

**A RESOURCE CLASSIFICATION AND VEGETATION CHANGE ANALYSIS  
OF THE JACKSON-FRAZIER WETLAND, BENTON COUNTY, OREGON**

by

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## **A RESOURCE APPLICATION AND VEGETATION CHANGE ANALYSIS OF THE JACKSON-FRAZIER WETLAND, BENTON COUNTY, OREGON**

**ABSTRACT** Benton County established the Jackson-Frazier Wetland as a park in 1992. My project was undertaken to assist Benton County Parks in managing the wetland. The project contains two elements: a GIS and a vegetation change analysis from 1936 to 1994. GIS coverages created in ARC/INFO were: 1) the course of the Jackson and Frazier Creeks as they enter the wetland; 2) study area boundary; 3) county ownership; 4) National Wetland Inventory map of wetland types; 5) ground control points selected for registration of the 1994 airphoto; 6) a generalized vegetation type map derived from Marshall's (1985) detailed plant community map; and 7) three classified vegetation maps from 1936, 1979 and 1994. My second objective was to assess the change in wetland vegetation over sixty years and involved a vegetation change analysis by classifying vegetation from airphotos of the wetland from 1936, 1979, and 1994. Wetland vegetation changed from a prairie-dominated landscape in 1936 to a forested wetland in 1994. Forest was initially confined to the northern portion of the wetland along the Jackson-Frazier Creek, but subsequently spread south and westward. Shrub-scrub also increased between 1936 and 1994 and the total area of emergent wetland remained relatively unchanged. Management manipulation might be required to further prevent the wetland progressing to a forested state.

### **INTRODUCTION**

Historically wetlands have been considered to be mysterious and fascinating ecosystems. With settlement throughout the United States came the destruction of these complex and diverse environments. Wetlands exist almost everywhere and numerous recent scientific investigations into their functions and values led to their protection and management.

Wetlands are difficult to define because of the numerous criteria by which they might be defined and the diversity of hydrologic conditions and variety of geographic locations in which they are found. The search for a formal, generalized definition has therefore been challenging, but in 1984 the U.S. adopted legal definition as described by Mitsch and Gosselink (1993) is:

*The term "wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.*

In general, wetlands are often considered to be transitional zones between upland and deepwater habitats and have the distinction of being among the most productive ecosystems on the earth (Mitsch and Gosselink, 1993). Recently the National Research Council reviewed problems in defining wetlands (National Research Council, 1995).

The Willamette Valley in western Oregon became attractive for settlement and agricultural development in the 19<sup>th</sup> century because of its rich, fertile soils, multitude of rain and proximity to the Willamette River and consequently lost most of its abundant wetlands. Located in Benton County, just north of the Corvallis city limits (Fig. 1), the 147-acre Jackson-Frazier Wetland was recognized in the early 1980s as one of the few remaining wetlands because of its "relatively large size in the face of the fragmentation of Willamette Valley wetlands" and was slated for protection by Benton County (JFWMTF, 1992).

The Jackson-Frazier wet prairie tract was burned prior to the 1850s by native Americans. Soon thereafter it was incorporated into a farm, but was never used as an agricultural base because of a poor drainage. The tract of land was heavily grazed and harvested for rough (unplanted) hay until the 1960s (JFWMTF, 1992). In 1990 Benton County assumed ownership of the wetland after an extended controversy, and the natural value, site characteristics, and land use constraints were then re-evaluated and documented (JFWMTF, 1992).

The Jackson-Frazier Wetland was considered an excellent site for preservation because it represents the typical regional wetland type that once prevailed in the valley and contains

threatened and endangered plant species. Its proximity to an urban area also made the wetland an ideal location for passive recreation and educational use as well as a site for further wetland ecology research opportunities (JFWMTF, 1992).

There have been limited studies of the Jackson-Frazier Wetland. Prior to the 1990s, the Jackson-Frazier Wetland was viewed as having important ecological and hydrological functions. Drost (1985) examined the basic hydrologic conditions of the wetland in terms of relationships between stage/discharge, time/discharge, rainfall/runoff, and inflow/outflow. She concluded that the inputs into the Frazier Creek along the northwest corner of the wetland are highly correlated with the amount of storage and outputs of water through a human constructed ditch along the southern portion of the wetland. Her comparisons of rainfall and runoff, however, were inconclusive because she only took measurements for three months (Drost, 1985).

Marshall (1985) used the "Larson Model", a tested assessment model for eastern Massachusetts wetlands, to assess the non-market value of the Jackson-Frazier Wetland. This model provides a guideline for decision-makers when attempting to describe the advantages of wetland preservation versus alternative uses (Marshall, 1985). Marshall commented that this wetland was ideal for this kind of assessment because of the presence of rare plants, availability of wetland ecology information, and rare habitat types and concluded that this model was a valid test to categorize "traditionally intangible wetland preservation values" into tangible cost assessment measurements for the Jackson-Frazier (Marshall, 1985).

Griffith (1989) used the wetland evaluation technique (WET), a method for rapidly assessing wetland functions, on the Jackson-Frazier Wetland to evaluate the methods applicability to Oregon's statewide land use planning requirements. The WET method was

developed for the Corps of Engineers as an alternative to time-consuming detailed site-specific studies conducted by regulatory agencies with a lack of finances, or expertise in field investigations (Griffith, 1989). He found that the first and second level assessments of the WET technique can be completed in a relatively short period of time, but that in areas where wetlands exist in great numbers, this method would require too much data and time to be applied efficiently (Griffith, 1989). Griffith found the method useful in situations where a limited number of wetlands needed to be compared, evaluated, and prioritized.

D'Amore (1995) examined the soil, hydrological, and biogeochemical characteristics of the Jackson-Frazier Wetland soils in order to depict the degree and duration of saturation and anaerobic conditions in the soil over time. He discovered that anaerobic conditions in the Jackson-Frazier Wetland corresponded to periods of soil saturation indicated by permanently installed piezometers in the wetland (D'Amore, 1995). Concentrations of iron and manganese also confirmed prolonged soil saturation (D'Amore, 1995). D'Amore commented that such detailed information is important for correctly classifying and assessing wetland areas.

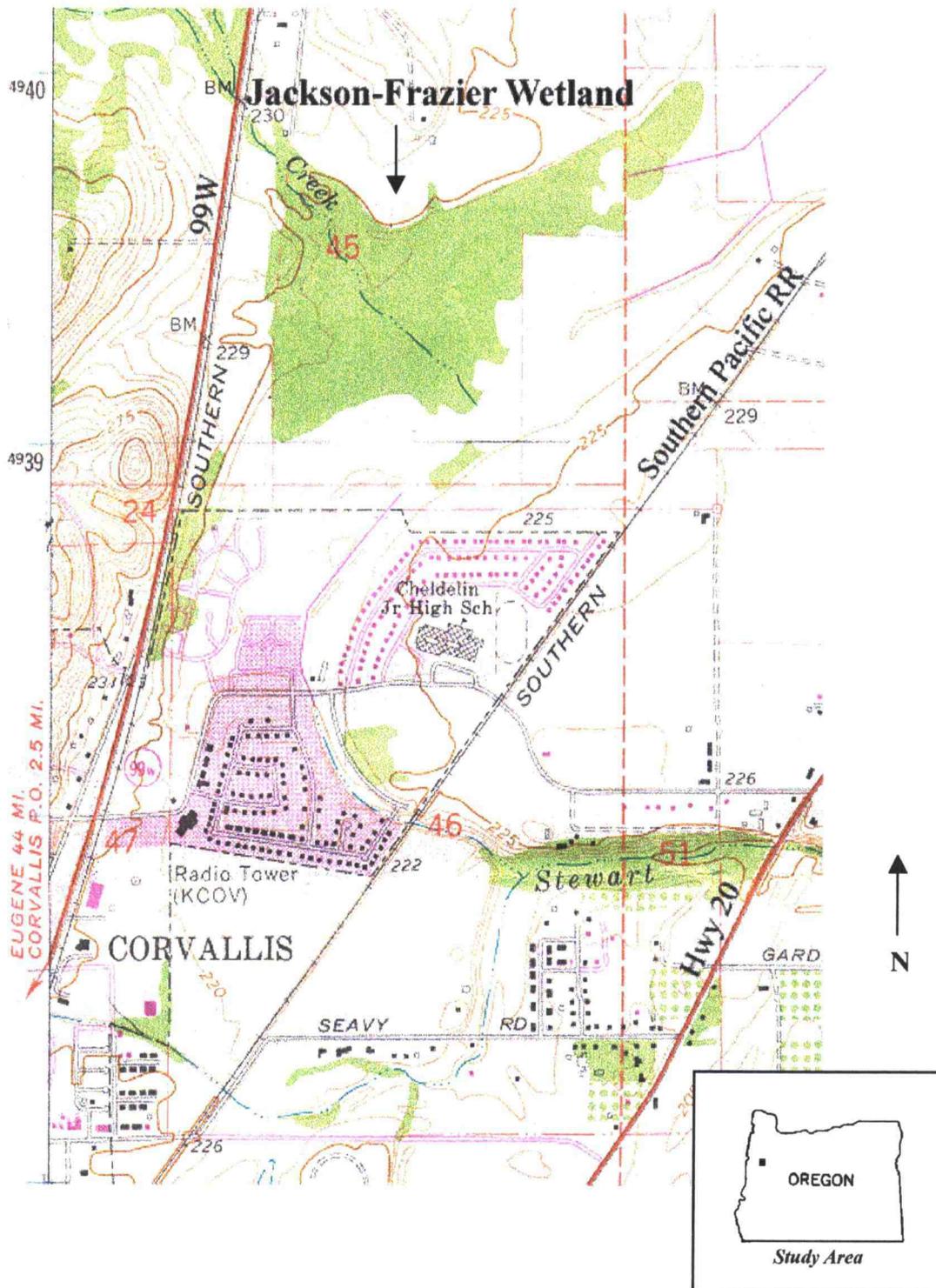


Figure 1. Location of the Jackson-Frazier Wetland, Benton County, Oregon.

## **1. Objectives**

In 1990 Benton County assumed ownership of the Jackson-Frazier Wetland and in 1992 the Jackson-Frazier Wetland Management Task Force (JFWMTF) was created by the County Board of Commissioners to assess the needs and management objectives for the continued management, monitoring, and protection of the wetland. Among the management issues outlined in the Jackson-Frazier Wetland Management Plan produced by the Task Force were: management goals, type of administrative structure, vegetation management, hydrology, public uses, wildlife management, and adjoining land uses and ownerships. Subsequently, the Benton County Board of Commissioners appointed the Jackson-Frazier Wetland Advisory Committee which convened in 1993 and adopted the management plan.

As a result of Benton County's and the Jackson Frazier Wetland Advisory Committee's desire to protect and effectively manage the wetland, two objectives were outlined for this research project. These objectives have the potential of assisting the committee in achieving its mission. My first objective was to develop a geographic information system (GIS) to aid the Jackson Frazier Wetland Advisory Committee in compiling a relevant spatial resource database useful for the management of the wetland. My second objective was to assess the change in wetland vegetation over sixty years and to make predictions for its future management. This second objective involved a historical vegetation change analysis.

## **METHODS**

### **1. Data Base Development**

To accomplish these objectives, primary database information, airphoto referencing, rectification, and airphoto interpretation were performed using ARC/INFO. ArcView was

chosen for cartographic production and display. The historical change analysis was completed using the GIS/MATRIX module of IMAGINE.

To establish a GIS database, primary base information for this research project were digitized, including the National Wetlands Inventory Map of the Jackson-Frazier wetland types, wetland and ownership boundaries, and course of the Jackson and Frazier Creeks (Table 1). An ARC/INFO coverage was first created for each data file using the CREATE command initiated at the ARC prompt. The National Wetlands Inventory map, which is rectified to the USGS Riverside 7.5-minute quadrangle, was used to create each new coverage because of its reliability as a base data layer and because the INFO file contained the four tic marks used for registration of each coverage.

Primary base information (Table 1) was digitized using Arc Digitizing Service (ADS) in ARC/INFO. Excluding the Marshall (1985) vegetation map, all data files were digitized in decimal/degrees (latitude and longitude) and converted to Universal Trans-Mercator coordinates (UTM) zone 10 using the TRANSFORM command in ARC/INFO. Each of these four primary layers had the same mapextent coordinates.

**Table 1.** Primary base information for the Jackson-Frazier Wetland.

<b>Description</b>	<b>File Name</b>	<b>Source</b>	<b>Format</b>
<i>NWI Map</i>	Nwiutm	NWI Map, 1994	ARC/INFO layer
<i>J-F Wetland Boundary</i>	Jfbndutm	NWI Map, 1994	ARC/INFO layer
<i>County Ownership Boundary</i>	Cntyown-1	Faegre and Assoc, 1995	ARC/INFO layer
<i>Jackson-Frazier Creek</i>	Jfcreek	USGS Riverside quad.	ARC/INFO layer
<i>Marshall Vegetation Map</i>	Marshall	Marshall, 1985	ARC/INFO layer

Digitizing the detailed Marshall vegetation survey map presented a challenge because it had no registration markers aside from the township and range reference system. This map was available on a mylar transparency. Using the Riverside orthophotoquad, six ground

control points (GCPs) were estimated that outlined the west, south, and eastern portions of the wetland. These GCPs were selected as label points, ungenerated in ARC, viewed in a DOS editor, and thereafter used as tic points.

After overlaying Marshall's map onto the registered and rectified 1994 airphoto of the Jackson-Frazier Wetland, I determined that Marshall had overextended the northern wetland boundary, therefore I rubber-sheeted Marshall's map to fit the rectified shape of the wetland. The 1994 airphoto was selected for this rubber-sheeting process because it was the only photo of the three (Table 2) flown at the scale listed on the photograph.

### 1.1 Image Selection

Three airphotos were chosen for the vegetation change analysis. The contemporary and two historic aerial photographs selected for this research project were chosen based on availability and image quality. All selected photography was available within Corvallis. The 1936 historic airphoto was obtained from the limited aerial photography collection of the map room of the Oregon State University Valley Library. The 1979 historic photo was acquired from the Benton County Parks Department. The 1994 airphoto was made available by the City of Corvallis GIS & Mapping Department. The specific images were chosen so as to contain the wetland closest to the center, or principal point of the image, reducing the inherent distortion effects due to view angle or terrain relief (Pope *et al.*, 1996)

Since the historical change analysis was an integral part of this project, the earliest available airphoto (1936) of the site and the most recent (1994) were initially chosen as two of three photos for the analysis. The third (1979) was chosen to represent the wetland's vegetation at an intermediate point in time in which change would be clearly evident as a result of the cessation of cattle and sheep grazing in the 1960s. Although the 1936 and 1979

airphotos were listed as scales of 1:4800, it is assumed that they were flown at a much smaller scale, and that the area of the wetland was selected and enlarged.

**Table 2.** Aerial photography information and source of airphoto acquisition.

Year	Scale	Format	Source
1936	1:4800	B/W	OSU Map Room, Oregon State University
1979	1:4800	CIR	Benton County Parks Dept., Corvallis
1994	1:6000	B/W	GIS & Mapping Dept., City of Corvallis

These three high-resolution airphotos were digitally scanned and saved as TIFF files. The 1936 and 1979 photographs were scanned at 300 and 150 dots per inch (DPI) respectively using the Environmental Protection Agency's (EPA) Howtek 2500 scanner and the Polaris scanning program. This information was saved onto the EPA's anonymous FTP site and was transferred to the Department of Geosciences Terra Cognita Laboratory. The 1994 airphoto was scanned at 300 dpi using the HP Desk/Jet 4c Desk Scan II program provided by the Department of Geosciences.

Although the quality of the 1936 image was acceptable for interpretation, contrast and brightness were enhanced using Adobe Photoshop 3.0. The 1936 airphoto showed its age and had numerous waterspots; these were rubber-stamped away using Adobe Photoshop. This process of 'cloning' simply copies over the selected affected pixels with the texture and tone of pixels that I chose. This process of simulation was not done within the confines of the wetland itself because any change of the perceived vegetation would affect the resulting classification.

### 1.2 Georeferencing and Rectification

The Riverside quadrangle orthophotoquad provided by the Oregon Department of Fish and Wildlife (ODFW), was used to locate ground control points used for the registration of

the airphotos. Selecting GCPs from an orthophotoquad eliminated the time needed to capture coordinates through a global positioning system (GPS) in the field.

After obtaining the GCPs necessary for georeferencing, the entire process of registration was fairly straightforward. For accurate registration of the airphotos a minimum of four GCPs are necessary for the registration process. Ground control points were selected based on the recognition of road intersections or other linear features common to the orthophotoquad and the airphotos in each of the three years.

Each scanned airphoto was saved and GCPs were selected with ADS in ARC/INFO from the orthophotoquad as label points, ungenerated as points, and viewed and printed from the DOS editor. The UTM-transformed National Wetland Inventory Map was used as control coverage. The root mean square (RMS) error before digitizing was .002, well within the recommended limits of .005. Finally, the airphotos were transferred to a UNIX workstation in the Department of Geosciences Terra Cognita Laboratory. All registration was performed in ARC using the REGISTER command.

The REGISTER command entered at the ARC prompt initiates an interactive program that allows georeferencing of an image. REGISTER uses a six-parameter affine transformation to calculate the amount of scaling, rotation, and translating required to align the image to map coordinates and requires a minimum of three links to register the image (ESRI, 1995). When more than three links are added, REGISTER cannot exactly map all the image locations to their corresponding map locations, so a least squares solution is used to yield the best possible registration by minimizing the sum of the offset distances for each link (ESRI, 1995).

Between 8 and 11 GCPs were obtained for registration purposes. In order to achieve at least five-meter accuracy, GCPs were systematically eliminated until the RMS error was within acceptable limits. Each registered airphoto contained a minimum of four ground control points.

Once the image-to-world transformation was established, the image could be viewed concurrently with other spatially referenced data. After the registration process, the RECTIFY command was used to create a new image by permanently transforming the image data to real-world coordinates (ESRI, 1995). Only images and coverages aligned to the same map coordinate system can be displayed together.

The RECTIFY command applies an affine transformation to the image, thereby removing any rotational or differential scaling component from the image and aligning it to the chosen map coordinate system (ESRI, 1995). The *nearest neighbor interpolation* process was chosen as the resampling method used in the image transformation process because it “calculates the value for an output pixel by assigning it the value of the nearest pixel in the input image” (ESRI, 1995).

### 1.3 ARC/INFO, ArcView and IMAGINE

The ARC/INFO GIS was chosen as the source for primary database creation because of its compatibility with other GIS software and because it is the most widely used GIS in the private and public sector. This was important for my project since I wished to have the GIS compatible with Benton County’s system. The INFO aspect of this software is particularly useful because it offers the option to store and manipulate feature attribute and related layer or coverage information. The final project was created in the UNIX version of ArcView 3.0.

ERDAS's IMAGINE 8.3, raster-based GIS, was chosen for the change analysis portion of this project because of its ease at accepting ARC/INFO coverage's and because of the matrix produced after the change analysis. The matrix numerically describes the type of vegetation change from one time period to the next. Within the IMAGE INTERPETER module of IMAGINE, ARC/INFO vector files are selected as files used in the change analysis, and the INFO attribute indicating vegetation class identifiers (*mycode*) was selected as the feature to be treated as pixel (raster) values. Each vegetation class (i.e., forest, or emergent wetland) was given its own unique identifier – a single-digit number which was used in the change analysis from the change detection matrix. This category identifying each vegetation class was selected for the matrix analysis as a specific INFO attribute, where these attributes are used as pixel values in the IMAGE INTERPRETER, GIS/MATRIX menu in IMAGINE (Table 3). The output file, which is a combination of the two airphoto dates used in the change analysis, are given an *.img* file extension; the resulting file a raster image with associated raster attributes.

**Table 3.** Vegetation classes (*mycode*), vegetation class descriptions, and abbreviations.

Vegetation class identifiers	Vegetation description	Abbreviation
1	Emergent Wetland	EmW
2	Prairie	P
3	Shrub-Scrub	SS
4	Shrub-Scrub/Forest	SS/F
5	Forest	F
6	Non-wetland (upland)	U

## 2. Vegetation Classification and Change Analysis

Vegetation of the Jackson-Frazier wetland was interpreted on three scanned images at scales of 1:4800 and 1:6000 (Table 2). The 1979 and 1994 airphotos were loaned out by the Benton County Parks Department and the City of Corvallis GIS and Mapping Department, respectively. The 1936 photo was part of the limited historical aerial photography collection at the Oregon State University Valley Library Map Room. The key recognition elements used in interpretation were identifying signs of image texture and tone.

### 2.1 Development of a Classification System

The accuracy of interpretation of the vegetation relies heavily upon the knowledge and expertise of the interpreter. I was assisted in interpretation by Dr. Bob Frenkel a vegetation scientist and specialist in the study area. Dr. Frenkel also served as guide in creating the classification scheme and evaluated its accuracy.

My classification scheme was based on Anderson *et al.* (1976) land use and land cover classification system for use with remote sensor data and Cowardin *et al.* (1979) wetlands classification. Anderson *et al.* (1976) stressed the importance of a minimum of 85 percent interpretation accuracy, repeatable results from one interpreter to the next, a classification system suitable for use with remote sensor data at different times of the year, and the recognition of multiple uses of land when possible (Anderson *et al.*, 1976). The authors' also recognized that this classification scheme could be modified depending on the landscape scale and cover type being researched.

The Cowardin *et al.* (1979) classification system is hierarchical and progresses from systems to subsystems, and from classes, to subclasses, and finally to dominance types. Choosing a classification system based on these principles would have been too complex for

the change analysis portion of this project. Since all the Jackson-Frazier Wetland is embraced in Cowardin's palustrine system, the classification scheme devised for the Jackson-Frazier Wetland is non-hierarchical based on dominance types with six classes, and is shown in Table 4.

For simplicity, six vegetation classes were selected to represent predominant easily identified vegetation types of the Jackson-Frazier Wetland. The forest category consists of grouping low stature, closed canopy forest; the shrub-scrub/forest class contains dominance of tall shrubs in an open low stature; shrub-scrub consists of areas with low shrubs and some prairie; the prairie class contains areas with little or no woody vegetation but a dominance of herbs (forbs, sedges and grasses); emergent wetland is an area inundated by water at least through April and is dominated by graminoid (sedges and grasses) emergent vegetation; and the non-wetland class is a slightly elevated area and is not included as part of the wetland.

**Table 4.** Vegetation classes and descriptions used in the Jackson-Frazier Wetland classification system.

<b>Vegetation class</b>	<b>Description</b>
<b>Wetland</b>	
♦ <i>Forest</i>	♦ Closed forested areas with tall and low trees.
♦ <i>Shrub-Scrub/Forest</i>	♦ Dominate shrubby areas with open cover of trees, or in some cases forested areas with clear shrub-scrub understory.
♦ <i>Shrub-Scrub</i>	♦ Shrubby, textured areas, inclusive of some prairie
♦ <i>Prairie</i>	♦ Open smoothly textured areas with little or no woody vegetation present.
♦ <i>Emergent Wetland</i>	♦ Open smoothly textured spaces with no woody vegetation present and characterized by dark tones (low reflectance indicating water saturation). Cattail and reed canarygrass common.
<b>Non-Wetland</b>	
♦ <i>Upland</i>	♦ Non-wetland, upland area dominated by large crowns of maple.

## 2.2 Change Analysis and Change Detection Matrix

Change detection is “the process of identifying differences in the state of an object of phenomenon by observing it at different times” and uses various forms of remotely sensed data to aid in the analysis (Singh 1989). A vegetation change analysis was conducted on the Jackson-Frazier Wetland by examining three high-resolution airphotos taken in 1936, 1979, and 1994.

The ideal change analysis is performed on selected photography with the highest possible contrast, the greatest amount of ground detail possible, the best possible physical condition of the photograph, and the same instantaneous field-of-view (Pope *et al.*, 1996, Jensen *et al.*, 1987). Other factors to consider are the time of year when the photo was taken, atmospheric conditions such as cloud cover or sun angles, and photography acquired at approximately the same altitude (Jensen, 1996, Lillesand and Kiefer, 1994). This research project was conducted independently, therefore forcing me to use airphotos that were available on a no-cost, loan basis.

A matrix analysis produces a thematic layer containing a separate and unique class (or matrix number) for every coincidence of classes in two layers. The output is best described with a matrix diagram, in which the classes of the two input layers represent rows and columns of the matrix (Table 5). The output classes are then assigned a class of change or no change according to the coincidence of any two input classes.

Each vegetation class (i.e., forest, or emergent wetland) is given a unique identifier used in the matrix analysis labeled *mycode* (Table 3). These identifiers were added as items in the INFO table of each ARC coverage used in the analysis. Each identifier (1 through 6) represents one of the vegetation classes. In Table 5, the 1979 vegetation classes represented

numerically in the classification of that year are shown down the side. The 1936 vegetation classes are listed numerically across the top. Each one of the cells (1 through 36) represented by numbers represent unique combinations of classes. For example, a value in cell 8 in the matrix represents no change in vegetation from 1936 to 1979, but a value in cell 19 indicates that there was a change from EmW (emergent wetland) to SS/F (shrub-scrub/forest).

**Table 5.** Matrix diagram for the 1936 to 1979 change analysis. Each identifier, 1 through 36 in the body of the table, represent unique combinations of classes indicating either a change from one class to another or no change (along the diagonal).

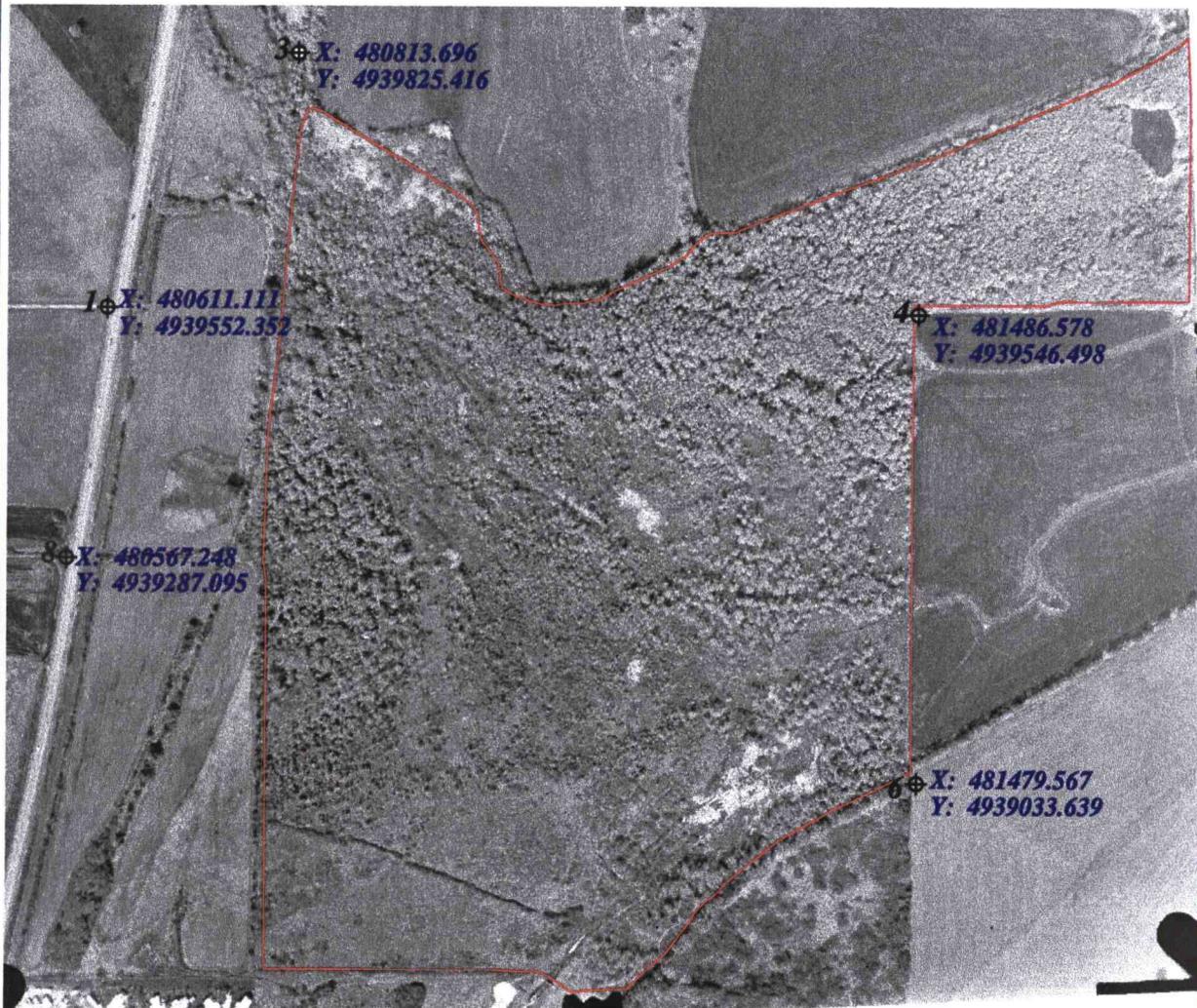
		1936 Vegetation Class Identifiers					
		1	2	3	4	5	6
1979 Vegetation Class Identifiers	1	1	2	3	4	5	6
	2	7	8	9	10	11	12
	3	13	14	15	16	17	18
	4	19	20	21	22	23	24
	5	25	26	27	28	29	30
	6	31	32	33	34	35	36

## RESULTS

### 1. GIS

ArcView themes included in this GIS are displayed in Figures 2-6. First, ground control points used in registration of the 1994 airphoto are overlaid on the 1994 rectified image (Fig. 2). Second, the study area boundary and course of the Jackson-Frazier Creek as it enters the wetland is shown in Fig. 3. Third, the Benton County ownership boundary is shown overlaid on the 1994 rectified image as Fig. 4. Fourth, the National Wetland Inventory displaying the Jackson-Frazier wetland types is shown as Fig. 5. Fifth, the Marshall vegetation map of generalized vegetation types is displayed as Fig. 6. The 1936, 1979 and 1994 vegetation classifications overlaid on their respective airphotos are shown as Figures 7-9 and are additional ArcView themes.

# 1994 ground control points



60 0 60 120 180 Meters

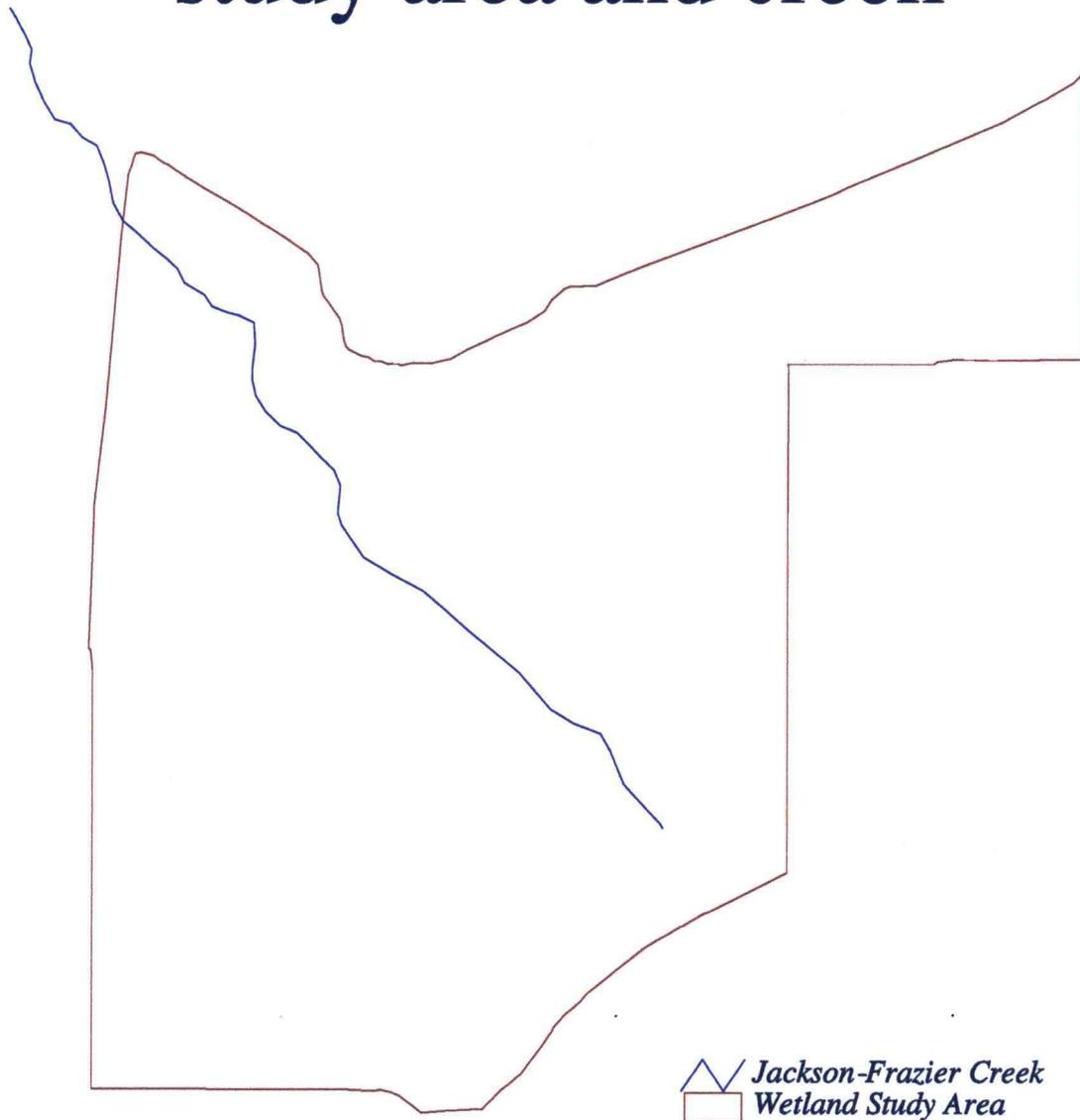


 Study Area with 1994 GCPs

Figure 2. Ground control points (GCP) selected for registration of the 1994 Jackson-Frazier Wetland airphoto. UTM X and Y coordinates are shown.

LDJ 2/98

# Jackson-Frazier Wetland study area and creek



60 0 60 120 180 Meters



Figure 3. Wetland study area and the combined Jackson-Frazier creek.

LDJ 2/98

# County ownership boundary



60 0 60 120 180 Meters



 *County Ownership*

Figure 4. The Benton County ownership boundary overlaid on the 1994 airphoto of the Jackson-Frazier Wetland.

LDJ 2/98

# NWI map of J-F wetland types

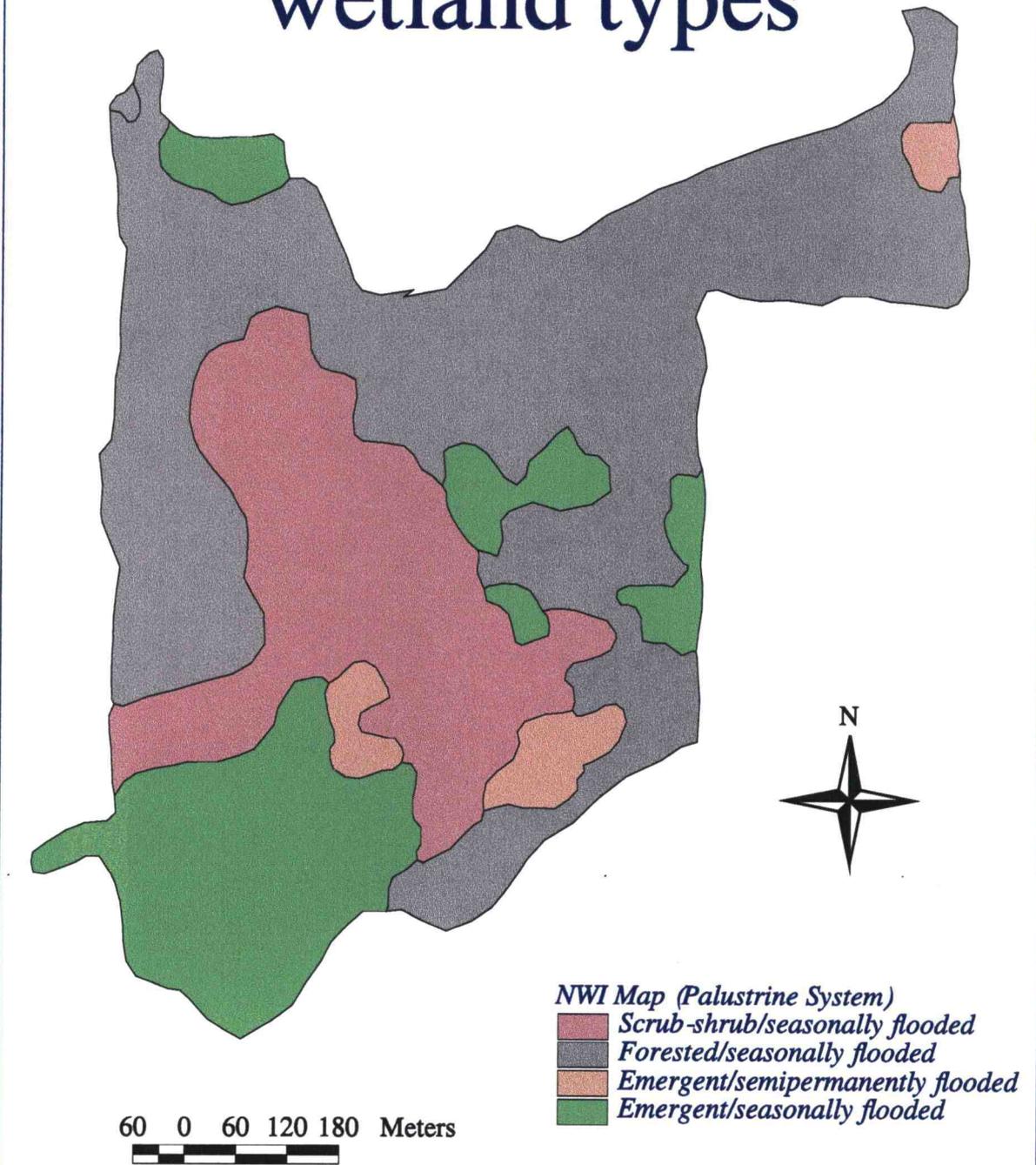


Figure 5. 1994 National Wetland Inventory (NWI) map of the J-F Wetland.

LDJ 2/98

# Marshall vegetation type map



60 0 60 120 180 Meters

*Vegetation Type*

- Forested Wetland*
- Emergent Wetland*
- Scrub-Shrub*
- Open Water*
- Forested Nonwetland*

Figure 6. Generalized Marshall (1985) map of vegetation types.

LDJ 2/98

## 2. Vegetation Classification

The digitized 1936, 1979 and 1994 vegetation classes are displayed in Figures 7-9. Each year's corresponding airphoto served as a background layer and aid in on-screen photo interpretation and classification. The end results are three ARC/INFO vector files used as themes in the final change analysis segment of this project. The same vegetation classes were used for each year.

Over 50 percent of the wetland in 1936 was dominated by prairie and emergent wetland types, while 25 percent was covered by either shrub-scrub/forest, or forested wetland (Table 6). Eighteen percent of the wetland in 1936 was shrub-scrub. In 1979, shrub-scrub (15.7 percent) and forest (40 percent) dominated 55 percent of the wetland. Emergent wetland and prairie accounted for nearly 25 percent of wetland vegetation, and the area of shrub-scrub stayed constant at 18 percent although its position changed. 1994 image showed a modest increase in emergent wetland from 3 acres (2.1 percent) in 1979 to 5 acres (3.6 percent) in 1994. By 1994, prairie decreased to 26 acres (18 percent) from 33 acres (22.4 percent) in 1979, while shrub-scrub decreased slightly representing 16.5 percent of wetland vegetation. Only 1 percent (2 acres) of the wetland were classified as shrub-scrub/forest in 1994, and the forest class increased to nearly 60 percent (86 acres) of total vegetation in the. The non-wetland (upland) area remained constant with 1.5 percent of the total vegetation for each year in the analysis.

Overall, there was a massive increase of forest and decrease in prairie and emergent wetland. Forest confined to the north of the study area near the Jackson-Frazier Creek in 1936 spread south and west.

**Table 6.** Total area (acres) and percent in vegetation classes by year and vegetation type.

<i>Vegetation Class</i>	<b>1936</b>		<b>1979</b>		<b>1994</b>	
	<i>Acres</i>	<i>Percent</i>	<i>Acres</i>	<i>Percent</i>	<i>Acres</i>	<i>Percent</i>
<i>Emergent Wetland (EmW)</i>	12.7	8.7	3.1	2.1	5.2	3.6
<i>Prairie (P)</i>	67.9	46.5	32.7	22.4	26.3	18.0
<i>Shrub-Scrub (SS)</i>	26.6	18.2	26.7	18.3	24.1	16.5
<i>Shrub-Scrub/Forest (SS/F)</i>	13.8	9.5	23.0	15.7	2.0	1.4
<i>Forest (F)</i>	22.7	15.6	58.4	40.0	86.3	59.0
<i>Non-wetland (U)</i>	2.2	1.5	2.2	1.5	2.2	1.5

**1936 Imagery.** The approximately 24x24-inch black and white aerial photograph used in the 1936 vegetation classification was digitally scanned, and registered and rectified in ARC/INFO. The photograph scale was listed at 1:4800. Because of quality and age of the image, a 9x9-inch black and white photograph of the wetland flown in 1939 was used as an aid in image interpretation and classification. The wetland study area represents the minimum common area between the 1936, 1979, and 1994 study years (Fig. 3)

In 1936, distribution of forest remained confined to the northern portion of the wetland along the Jackson-Frazier Creek and was relatively open (Fig 7). The shrub-scrub/forest and shrub-scrub areas were located near the forested areas in the northern portion of the wetland and along the west-central border of the wetland; an exception being a small portion of shrub-scrub located along the southeast border of the study area and an island of shrub-scrub in the northwest section of the wetland. Prairie was the dominant vegetation type of the Jackson-Frazier in 1936, with the entire southwest and central sections of the wetland and portions along the north and east of the wetland border being prairie. Emergent wetland was confined to small sections in the southwest and east central portions of the wetland and to an excavated duck pond in the southeast (shown by dark tone) which was heavily grazed. The non-wetland (upland) category is confined to a slightly elevated area in the northwest region

of the wetland. Areas to the east of the Jackson-Frazier Wetland were non-farmed wetlands in 1936.

**1979 Imagery.** The 17x17 inch 1979 color infrared airphoto of the Jackson-Frazier Wetland was digitally scanned, and registered and rectified in ARC/INFO. The scale listed on the image is 1:4800, but is presumed to be enlarged from a smaller scale because of the availability of other hard-copy imagery at different scales of the same flight date. Although the quality of the image was exceptional, a 1:3000 color positive of the same date, was used as an aid in interpretation and vegetation classification.

The northern portion of the wetland, except for an area of prairie in the very northwest corner of the wetland and a small recently excavated pond classified as emergent wetland in the northeast region, was completely enveloped by closed-canopy forest and extended southward along the east and west borders of the wetland (Fig. 8). The area along the southeast border of the wetland classified as shrub-scrub in 1936 developed into forest in 1979. Shrub-scrub heavily dominated the central wetland, with shrub-scrub/forest occupying the borders of forested areas in the west, north central, and eastern regions of the wetland. Formerly classified emergent wetland areas in the east-central region of the wetland in 1936, progressed to prairie. Prairie still dominated in the southwest, and surrounded the recently excavated round duck pond in the northeast. Emergent wetland types such as reed canarygrass began to invade the southeast border of the study area. By 1979 the former wetland to the east of the study area was drained and farmed.

**1994 Imagery.** The 1994 black and white airphoto of the Jackson-Frazier Wetland was flown in March 1994 at a scale of 1:6000. The quality of the 9x9-inch image was exceptional and no other data were used as an aid in interpretation and classification. Forest was the

dominant vegetation class in 1994 (Fig. 9). It encompassed the entire north, west, and most of the central-eastern regions of the wetland; exceptions being the duck pond in the northeast and a former prairie area in the northwest, which was invaded by reed canarygrass and classified as emergent wetland. Only a small section remained of shrub-scrub/forest in the north-central wetland, and shrub-scrub was confined to a smaller section of the central wetland as compared to its size in 1979. Prairie still dominated the southwest section of the wetland and existed in small sections in the east-central and west-central areas of the wetland and around emergent wetland in the southeast. Reed canarygrass, classified as emergent wetland, invaded former prairie sections in the northwest, central, and a small part in the west of the Jackson-Frazier Wetland. It was recognized and classified based on its high reflectivity.

# 1936 vegetation classes



60 0 60 120 180 Meters

*F:* Forest  
*SS/F:* Shrub scrub/Forest  
*SS:* Shrub scrub  
*P:* Prairie  
*EmW:* Emergent Wetland  
*U:* Non-wetland (upland)

Figure 7. The 1936 Jackson-Frazier Wetland vegetation classes.

LDJ 2/98

# 1979 vegetation classes



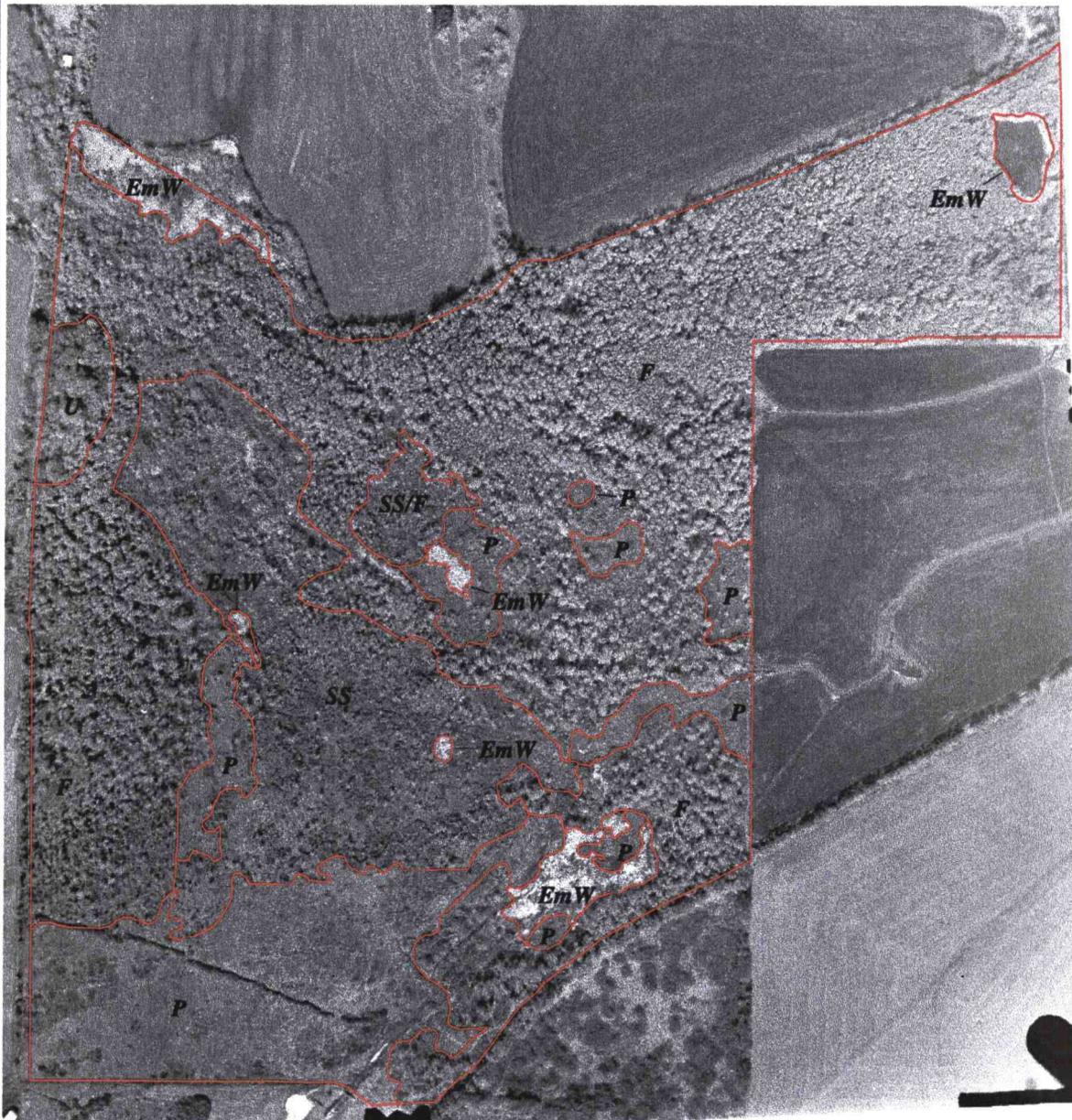
60 0 60 120 180 Meters

*F:* Forest  
*SS/F:* Shrub scrub/Forest  
*SS:* Shrub scrub  
*P:* Prairie  
*EmW:* Emergent Wetland  
*U:* Non-wetland (upland)

Figure 8. The 1979 Jackson-Frazier Wetland vegetation classes.

LDJ 2/98

# 1994 vegetation classes



60 0 60 120 180 Meters



- F:* Forest
- SS/F:* Shrub scrub/Forest
- SS:* Shrub scrub
- P:* Prairie
- EmW:* Emergent Wetland
- U:* Non-wetland (upland)

Figure 9. The 1994 Jackson-Frazier Wetland vegetation classes.

LDJ 2/98

### 3. Change Analysis

A vegetation change analysis was conducted on the Jackson-Frazier Wetland by examining airphotos taken in 1936, 1979, and 1994. Vegetation change was examined between 1936 to 1979 and 1979 to 1994 time periods; the results are two separate matrix layers indicating the nature of change. Table 7 summarizes the complete matrix diagram (Appendix B) of the total change in acreage and percentage of six wetland classes from these time periods.

**Table 7.** Summary of change in vegetation class area from one time period to the next accounting for all individual inputs from all vegetation classes (Appendix B1 and B2) in the Jackson-Frazier Wetland.

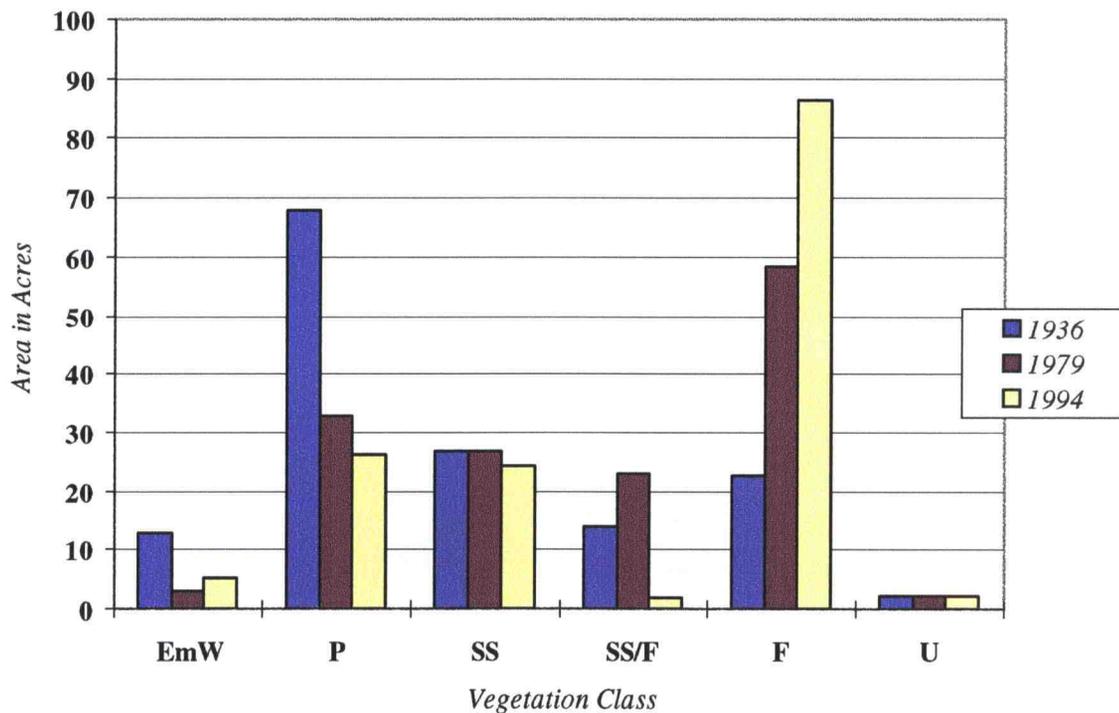
Vegetation class	1936 to 1979		1979 to 1994	
	Acres	Percent	Acres	Percent
<i>Emergent Wetland (EmW)</i>	3.1	2.1	5.3	3.6
<i>Prairie (P)</i>	33.2	22.6	26.7	18.2
<i>Shrub-Scrub (SS)</i>	26.5	18.1	24.1	16.5
<i>Shrub-Scrub/Forest (SS/F)</i>	23.1	15.8	2.1	1.4
<i>Forest (F)</i>	58.3	39.9	86.2	58.8
<i>Non-wetland (U)</i>	2.2	1.5	2.2	1.5

It is important to realize that the change in a vegetation class shown in Table 7 summarizes the flows of each of five vegetation classes into and out of a given vegetation class. Appendix B gives the detailed flows between every vegetation class. For example, Table 7 indicates that for the 1936/1979 analysis the change in prairie is 33.1 acres. The results from the complete matrix in Appendix B indicate that 5.7 acres changed from emergent wetland to prairie; 2.5 acres changed from shrub-scrub to prairie; <0.1 acres changed from shrub-scrub/forest to prairie; 0.1 acres changed from forest to prairie; and 24.9 acres did not change. These changes are shown in Table 8.

**Table 8.** Change in prairie vegetation class, accounting for all individual inputs from all other vegetation classes shown in Appendix B1.

	1936 to 1979 area of change for prairie
Vegetation class	Acres
No change	24.9
EmW to P	5.7
SS to P	2.5
SS/F to P	<0.1
F to P	0.1

Table 6, however, shows that in 1979 prairie decreased from 67.9 acres in 1936 to 32.7 acres in 1979, a total decrease of 25.2 acres. Figure 10 is a graphical representation of Table 6 and is particularly useful for depicting total landscape change in vegetation types. Table 7, on the other hand, gives a summary of the *overall flows* from one vegetation type to another, but does not give the acres of change at the end of a given time period.



**Figure 10.** Area of vegetation types for 1936, 1979, and 1994 based on data in Table 6.

## DISCUSSION

### 1. Database Development

Geographic information systems (GIS) permit the creation, analysis, and display of spatial information. Encompassed in this project was the use of two GISs, ARC/INFO and ArcView, and the GIS/Matrix module of IMAGINE; each having a specific function to meet the objectives outlined for this research paper. Included in the creation of a preliminary GIS for the Jackson-Frazier Wetland required putting together information from a variety of sources.

Primary database information such as the course of the combined Jackson and Frazier Creeks as they enter the wetland (Fig. 3) was digitized from the USGS Riverside topographic quadrangle and created as a separate layer in ARC/INFO. The USGS quadrangle did not contain any other hydrologic features aside from the creek and few excavated ditches that pertained to the Jackson-Frazier Wetland. The National Wetlands Inventory map (Fig. 5) which is overlaid on the Riverside quadrangle, was the first coverage to be digitized and served as base data layer for all other digitized coverages because of its topographic registration. As with any project, the accuracy of the compiled data and number of errors relies upon the expertise of the researcher and the nature of the original data. However, as with any techniques-oriented project, questions and problems often arise.

Marshall (1985) created a detailed field-based vegetation map of the Jackson-Frazier Wetland at the plant community level that was important to include in the ArcView project. The map was available only as hard copy and needed to be digitized and georegistered to the other data in order to be included in the GIS. Unfortunately his map included only the township and range mapping system and not have any other precise geographic coordinates.

To register this vegetation map to real-world coordinates, I had to locate ground control points that were common to the 1976 orthophotoquad and year of the Marshall map. I therefore made the assumption that certain defining areas and points along the boundary of the wetland would not have changed too much between 1985 and 1994; therefore I selected ground control points (GCPs) from 'corners' of the west, south, and eastern portions of the wetland. I also found that for the final display of Marshall's map it was less confusing to show the major vegetation types in the legend than his more detailed plant community classification, although plant communities are also digitized but not identified in the legend.

After selecting the GCPs and then digitizing the map, I overlaid this information onto the georegistered 1994 airphoto and adjusted mislabeled areas. The northern boundary of the original map extended beyond the northern boundary of the wetland and needed to be adjusted. This process is known as 'rubber-sheeting' and was easily accomplished using the ADJUST command in the ARC/EDIT module of ARC/INFO.

Because the 1994 airphoto was the first airphoto to be registered, I chose GCPs recognizable from both the orthophotoquad and the 1994 airphoto. The airphoto was flown in March at 6,000 ft and the Jackson-Frazier Wetland was contained within the center of the image view. Because of the photos size (9x9 inches), it was difficult to locate linear features such as road intersections, for reliable registration.

Special problems also arose when attempting to accurately register both the 1936 and 1979 airphotos. It was difficult to locate GCPs that existed in 1936 and in 1976, the year the orthophotoquad was created, and because of the size of the photographs (24x24 inches for the 1936 airphoto, and 17x17 inches for the 1979 airphoto), a larger scanner needed to be located in order to scan enough area to accurately register the airphotos. Common GCPs were not

chosen for all three registered airphotos except the bridge crossing over the Jackson-Frazier Creek along HWY 99.

## **2. Vegetation Classification**

The ideal vegetation classification is created based on a priori knowledge of the study area's vegetation types and includes the ability to field check the accuracy of classification. Unfortunately this type of ground-truthing is impossible where historical airphotos are being used. Furthermore, the logistical problem of getting around the wetland at present time made ground-truthing beyond my ability. Therefore, I had to rely on the accuracy of key recognition elements chosen for airphoto interpretation such as texture and tone and the expertise of Dr. Bob Frenkel.

Time of year at which imagery was taken was critical for interpretation. I assumed that the 1936 image was taken in spring because of a number of dark toned areas indicating saturated soils. The 1979 and 1994 images were taken in late summer and spring, respectively, as dated on each air photo. The season of photography was especially important in identifying wet areas. Because of the lack of information regarding the 1936 airphoto, such as the exact image scale or date at which the photo was taken, it was necessary to examine other airphotos flown near that time period. A 1939 9x9-inch black and white airphoto was used to aid in interpretation. For the 1979 classification, another larger color positive photographic print of 1979 flight and a high-resolution 1985 ozalid photograph of the wetland served as interpretation aids.

Because of the slight differences in the edges of the Jackson-Frazier Wetland at different dates, a common area defined by a common boundary to all three airphotos was chosen as the

wetland study area (Fig. 3). By choosing a common area, small portions of each of the study years at the edges of the wetland were not classified.

With the post-classification method, which is a widely used change detection method and considered to be relatively easy to understand, there are inherent problems in the separate classification methodology including generalization of vegetation classes which would lead to inaccurate change analyses, or problems in airphoto registration. Therefore it was imperative that the individually classified maps used in the post-classification change detection method be as accurate as possible, so as to eliminate potential errors that would be present in the final change analysis.

Generalization was also important to a vegetation classification because there were often confusions from one time period to the next as to what class a given portion of the photo should be assigned. In certain instances, the exact boundary between two adjacent vegetation groups was difficult or impossible to discern from the airphotos. Initially, for the 1979 vegetation classification, an area along the southwest portion of the wetland was classified as shrub-scrub, shrub-scrub/forest, and forest, but in the same area on the 1985 hard-copy map, which served as an aid in airphoto interpretation of this year, the same area appeared clearly as prairie with scattered trees. I classified this area as prairie.

After each year (1936, 1979, 1994) was independently classified, Dr. Frenkel examined the vegetation categories for consistency from year-to-year, and logic in progressive succession. At his suggestion, I made the succession assumption in my interpretation that vegetation will develop from open water or emergent wetland to prairie to shrub-scrub to open forest with shrub understory to closed canopy forest. It would be unlikely that there would be reversals in this sequence. I purposely limited my classification to large

physiognomic categories because the detailed vegetation interpretation and map produced by Marshall (1985) represented ephemeral communities.

Considering that succession is a “directional, cumulative change in the vegetation that occupy an area through time” (Barbour *et al.*, 1987, p. 230), I was not expecting to observe forested or shrub-scrub/forest areas, respectively, to revert to shrub-scrub or emergent prairie because succession tends to be uni-directional unless a new disturbance regime is instituted. Before the matrix analysis, I was able to overlay the 1936/1979, and 1979/1994 classifications in ArcView to ascertain any inconsistencies in my succession assumption. In certain instances where this occurred, I was able to carefully adjust minor mistakes in classification by redrawing vegetation classes in ARC/EDIT.

The initial classification of all three airphotos revealed some difficulties in airphoto interpretation, especially along areas where boundaries between two vegetation groups were not clear, or where airphoto interpretation recognition elements used were not sufficient to correctly classifying the wetland. Key recognition elements such as tone and texture assisted in interpretation, but were inadequate in interpreting some areas of the wetland. In this regard, it became necessary to verify the accuracy of the classification by use of supplementary imagery or someone with a priori knowledge of the wetland’s vegetation.

### **3. Change Analysis**

The change analysis was conducted for the 1936 to 1979 and 1979 to 1994 time periods. Considering that 43 years passed between the first two chosen years of the analysis and 15 years elapsed between the 1979 and 1994 analysis, images should indicate the overall trend of vegetation change.

It is important to examine the change of vegetation among individual categories. The matrix summary (Table 7) and full matrix (Appendix B) of the change analysis in IMAGINE provide useful information as to the details of change of a particular cover type involved for a given time period. The area of the six vegetation types as shown in Table 6 and Figure 10 gives a good idea of vegetation trend.

Human induced disturbances had a significant impact on the nature and change of vegetation in the wetland. The 1979 airphoto was chosen for the change analysis because it represented a period after the cessation of cattle and sheep grazing in the early 1960s. A result of the reported elimination of grazing in the 1960s associated with change in land ownership, shrubs and trees rapidly replaced prairie. This is shown in the 1936 to 1979 analysis. Also, damage done by scraping surface vegetation into windrows in the southwest part of the wetland in 1985 by the owner temporarily stabilized prairie vegetation, thereby slowing succession towards a shrubby or forested state for this area in the 1979 to 1994 analysis. A comb-like texture associated with mechanized vehicle tracks is clearly visible in the 1994 airphoto documenting this human-induced disturbance (JFWMTF, 1992).

Another human-associated problem is the appearance of reed canarygrass, an introduced weed, seen by its high reflectance in wetter areas. It is clear also, that the advent of reed canarygrass sometime prior to 1979 and its rapid establishment by 1994 indicates the wettest areas will trend toward complete cover by this aggressive perennial.

## **CONCLUSIONS**

The information collected and analyzed for this research project demonstrated the complex nature of creating a preliminary database system for the management of the wetland. A GIS, especially ArcView and ARC/INFO are effective tools for storage and querying of the

information regarding the wetland. It is an open-ended tool allowing for incorporation of additional spatial data as it becomes available such as the location of the Jackson-Frazier Wetland boardwalk or fine-scale elevation diagrams.

Historical change analyses are useful in characterizing an aspect of the history of the landscape. In general, historic airphoto interpretation is useful for examining the change of vegetation over time and provides a unique documented perspective of a particular kind of physical feature of the Earth. The Jackson-Frazier Wetland has progressed from a mostly wet prairie-dominated landscape to a forested wetland. This is clearly documented by the decrease in prairie and increase in shrub and forest types between the 1936/1979 analysis, after the cessation of grazing in the 1960s and further documented by the 1979/1994 analysis.

This research points to the succession of vegetation after a disturbance is removed; the need for monitoring vegetation change; and need for manipulative management of the wetland in order to maintain a semblance of its nature at settlement time in the 1840s. Only through the imposition of disturbance regimes such as reinstating fire, mowing, or grazing will vegetation return to more open conditions. It is likely that those trends that progressed greatly in 60 years will continue to occur unless stringent management activities are taken to maintain a given vegetation type.

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## APPENDIX A

1. Ground control points selected for registration of the 1936 Jackson-Frazier Wetland airphoto. Ten points were initially used for the registration process, but only four were chosen. They are highlighted in the table below. True and calculated X and Y values are listed in Universal Trans-Mercator coordinates. Offset distances are listed in meters.

<i>GCP</i>	<i>True X</i>	<i>True Y</i>	<i>Calculated X</i>	<i>Calculated Y</i>	<i>Distance(m)</i>
1	480566.30	4939291.00			
2	<b>480607.00</b>	<b>4939558.00</b>	<b>480607.249</b>	<b>4939558.667</b>	<b>.712</b>
3	480676.50	4939916.00			
4	<b>481778.10</b>	<b>4939552.00</b>	<b>481777.639</b>	<b>4939550.766</b>	<b>1.318</b>
5	481494.30	4939552.00			
6	<b>481483.10</b>	<b>4939034.00</b>	<b>481483.810</b>	<b>4939035.901</b>	<b>2.030</b>
7	481757.20	4938764.00			
8	481483.20	4938770.00			
9	<b>480774.20</b>	<b>4938822.00</b>	<b>480773.702</b>	<b>4938820.666</b>	<b>1.424</b>
10	480497.80	4938902.00			

*Scale (x,y): 0.413, 0.410*

*Image Rotation: 2.189 degrees*

*RMS error (image, cover): 3.520, 1.448*

2. Ground control points selected for registration of the 1979 Jackson-Frazier Wetland airphoto. Ten points were initially used for the registration process, but only five were chosen. They are highlighted in the table below. True and calculated X and Y values are listed in Universal Trans-Mercator coordinates. Offset distances are listed in meters.

<i>GCP</i>	<i>True X</i>	<i>True Y</i>	<i>Calculated X</i>	<i>Calculated Y</i>	<i>Distance (m)</i>
1	480574.60	4939286.00			
2	<b>480677.40</b>	<b>4939925.00</b>	<b>480678.998</b>	<b>4939922.680</b>	<b>2.817</b>
3	480725.20	4940228.00			
4	480885.40	4940225.00			
5	<b>480814.40</b>	<b>4939833.00</b>	<b>480813.252</b>	<b>4939836.389</b>	<b>3.548</b>
6	<b>482363.30</b>	<b>4940023.00</b>	<b>482361.883</b>	<b>4940021.398</b>	<b>2.139</b>
7	482158.30	4939828.00			
8	<b>482279.70</b>	<b>4939444.00</b>	<b>482281.299</b>	<b>4939445.420</b>	<b>2.138</b>
9	<b>480717.80</b>	<b>4938652.00</b>	<b>480717.168</b>	<b>4938651.113</b>	<b>1.090</b>
10	480576.60	4939290.00			

*Image Rotation: .636 degrees*

*RMS error (image, cover): 3.086, 2.493*

3. Ground control points selected for registration of the 1994 Jackson-Frazier Wetland airphoto. Eight points were initially used for the registration process, but only five were chosen. They are highlighted in the table below and in Figure 2. True and calculated X and Y values are listed in Universal Trans-Mercator coordinates. Offset distances are listed in meters.

<i>GCP</i>	<i>True X</i>	<i>True Y</i>	<i>Calculated X</i>	<i>Calculated Y</i>	<i>Distance (m)</i>
<b>1</b>	<b>480612.50</b>	<b>4939552.00</b>	<b>480611.111</b>	<b>4939552.352</b>	<b>1.433</b>
2	480681.20	4939915.00			
<b>3</b>	<b>480814.40</b>	<b>4939826.00</b>	<b>480813.696</b>	<b>4939825.416</b>	<b>.914</b>
<b>4</b>	<b>481485.00</b>	<b>4939546.00</b>	<b>481486.578</b>	<b>4939546.498</b>	<b>1.655</b>
5	481561.20	4939209.00			
<b>6</b>	<b>481480.90</b>	<b>4939034.00</b>	<b>481479.567</b>	<b>4939033.639</b>	<b>1.381</b>
7	480775.60	4938817.00			
<b>8</b>	<b>480565.40</b>	<b>4939287.00</b>	<b>480567.248</b>	<b>4939287.095</b>	<b>1.851</b>

*Scale (x,y): .517, .509*

*Image Rotation: .539 degrees*

*RMS error (image, cover): 2.885, 1.481*

## APPENDIX B

1. Matrix table for the 1936 to 1979 change analysis. Matrix identifiers are unique combinations of vegetation classes changed over a given time period. Histogram numbers represent the frequency of pixels of each value. Year classes account for the vegetation class (listed as *mycode* in Table 3) that change. Areas show change from 1936 vegetation classes to 1979 vegetation classes.

MATRIX IDENTIFIER	HISTOGRAM NUMBERS	1936 CLASS	1979 CLASS	36 to 79 CHANGE	AREA IN ACRES	AREA IN HECTARES
0	564035	0	0		139.38	56.4035
1	8243	1	1	no change	2.037	0.8243
2	3592	2	1	P to EmW	0.89	0.3592
3	864	3	1	SS to EmW	0.21	0.0864
4	0	4	1		0	0
5	0	5	1		0	0
6	0	6	1		0	0
7	22929	1	2	EmW to P	5.67	2.2929
8	100673	2	2	no change	24.88	10.0673
9	10152	3	2	SS to P	2.51	1.0152
10	20	4	2	SS/F to P	0.01	0.002
11	271	5	2	F to P	0.07	0.0271
12	0	6	2		0	0
13	939	1	3	EmW to SS	0.23	0.0939
14	89124	2	3	P to SS	22.02	8.9124
15	17274	3	3	no change	4.27	1.7274
16	48	4	3	SS/F to SS	0.012	0.0048
17	0	5	3		0	0
18	0	6	3		0	0
19	13312	1	4	EmW to SS/F	3.29	1.3312
20	27115	2	4	P to SS/F	6.70	2.7115
21	32216	3	4	SS to SS/F	7.96	3.2216
22	20659	4	4	no change	5.11	2.0659
23	60	5	4	F to SS/F	0.015	0.006
24	0	6	4		0	0
25	7085	1	5	EmW to F	1.75	0.7085
26	55222	2	5	P to F	13.65	5.5222
27	46931	3	5	SS to F	11.60	4.6931
28	36343	4	5	SS/F to F	8.98	3.6343
29	90246	5	5	no change	22.30	9.0246
30	0	6	5		0	0
31	0	1	6		0	0
32	0	2	6		0	0
33	0	3	6		0	0
34	0	4	6		0	0
35	0	5	6		0	0
36	9041	6	6	no change	2.23	0.9041

2. Matrix table for the 1979 to 1994 change analysis. Matrix identifiers are unique combinations of vegetation classes changed over a given time period. Histogram numbers represent the frequency of pixels of each value. Year classes account for the vegetation class (as listed as *mycode* in Table 3) that change. Areas show change from 1979 vegetation classes to 1994 vegetation classes.

MATRIX IDENTIFIER	HISTOGRAM NUMBER	1979 CLASS	1994 CLASS	79 to 94 CHANGE	AREA IN ACRES	AREA IN HECTARES
0	563786	0	0		139.31	56.3786
1	8005	1	1	no change	1.98	0.8005
2	9620	2	1	P to EmW	2.38	0.962
3	1197	3	1	SS to EmW	0.30	0.1197
4	874	4	1	SS/F to EmW	0.22	0.0874
5	1582	5	1	F to EmW	0.39	0.1582
6	0	6	1		0	0
7	2591	1	2	EmW to P	0.64	0.2591
8	90300	2	2	no change	22.31	9.03
9	6625	3	2	SS to P	1.64	0.6625
10	4363	4	2	SS/F to P	1.08	0.4363
11	4185	5	2	F to P	1.03	0.4185
12	0	6	2		0	0
13	0	1	3		0	0
14	14266	2	3	P to SS	3.53	1.4266
15	81223	3	3	no change	20.07	8.1223
16	877	4	3	SS/F to SS	0.22	0.0877
17	1091	5	3	F to SS	0.27	0.1091
18	0	6	3		0	0
19	0	1	4		0	0
20	223	2	4	P to SS/F	0.06	0.0223
21	751	3	4	SS to SS/F	0.19	0.0751
22	7218	4	4	no change	1.78	0.7218
23	0	5	4		0	0
24	0	6	4		0	0
25	2098	1	5	EmW to F	0.52	0.2098
26	19804	2	5	P to F	4.89	1.9804
27	17596	3	5	SS to F	4.35	1.7596
28	79974	4	5	SS/F to F	19.76	7.9974
29	229109	5	5	no change	56.61	22.9109
30	0	6	5		0	0
31	0	1	6		0	0
32	0	2	6		0	0
33	0	3	6		0	0
34	0	4	6		0	0
35	0	5	6		0	0
36	9036	6	6	no change	2.23	0.9036