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A GEOGRAPHIC INFORMATION SYSTEM FOR COLUSA COUNTY, CALIFORNIA

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ABSTRACT

Resource and planning agencies are increasingly faced with the monumental task of analyzing, storing and updating large volumes of environmental data. In Colusa County, California, the local field office of the Soil Conservation Service is currently mandated to preserve wetland environments from conversion to other land uses. In order to meet this mandate an inventory system was needed which could be used for periodic identification and mapping of wetlands in an efficient and timely manner. The Remote Sensing Research Program and the Soil Conservation Service are therefore cooperating in the development of a Landsat-based geographic information system designed to identify, inventory, store and update data on the distribution of wetlands throughout the agricultural portion of the County.

I. INTRODUCTION

During the past decade the use of computer-based geographic information systems has become an important part of the planning and resource analysis process. This has resulted in large part because these agencies are increasingly faced with management decisions that require collecting, analyzing and regularly updating large amounts of data on short notice. The problems associated with data storage and analysis are especially critical at the local level where funding and staff are always in short supply. One option available to many local agencies is to develop a geographic information system specific to their own area and purpose, and then store this system on another group's computer. This is the approach currently being taken by the United States Soil Conservation Service (SCS) in Colusa County, California.

The University of California's Remote Sensing Research Program (RSRP) and the Colusa County SCS Office recently began a joint project to develop a County level geographic information system (GIS). Specifically, it is designed to provide SCS resource managers with a computer-based system which can be used to identify and periodically monitor changes in the County's wetland areas. The identification and monitoring of wetlands is based on the analysis of two multi-temporal digital Landsat data sets from 1976 and 1979.

II. BACKGROUND

Much of California's Central Valley landscape was once characterized a wetland plant community, commonly referred to as the "tule lands." The original extent of this community is not precisely known, but has been estimated at between 200,000 and 1,860,000 hectares statewide.[1,2] In the Central Valley these wetlands were primarily restricted to the flood basins which parallel both the Sacramento and San Joaquin Rivers, and to the Tulare and Buena Vista Lake Basins (Fig. 1). In their natural state these basins were subject to annual inundation and much of their area was covered with a few inches of water during the greater part of the year. As the annual flood waters receded, the distribution and areal extent of the wetlands changed until they were to be found only in the most poorly drained portions of the basins. The principal dominants of this wetland community are the common tule (Scirpus acutus), cat-tail (Typha latifolia), spikerushes (Eloecharis spp.) and sedges (Carex spp.).

The gradual disappearance of these wetlands during this century has gone largely unrecorded. This was a result of the fact that (1) the distribution and extent of these areas were constantly changing, both on an annual and seasonal basis, and (2) it was a commonly held view that wetlands were unhealthy and unproductive environments.

During the last quarter-century, however, understanding of the ecological and environmental importance of wetlands has been increasing. Wetland environments have recently been shown to have many beneficial aspects which make them valuable and worth preservation. Among the more important of these is the role wetlands play in ground water recharge, wildlife habitat and recreation.[3]

The realization that wetlands are a valuable resource has lead to efforts at the Federal, State and local level to protect those wetlands which still remain. Different approaches have been tried, including direct acquisition, tax incentives and regulation under specific wetland legislation.[4,5] One factor that all these programs of regulation and management have in common is that in order for them to be successful, an accurate and reliable survey of the wetland resource must be available. Traditionally, wetland surveys have been accomplished either by field work or the interpretation of aerial photography. Such surveys are often costly and difficult to accomplish because of the nature of the wetland environment.

Federal and State programs require local resource managers to inventory and monitor existing wetland areas on a regular basis. One approach to accomplishing this has been through the use of digital Landsat data.[6,7,8] Landsat data are especially well suited for this type of survey work since they provide repetitive coverage over large areas, can be machine processed, and are easily incorporated into a computer-based information system and updated. The cost of a Landsat-based inventory system is relatively low compared to that of a traditional ground or aerial survey in an area the size of Colusa County.

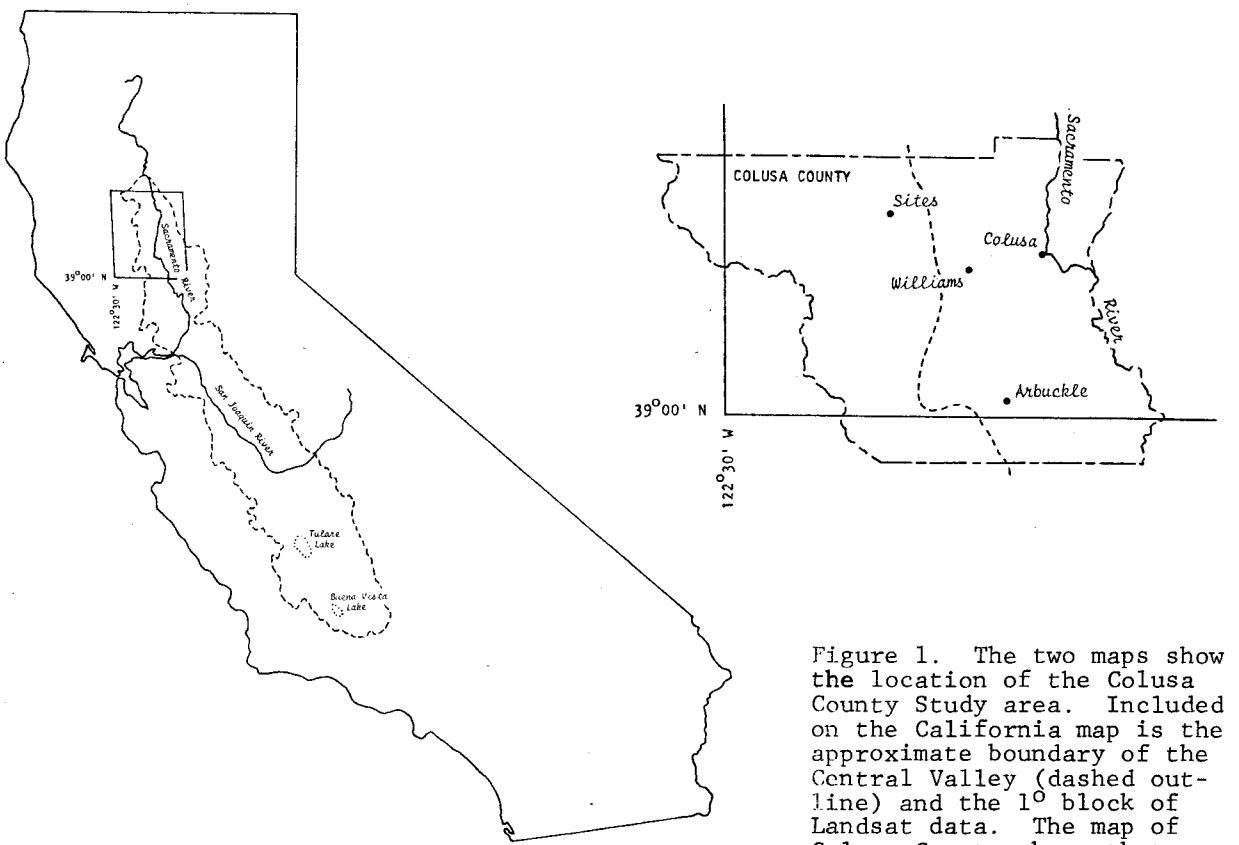

Figure 1. The two maps show the location of the Colusa County Study area. Included on the California map is the approximate boundary of the Central Valley (dashed outline) and the 1° block of Landsat data. The map of Colusa County shows that portion of the county covered by the 1° block.

III. STUDY AREA

Colusa County is located in the central portion of the Sacramento Valley along the west side of the Sacramento River (Fig. 1). Approximately 70 percent of its 2,964 square kilometers is presently cultivated, or in pasture.[9] Nearly all of the cultivated area is located in the level Central Valley portion of the County since the western third of the County is too rugged for most agricultural practices.

Dispersed throughout the 201,000 hectares under cultivation are 2,600 hectares of privately owned wetlands.[10] Prior to extensive reclamation for agriculture and flood control, it is estimated that the wetland area may have exceeded 40,000 hectares.[11] The disappearance of these wetlands in Colusa County, like most of those in California, went unrecorded until fairly recently. In 1979 Colusa County SCS and California Department of Fish and Game personnel produced detailed wetland maps for about 50 percent of the agricultural portion of the County. Most wetland areas within the County were included on these maps which were produced using interpretation of color infrared highflight photography and detailed ground surveys. The results of the 1979 survey were recorded on nine 7.5' USGS quadrangles (Fig. 3). As part of this survey an attempt was made to document the disappearance of wetlands based on an interpretation of available aerial photography. It was determined that since the early 1950's, nearly half of the privately held wetlands had been reclaimed for agriculture or other uses (Fig. 2).[10]

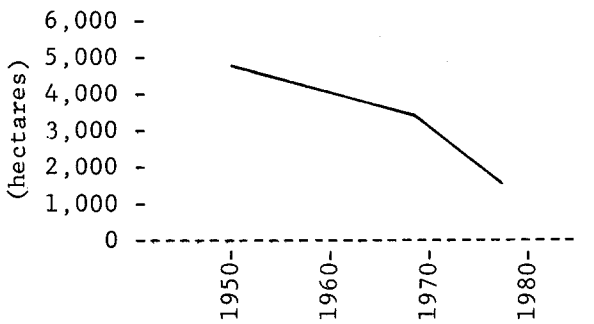

Figure 2. Graph showing loss of wetlands in the agricultural portion of Colusa County, California.

The 1979 wetland survey of Colusa County, while costly and time-consuming to produce, does provide local resource managers a partial base from which to document future changes in wetland environment. What is needed, however, is a relatively fast and inexpensive method to regularly inventory the entire agricultural portion of the County and store these data for future reference.

Resource managers from the Colusa County SCS Office, having previously worked with RSRP personnel in the application of aerial photography and digital Landsat data to resource analysis, were eager to participate in the development of a Landsat-based geographic information system designed to help monitor wetland environments. The resulting system focuses on the agricultural portion of Colusa County, where most of the remaining wetland areas are located.

Individuals from the Colusa County SCS Office, the California Department of Water Resources (DWR), the California Department of Fish and Game, NASA Ames Research Center and RSRP defined the basic data inputs necessary to develop a wetlands monitoring system. They decided that the resulting GIS should be user-oriented and rely as much as possible on currently available data and technologies. It should also be easily updated when additional data are made available from other agencies or sources. Of specific interest were the Landsat data which might be available from DWR as a result of its inventory of irrigated lands in California.

Six distinct levels of data have been identified as important components for the system's development and use. These levels are:

- A multi-year digital Landsat data set. This consists of three registered dates each from 1976 and 1979 and was available in-house as part of an on-going RSRP/DWR project to inventory irrigated lands in California. Each of these multi-temporal data sets covers a 1° block in the Sacramento Valley (Fig. 1).[13] The agricultural portion of Colusa County is contained within this block. The 1976 and 1979 data sets consist of the following dates which have been selected for analysis:

1976

Scene 47-33	Scene 48-32
30 May	22 May
28 August	20 August
03 October	04 October

1979

Scene 47-33 & 48-32

11 June
08 July
18 September

- Land use maps. These maps were produced by the California Department of Water Resources for the years 1954, 1955, 1961, 1967, 1976 and 1980, and are based on USGS 7.5' quads. They provide detailed field-by-field data on irrigated and unirrigated agricultural land use. The information system also includes five primary "native" classes, one of which is riparian. This riparian class contains three wetland or marsh vegetation classes, based on management practices. A total of 21 maps covering all of Colusa County are available for each year (Fig. 3).

- A detailed soils map and description. This soil survey, which was published in 1948, contains 226 separate soil types. For purposes of this GIS, these 226 soil types have been grouped into 60 classes based on natural land divisions as defined within the survey. The resulting 60 classes adequately characterize the areas most often associated with wetlands.

- Hydrologic and drainage information. This level of information is being included since many of the natural waterways and irrigation and drainage canals support a wetland-type vegetation. The linear nature of these features greatly increases the total wetland habitat within the County.

- Ownership and jurisdictional information. These data are being compiled in order to help analyze changes in land use within wetland areas.

- Basic geographic reference data. These data include roads, railroads and urban areas. All levels are to be registered to both the Universal Transverse Mercator (UTM) grid and the Township and Range system, since both appear on standard USGS 7.5' quads.

V. DESIGN OF THE GEOGRAPHIC INFORMATION SYSTEM

The development of the Colusa County geographic information system is based on the RSRP's NOVA 840 mini-computer. This computer system allows for the storage and interactive analysis of multiple levels of data per file. Currently, the information system is intended to contain between four and ten levels of background or reference data. This would include the basic soils, drainage, ownership and geographic reference levels. To this will be added the 1976 Department of Water Resources land use classification. The inclusion of this land use information is important in that it provides ground data to which the classification of the 1976 Landsat data can be evaluated. Other land use data sets will be added to provide a historical record of the changes which have taken place in the wetland areas.

The multi-temporal digital Landsat data for 1976 and 1979 can be registered to the reference or background data and included as additional levels within each file. Once these registered data files have been created, analysis and classification procedures can be performed on an area the size of one or more standard USGS 7.5' quads.

To register the Landsat data to a 7.5' map base a procedure was performed requiring the selection and measurement of identical control points on each Landsat acquisition and the map base. For ease of storage, display and analysis on the NOVA 840 interactive image analysis system, the 1^{o} block was divided into four 30' blocks. Control point coordinates were obtained by displaying the raw Landsat data, moving a cursor to a selected point, and recording the X and Y "point and line" coordinates of that location. The X and Y coordinates of each control point were then measured on 7.5' USGS quadrangles using the Universal Transverse Mercator (UTM) grid. The UTM ground coordinate system, which is based on a 1,000 meter square grid, was selected because it is a square grid and is found on most current USGS maps. These control points were distributed as evenly as possible over each 30' block, with approximately three points per 7.5' quad. A re-

gression relationship was then established between the Landsat and ground control point pairs; the resulting correlation coefficient was used to register the Landsat data to the ground coordinate file.[12,13]

A similar process is required to register each additional level of data as it is digitized and incorporated into the information system. The registration process is essential to the development of any geographic information system since it allows the user to analyze computer processed data with reference to its true geographic location on the ground, and vice versa.

The Colusa County study area is contained in the half of the 1° block of Landsat data. Nearly all Colusa's wetlands are found within an area covered by twelve 7.5' quads. (Fig. 3). The grids proved to be a convenient way to split the data into manageable units for analysis. These 7.5' units are also compatible with DWR land use maps and SCS field survey maps. Each quad corresponds to roughly 30,000 Landsat pixels, which is a manageable unit for analysis and display purposes.

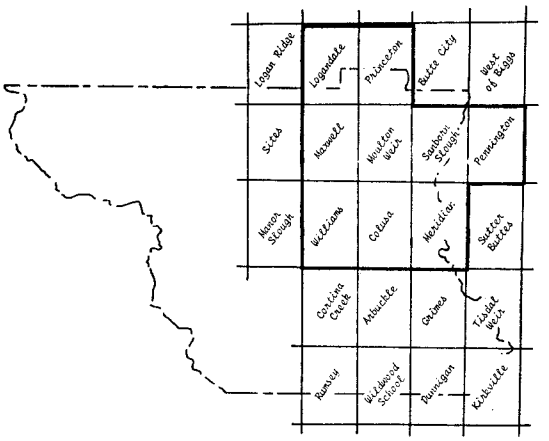

Figure 3. This map shows all 7.5' quads covering the agricultural portion of Colusa County. California Department of Water Resources land use maps exist for each of these quads. The quads in bold outline are included in the 1979 Soil Conservation Service wetland survey.

VI. SUMMARY AND PRELIMINARY DATA ANALYSIS

At the present time data analysis has been limited to a preliminary comparison of the spectral response of wetlands and other land use classes in a portion of the study area. This analysis was based on the MSS 7/5 ratio which was calculated during the registration phase of the irrigated lands project. This ratio was created for each date by multiplying the value of MSS 7 by 2 and dividing that product by the value of MSS 5 for each pixel. This ratio is a particularly effective discriminant for use in distinguishing different land use classes. The MSS band 5 has a relatively low brightness signal for vegetation while band 7 has a relatively high brightness value. The resulting ratio value is considerably higher for healthy vegetation than for other classes.[13]

For purposes of crop identification, 7/5 ratio values had been calculated for a total of five dates throughout the 1976 growing season. These values were plotted on a time scale, and resulting temporal profiles are now being studied in an attempt to distinguish between wetlands and other land use classes in the Colusa County area. The graphs in Figure 4 show the temporal profiles of wetlands and six selected land use classes commonly found in Colusa County.

Most wetland species are characterized by a rather dull brown-green color throughout most of the summer period in the Colusa County area. These species attain their maximum greenness in the late spring when available moisture is greatest. This is also the time when most agricultural crops (with the exception of small grains) have not yet emerged. It would therefore seem that wetlands could be most easily distinguished during the spring, or later in the growing season when crops are more vigorously growing and have higher 7/5 values than wetland areas.

In terms of the 7/5 ratio temporal profiles, it appears that the greatest potential for confusion is between wetlands, orchards, small grains and mixed pasture. Orchards should not be a serious confuser as they are poorly suited for areas that would support wetlands. Small grains are distinguishable since they are harvested in late spring. Mixed pasture has a consistently higher 7/5 temporal profile, but could easily be confused if its 7/5 values were to drop due to stress or lack of cultivation. The maintained pasture, alfalfa and rice classes are all distinguishable from wetlands based on their distinctive temporal profiles and

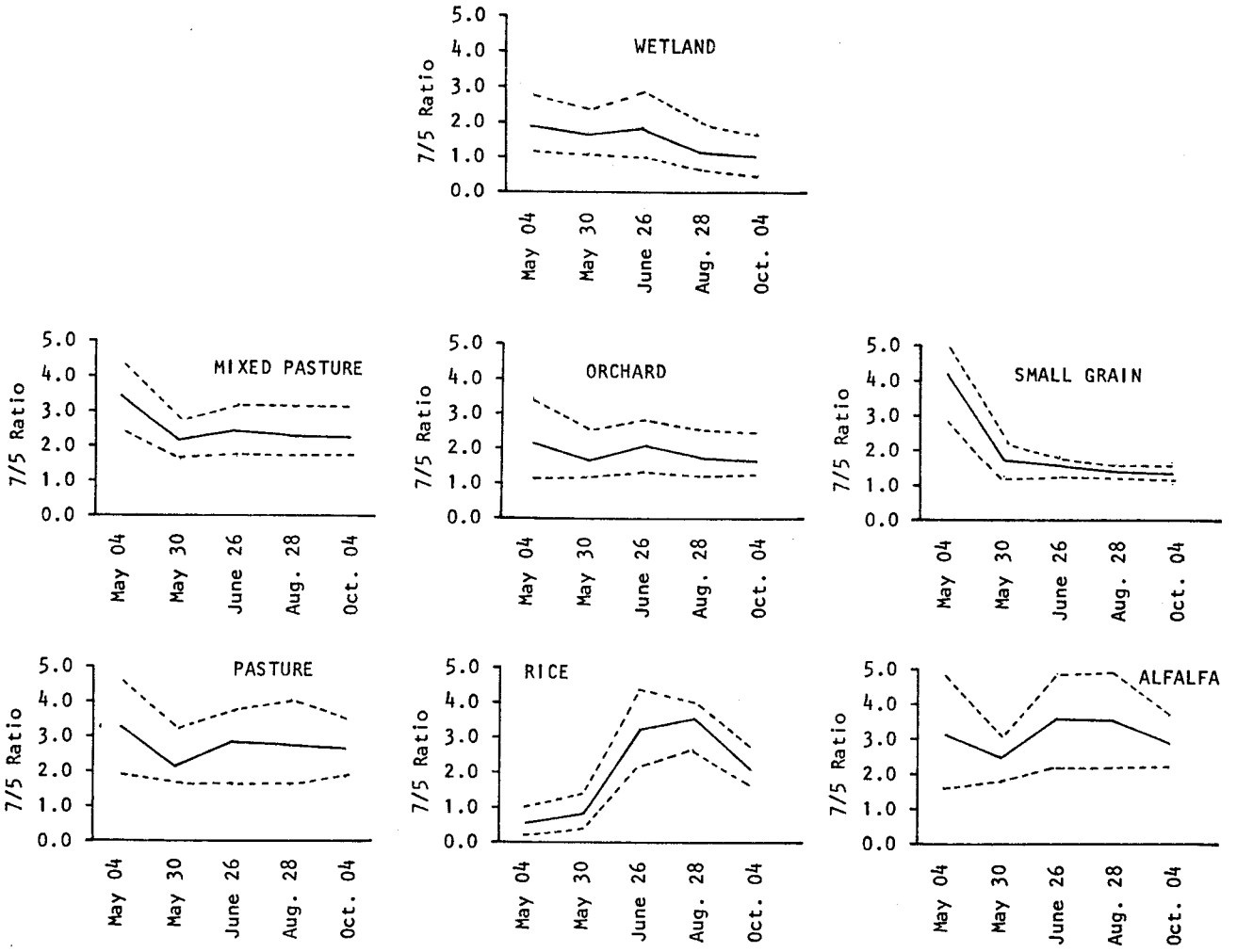

Figure 4. The graphs show 7/5 ratio temporal profiles for selected land use classes in Colusa County. The solid line is the mean value and the dashed represents one standard deviation from the mean value.

generally higher 7/5 ratio values. Most other crops commonly cultivated in this area have distinctive temporal profiles which distinguish them from those wetlands which have been studied to date. The mixed pasture class would seem to present the greatest potential for confusion with wetlands. This stems from the fact that the two classes have similar spectral temporal profiles and are commonly found adjacent to one another on the poorly drained basin soils throughout the County.

When this project began it was the opinion of most participants that wetland areas were diminishing at a very rapid rate. This view was supported by the 1979 survey conducted by SCS in Colusa County (Fig. 2). In an attempt to document this change all wetland and native vegetation classes were labeled and measured on the Colusa 7.5' DWR land use sheet from 1961, 1976, and 1980. The results of this limited inventory were surprising in that although a significant decrease in the native vegetation class was observed between 1961 and 1976, an increase in two classes of managed wetlands had occurred between 1976 and 1980 (Fig. 5). The two wetland classes which increased were seasonally flooded wetlands and permanently flooded wetlands. These designations are, however, somewhat deceptive since seasonally flooded wetlands can be any area, or land use class, that was flooded at the time of the land use survey. Permanently

flooded wetlands are managed wetland areas which are essentially "cultivated" for waterfowl habitat. These areas may be kept flooded for several years at a time.

	1961	1976	1980
	(Hectares)		
Native vegetation	3,112.0	772.0	499.0
Marsh	--	--	--
Meadows	--	--	--
Riparian	--	104.0	118.0
Seasonally flooded wetlands	--	466.0	709.0
Permanent duck marsh	--	499.0	650.0
Total Native Class	3,112.0	1,841.0	1,976.0

Figure 5. Total area classified as native vegetation classes on the Colusa 7.5' quad as mapped by the California Department of Water Resources.

Change in wetland areas appears to be going in two directions at the same time. As the value of waterfowl habitat increases many marginal agricultural areas are being converted to managed wetlands. Likewise, as the demand for agricultural land increases, especially land suited to the cultivation of rice, many wetland areas come under pressure for reclamation and cultivation. The documentation of this two-way change, and the mapping of its area extent, are the primary goals of this geographic information system.

VII. CONTINUING RESEARCH

At the present time the most important remaining tasks in the development of the Colusa County geographic information system are as follows:

- Complete the digitization and registration to the 1976 and 1979 Landsat data sets of all remaining information levels.
- Expand the analysis of the spectral temporal profiles of wetland and major land use classes within the study area.
- Identify all wetlands in the 1976 and 1979 Landsat data sets and compare the direction and rate of change in the wetland area.

VIII. REFERENCES

1. L.T. Burcham, "California Range Land", Div. of Forestry, Dept. of Natural Resources, State of California (1957).
2. A.W. Kuchler, "Potential Natural Vegetation of the Conterminous United States", American Geographical Society, Special Publication No. 36 (1964).
3. W. Niering, "Wetland Values", in Proceedings of the National Wetland Protection Symposium, FWS/OBS-78/97 (1978).
4. B. Bedford, "Wetlands Protection Efforts, Needs, and Priorities in Wisconsin", in Proceedings of the National Wetland Protection Symposium, FWS/OBS-78/97 (1978).
5. C.B. Myhrum, "Federal Protection of Wetlands Through Legal Process", Environmental Affairs, Vol. 7:567 (1979).
6. T.G. Neraasen, A.J. Macaulay, R.P. Mroczynski, "Pintails and Pixels: A Potential Application of Landsat Technology to Waterfowl Habitat Inventory", in Machine Processing of Remotely Sensed Data Symposium, (1981).
7. N.E.G. Roller, "Remote Sensing of Wetlands", NASA Contract No. NGR 23-005-522, Environmental Research Institute of Michigan, Ann Arbor, MI (Mar. 1977)
8. N.E.G. Roller, "Strategies for Information - Directed Wetlands", Environmental Research Institute of Michigan, Ann Arbor, in Machine Processing of Remotely Sensed Data Symposium (1981).
9. W.C. Disney, Jr., Agricultural Commissioner, "Annual Crop Report, Colusa County Dept. of Agriculture (1979).
10. C. Bell, "Colusa County Wetlands", unpublished memorandum (1978).
11. F.F. Harradine, "Soils of Colusa County California", Div. of Soils, University of California, Berkeley (June, 1948).
12. L.H. Beck, "An Evaluation of the Application of Digital Landsat and Terrain Data for Coordinated Resource Planning in Colusa County, California", California Space Group, Grant No. CS36-79, Space Sciences Laboratory Univ. of Calif., Berkeley (9/30/80)

13. S.L. Wall, et al, "Irrigated Lands Assessment for Water Management", Applications Pilot Test, NASA Grant NSG 2207, Remote Sensing Research Program, University of California, Berkeley (1980).

14. S.L. Wall, et al, "Irrigated Lands for Water Management", Application Pilot Test, NASA Cooperative Agreement NCC 2-54, Remote Sensing Research Program, University of California, Berkeley (1981).

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