAS Imagine, Version 8.2. To reduce computer processing time, only three of the seven TM bands were processed. TM bands two (green), three (red), and four (NIR) were used for the image merge. This band selection was the default in the ERDAS Imagine software for the Brovay transformation (ERDAS 1994). Brovay transformation was one of several different merging algorithms that could be used in the ERDAS Imagine software. The resampling technique used for the resolution merge was cubic convolution. Cubic convolution recalculates the values for the new cells by using a weighted average of values within a neighborhood of some 25 adjacent pixels (Campbell 1987). ERDAS Imagine software was chosen because it was the only software available that provided image merging techniques. Comparisons of the image resolutions used in the project are found in table 1.

Ancillary Data

Ancillary data can be integrated with remotely sensed imagery to increase the reliability of image classification (Campbell 1987). By using only satellite or remotely sensed images, classification is limited to using only electromagnetic energy as it is reflected from the Earth's

Natural Resources Department GIS, Coeur d'Alene Tribe; Department of Forest Resources, University of Idaho, respectively.

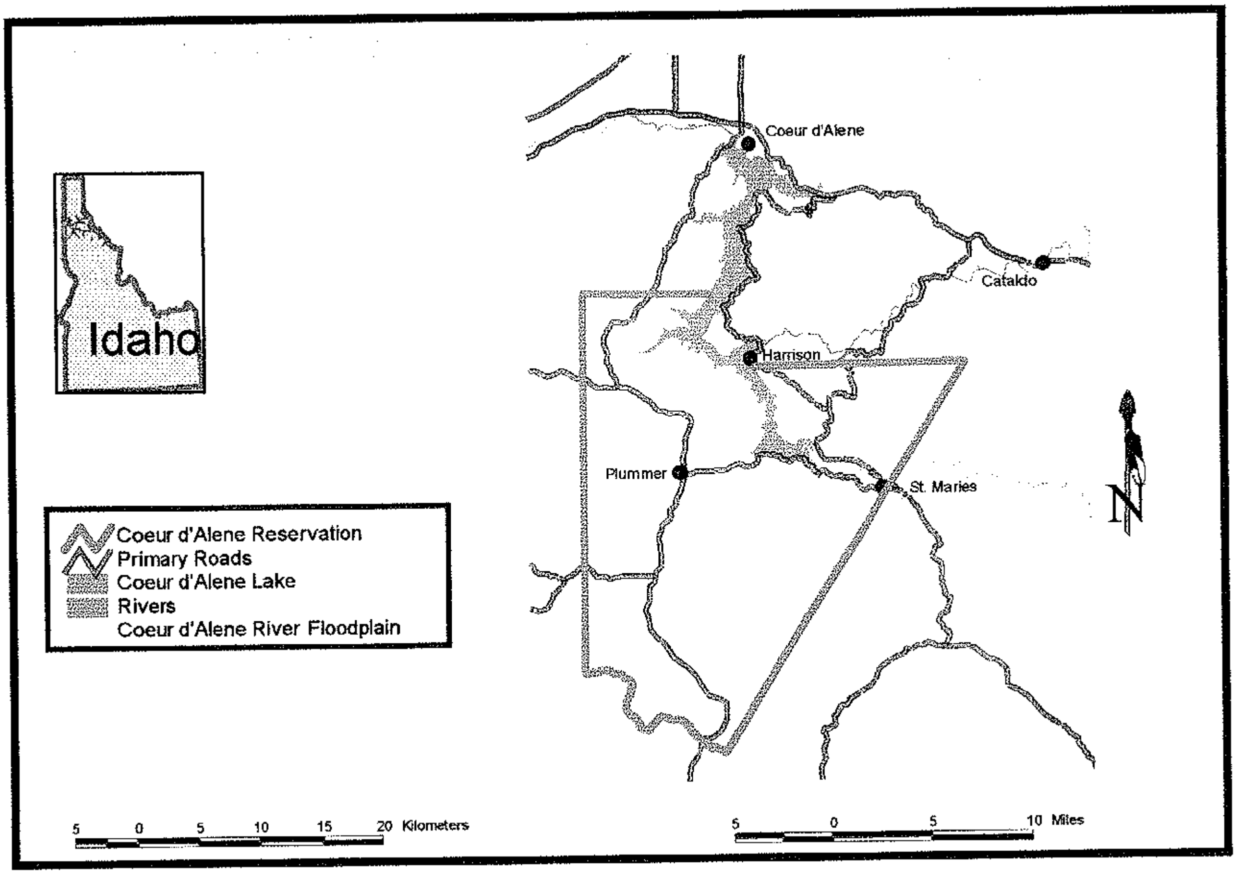

Figure 1.—*Locations of Coeur d'Alene River floodplain.*

Table 1.—*Comparison of criteria for all image formats used on Coeur d'Alene floodplain project*

Image format	Spatial resolution	Spectral resolution width	Bands	Temporal resolution
	m	*m*	*Number*	*Date*
SPOT Panchromatic	10 x 10	0.22	1	6/18/92
TM	30 x 30	0.08-0.14	7	6/18/92
Merged image	10 x 10	0.08-0.14	3	6/18/92

surface. When observing objects such as plants, reflective responses may change over time due to climate and seasonal growth patterns. However, certain features do not change over the course of the year, such as geologic features, soil types, and wetland habitat types. By integrating data on the distribution of these features with satellite imagery, the analysis algorithms are provided with additional data to aid in classifying the imagery.

Fish and Wildlife Service NWI data (fig. 2) were digitized from 1:24,000 scale maps by the Coeur d'Alene Tribe and the Bureau of Land Management (BLM) for use on the project. This layer was converted to raster format using the Arc/Info POLYGRID command. The grid was exported out of Arc/Info into band interleave by line (BIL) format using the Arc/Info command GRIDIMAGE. The BIL file was then brought into the ENVI image analysis software where they could be joined with the remotely sensed imagery.

Identification of Training Areas

In the process of supervised classification, it is necessary to provide the computer program with site locations of known vegetation. Site locations are known as training areas (Campbell 1987). Either point or polygon-type GIS coverages were developed for each of the four plant species of interest. These data files will be referred to as "training coverages."

Training coverages were compiled using two different methods. The first method used a Trimble Basic Plus resource-grade GPS unit to collect a point or a polygon of the vegetation. Both FWS and BLM field staff assisted the GIS staff in locating large patches of the desired vegetation. Preferred size for vegetation patches was 52.5 x 52.5 m or larger. Patches of this size enabled one pixel (17.5 m) of the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data to be free of edge effect that could be caused by other vegetation (fig. 3). The minimum acceptable patch size for the training data was set to 17.5 m. Analysis of the AVIRIS imagery will be reported elsewhere. In the field notes for the GPS units, an ocular estimate of patch size was recorded. Patch size was useful when selecting training sites on the imagery. Larger homogeneous patches of plants of the preferred size were found only in a few cases. The collection process was difficult because the wetland vegetation was extremely dense. Most of the transportation around the units was done in a canoe or a kayak. In some parts of the marsh, it was physically impossible to move the one-person kayak through the dense plant growth.

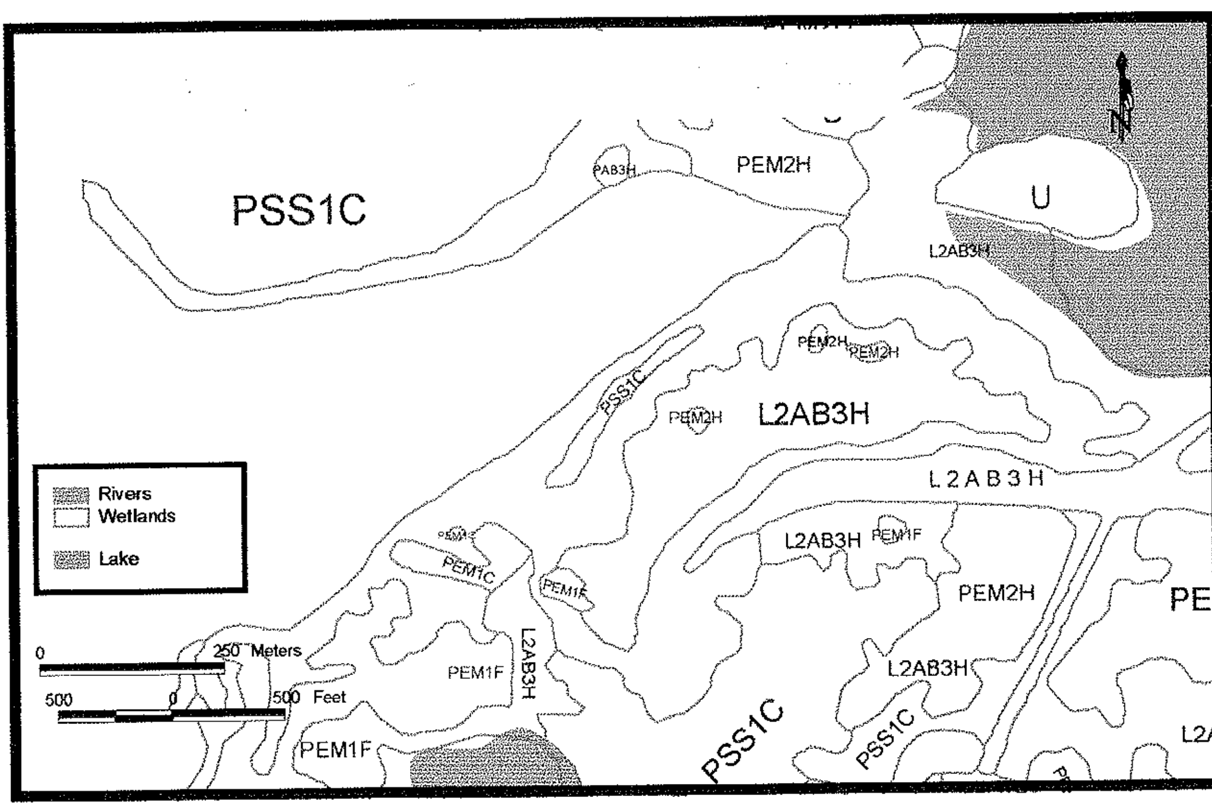

Figure 2.—*Sample National Wetland Inventory (NWI) GIS layer.*

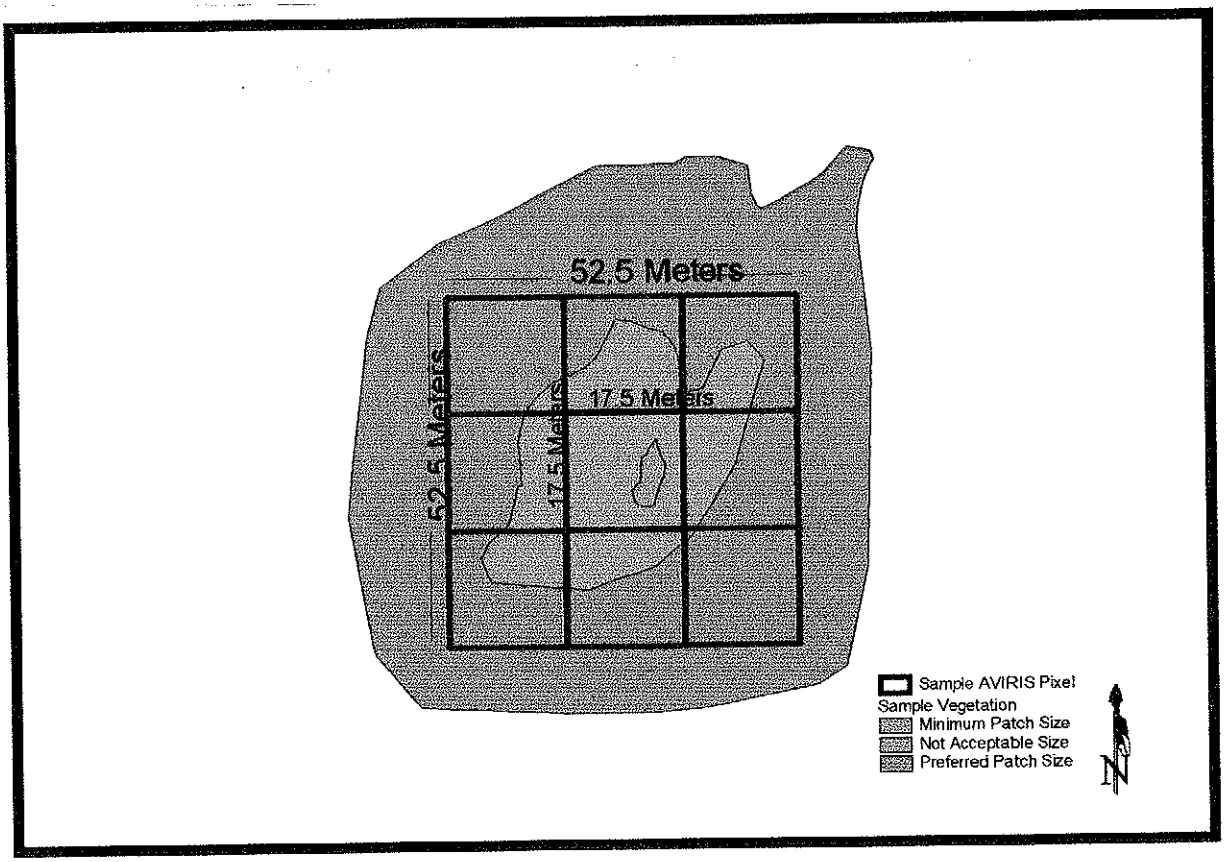

Figure 3.—*Example of AVIRIS 17.5 m pixel size in relation to training site.*

The GPS data were differentially corrected using Trimble's Pathfinder software version 2.5. The accuracy of resource grade GPS after differential correction is stated at 3 to 5 m (Trimble Navigation 1991). Using Arc/Info, the data were then converted into a DXF file format for the ENVI Software. Nine to 18 GPS points of data were collected for each wetland plant species (table 2).

To prepare additional training data, color aerial photographs, along with the images, were manually interpreted to find more potential patches of the desired wetland plants. This process allowed for collection of training data in areas that were inaccessible by field visits. Identifying training data using aerial photos was also done by Butera (1979) in his remote sensing of wetlands in Florida. Creation of additional training data from the aerial photo interpretation was completed using the ENVI software.

Table 2.—*Number of GPS points collected for each plant species*

Plant	Cattail	Horsetail	Wild rice	Water potato
Number of GPS points	12	9	12	18

Image Masking

Non-wetland vegetation was masked out of images to prevent misclassification of vegetation (Ramsey *et al.* 1994). To accomplish this, the FWS National Wetlands inventory GIS layer was used to create a mask of the wetlands. The mask was then used to eliminate any upland areas from the classification implementation.

Image Classification

Digital image classification is a technique that has been demonstrated in the literature to provide accurate classification of wetland vegetation (Butera 1979). The two image classification methods used in this project were the Spectral Angle Mapper (SAM) and the Minimum Distance (MD) classifiers. The SAM method "is a physically-based spectral classification that uses the *n*-dimensional Spectral Angle Mapper to match the reference spectra. The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra, treating them as vectors in space with dimensionality equal to the number of bands" (ENVI 1996). The

MD technique uses the mean vectors of the combined training sites for a given vegetation class and calculates the Euclidean distance from each unknown pixel to the mean vector (ENVI 1996).

Image analysis was run repeatedly using different input parameters to the MD and SAM classification techniques until a classified image was produced that visually matched the vegetative patterns found on the aerial photos for the study area. Changes in the input parameters increase or decrease (dependent upon the settings) the amount of vegetation identified. The FWS field staff had the greatest knowledge of vegetation types in the project area and therefore served as experts in the evaluation of the output results. Field staff evaluated the classified images from these techniques to determine if the classification matched conditions in the field. Input from FWS staff was then used to refine the image analyses.

Data Field Verification

Once the classified image was produced by the image processing software, the image was converted to an Arc/Info polygon coverage. Arc/Info's IMAGEGRID command was used to import the ENVI BIL file into Arc/Info. The grid was then converted into polygon layers using the GRIDPOLY command. Area and summary statistics for each type of vegetation were then calculated in Arc/Info. The new polygon coverage could then be used by the Arc/View GIS software. To increase the speed of display within Arc/View, the polygon coverage was converted into an Arc/View shape file. Arc/View was then used by the FWS field staff to produce maps of the study areas (fig. 4). These maps were taken to the field for ground validation.

The field verification involved the FWS staff performing an extensive field survey of the project area. The FWS staff used the classified maps in the field and identified where the maps were incorrect. After the field verification, the classified polygons were edited to correct errors based on the FWS expert judgment. Editing the shape files involved re-coding polygons with the correct vegetation code, moving existing polygon lines and vertices, and adding new polygons. This achieved the goals of acquiring accurate information to update the GIS layer. However, it did not provide completely unbiased information to produce a statistical summary of the classified image that came out of the remote sensing software before it was modified for the corrections.

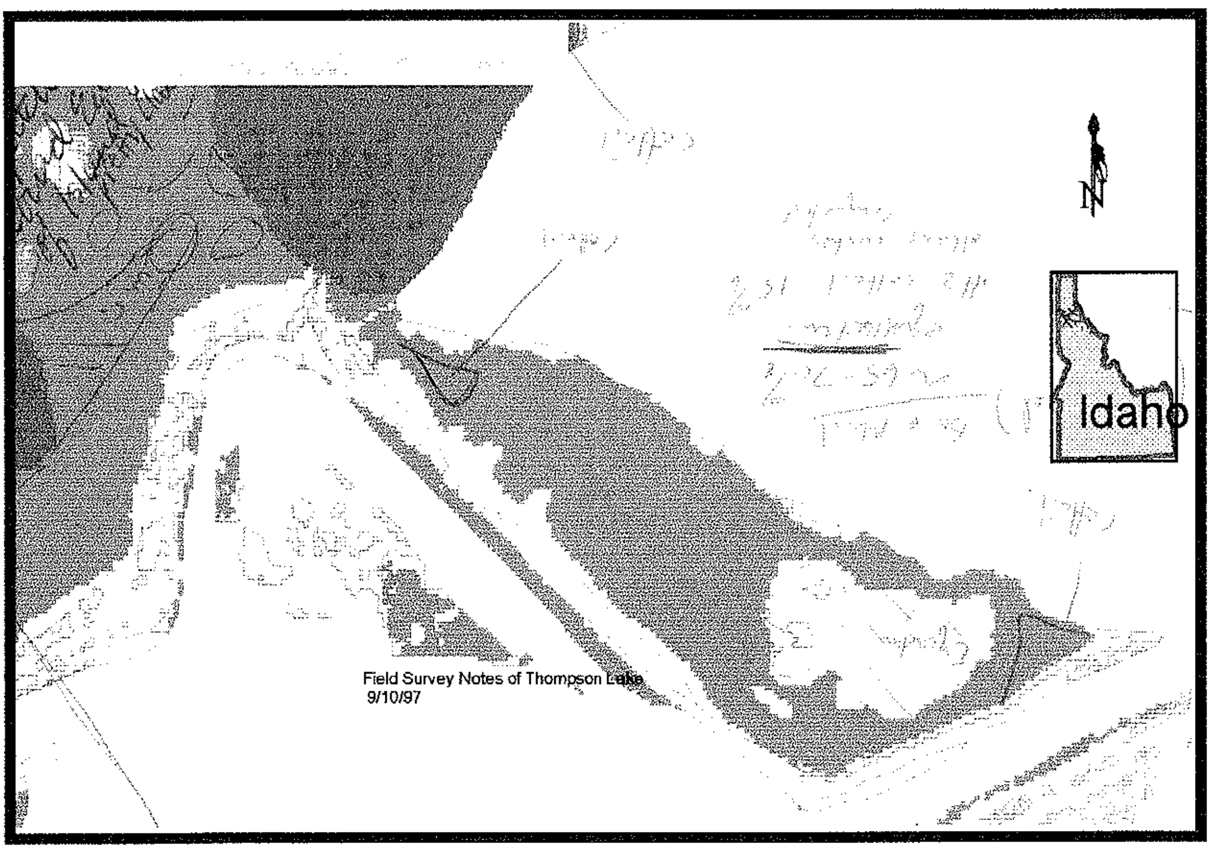

Figure 4.—*Sample ArcView field maps.*

RESULTS AND DISCUSSION

The objective of this research work was to use remotely sensed imagery to map and quantify the wetland plant components of the Coeur d'Alene floodplain ecosystem. At the end of the project this goal was met. The accuracy of the image classification in comparison to the final modified vegetation map made by the FWS was 89 percent correct (table 3). Water horsetail, which was dominant in the ecosystem, had an accuracy of 74 percent correct; less frequent species such as cattail, water potato, and rice had lower accuracies (63, 39, 63 percent, respectively).

Table 3.—*Percent correct on image classification compared to final plant map for each plant species*

Plant	Cattail	Horsetail	Wild rice	Water potato
Percent correct	63	74	63	39

Discussion

The ability to handpick the images for the project may have led to a higher level of accuracy in the final image classification. The analysis of images taken in early summer likely reduced our ability to discriminate some types of vegetation. The initial image classification might have been more accurate if the images had been collected in August when the vegetation was at its maximum phenologic development. In Thompson Lake, one of the floating islands had actually moved to a different part of the marsh in December 1995 (Snyder, M., FWS Biologist, pers. comm., 1998). Hence, the images used for this exercise misidentified the current location of the floating island and had to be corrected in the final wetland plant GIS layer. Images of the floating island that moved in Thompson Lakes are found in figure 5 and figure 6.

Locating homogenous vegetation patches that met the minimum dimension requirements was difficult. Most patches of wetland plants were found in long, narrow strips located along the shoreline. Relatively few of these patches of vegetation met the minimum width of 17.5 m to be used for training sites. In addition, most of the plant species mapped did not occur in homogeneous patches. An example of this is horsetail and water potato, which sometimes grew in together.

The on-ground training site collection provided valuable information that could be used when identifying plant species from aerial photographs. Vegetation types dominated by horsetail and cattail could be easily identified from the photographs, suggesting the utility of aerial photo interpretation for ground truthing in wetlands where access is difficult.

Examination of the images using the spectral plots of the training data revealed additional information about the data set. The NWI wetland delineation showed some degree of correlation with the location of the four plant species. For this reason, it was used as an ancillary band of information throughout the classification process.

Image masking proved to be a very useful technique. One of the benefits was that the geographic area covered by the images was reduced, which reduced the computer file size. Since the file size was reduced for each image, the image-processing speed increased. Image masking may have also increased the accuracy of the image classification.

Both image classification algorithms produced a variety of results. ENVI's SAM algorithm was a method not available with the other remote sensing software packages at the time and was highly recommended by the ENVI software support staff (Fegley, A., ENVI Software Specialist, personal communication, 1996). Yet, after repeated trials, at more than 20 different spectral angle settings, a suitable classification of the data set based on FWS's ocular inspection of the classified images was not found. Repeated tests of the MD algorithm did provide a suitable classification. This method was used in the final classification. A setting of 15 was the final MD parameter entered for the SPOT/TM image, and it seemed to produce the most representative classified image.

Conclusions and Recommendations

Many of the limitations expressed above with the SPOT/TM data may have been overcome if the scenes had been collected when the wetland plants were fully emerged. However, because of the limited 10-m resolution of the imagery, future efforts may be better invested in evaluating finer resolution imagery. One potential imagery source may be the Indian Remote Sensing 1C 5-m imagery. Another option may be to evaluate the use of resolution merging using digital orthophotos and some other form of multispectral data such as SPOT multispectral. With these two image formats, one might create a merged data set with greater spectral and spatial resolution.

Image processing software was one of the limiting factors in the project. Much time was spent in converting data between various software programs and in developing work-arounds for inadequacies in the software. One example: the ENVI software had a utility to export data into Arc/Info format, but the Arc/Info software could not

Figure 5.—*SPOT image before island moved.*

Figure 6.—*Aerial photo after island moved.*

read the "Arc/Info" format data out of ENVI. These barriers should be overcome by new releases of software.

Much of the time spent in this project was used for developing the methods to digitally classify wetland plant species. The authors are not aware of other studies attempting to identify individual wetland plants using any of the above image formats. The process outlined in this research represents only the first step in attempting to identify wetland vegetation, and more refinement and evaluation of the methods are required.

Digital remote sensing is useful in mapping wetland vegetation. As new sensors become available, delineation of individual wetland plant species may become more accurate. At this time, sensors such as SPOT, TM, and AVIRIS have limited spatial resolutions for identifying individual wetland plants. Species that grow in larger homogeneous patches may be mapped more easily than those that grow in small or mixed patches. The diversity and relatively rapid temporal changes that occur seasonally in the Inland Northwest pose great challenges to further attempts for remote sensing of wetland plants. Appropriate sensor selection and temporal criteria are crucial for successful application. These combined factors may determine that it will be possible to map only broader wetland plant community assemblages.

The modified classified image produced in this project should be used and further refined for ecosystem assessment in the Coeur d'Alene River floodplain. The wetland vegetation is just one potential piece of the puzzle required in analyzing the complex ecosystem problems that exist in the Coeur d'Alene floodplain. This layer, when combined with other spatial data such as water flow through the wetlands, animal mortality, and sediment samples, could be an extremely valuable data set for restoration and management planning activities.

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