USE OF GIS IN ASSESSING AREAS OF RAPID WETLAND CHANGE

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ABSTRACT

The Wetland Status and Trends component of the National Wetlands Inventory (U.S Fish and Wildlife Service) is charged with monitoring changes in wetland acreage for the United States. As part of this effort, Status and Trends is attempting to identify specific geographical regions where wetland losses may be proceeding at a rate higher than the national average. Past data indicate that this usually occurs in areas where rapid land use changes are ongoing, either because of population changes, agricultural or silvicultural practices, or changes in land values. Identification of these areas has been by field work or after-the-fact discovery. With the advent of Geographic Information Systems (GIS) technology it is hoped that the process of locating these "hot spots" can become more timely and efficient and less subjective.

This paper describes the process with the objective of using GIS to identify geographically discrete areas (usually counties) where significant wetland changes are taking place and prioritize further study of these areas based on wetland occurrence and resource priorities.

Currently Status and Trends has assimilated and assessed a number of national thematic GIS data layers and several others are being developed. Work is being done using the ARC/INFO GIS software running in a UNIX environment. To date several candidate areas have been identified for wetland loss studies. The process that led to their selection, as well as the specific challenges and benefits of this type of approach, will be discussed.

INTRODUCTION

The Wetland Status and Trends Unit is a component of the National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service (USFWS). Wetland Status and Trends monitors wetland acreage changes for the United States. As part of this effort Status and Trends tries to identify areas of the country where wetlands are being lost at an unusually fast rate. These "hot spots" of wetland loss are candidates for special studies to monitor land use changes over time and to help detect wetland policy or regulatory deficiencies, changes in land use practices, or other natural or man-induced phenomenon that may be promoting wetland losses. Priority is given to identifying hot spots that are discrete geographical units rather than addressing systemic national or statewide trends. For the purposes of

conducting this type of land use monitoring the county unit has been most appropriate.

Remote sensing has been used extensively by Status and Trends to monitor wetland acreage changes. Color infrared aerial photographs captured at different dates are compared and changes recorded. The advantages of using remote sensing are that it covers a fairly large area of the landscape and is relatively inexpensive. As part of this effort Status and Trends field verifies the aerial photography with on-ground conditions. However, because there may be one to three years lag time between the date of photo acquisition and actual analysis, routine field verification has yielded after-the-fact information about hot spot areas of wetland loss. Rather than this *post mortem* type of analysis, Status and Trends prefers to be as proactive as possible in determining land use changes affecting wetlands. There is also the concern that certain areas might be excluded from consideration since field work is limited to public access sites and is generally used to examine smaller portions of a state or region. For example, field crews may concentrate work efforts in the coastal zone of a state confirming photograph signatures, water conditions etc., while inland, wetland losses due to agricultural conversion or drainage may go undetected until final data analysis. Ultimately, GIS layering and analysis is considered the best tool whereby the nation could be examined in a timely and objective manner to help identify wetland loss "hot spots".

FACTORS INFLUENCING WETLAND CHANGE: TARGET DATA LAYERS

During past Status and Trends studies the types of land use activities that most influence wetland conversions have been documented (Dahl & Johnson 1991; Dahl 1993). These include:

Conversions to Agriculture -Agricultural land use may be defined broadly as land used primarily for production of food and fiber. Examples of agricultural land use include: cropland and pasture; orchards, groves, vineyards, nurseries, cultivated lands, and ornamental horticultural areas including sod farms; confined feeding operations; and other agricultural land including livestock feed lots; farmsteads including houses, support structures (silos) and adjacent yards; barns, poultry sheds, etc.. Historically agriculture has accounted for between 50 and 80 percent of wetland losses.

Conversions to Urban Development - Urban or Built-up Land is comprised of areas of intensive use with much of the land covered by structures (high building density). Urbanized areas are cities and towns that provide the goods and services needed to survive by modern day standards through a central business district. Services such as banking, medical and legal office buildings, supermarkets and department stores make up the business center of a city. Commercial strip developments along main transportation routes, shopping centers, contiguous dense residential areas, industrial and commercial complexes, transportation, power and communication facilities, city parks, ball fields and golf courses can also be included in the urban category.

Conversions to Rural Development - Rural developments occur in sparse rural and suburban settings outside distinct urban cities and towns. They are characterized by non-intensive land use and sparse building density. Typically, a rural development is a cross-roads community with a corner gas station and convenience store usually surrounded by sparse residential housing and

agriculture. Scattered suburban communities located outside a major urban center can also be included in this category as well as industrial and commercial complexes, isolated transportation, power and communication facilities, strip mines, quarries, and recreational areas such as golf courses, etc.

Conversion to Forested Plantations - Plantations include silvicultural areas such as planted pines, Christmas tree farms, clear cuts and other managed forest stands.

Conversion to Other Upland Land Use - Other land use is composed of uplands not fit fitting into the previous categories. Typically, these lands would include native prairie; unmanaged or non-patterned upland forests and scrub lands; and barren land. Lands in transition from one land use type to another may also fit into this category.

Understanding that these categories represent the fate of wetlands being converted to upland land use will help determine where and how to look for GIS layers that may be representative of these trends.

While the potential for wetland losses occur wherever the above land uses conflict with wetlands, as a general rule (Alaska being a notable exception), wetland losses are greatest where wetland abundance is greatest. This is because potential conflict with land development activities are more prevalent. For example, Arizona cannot lose wetlands at the same rate as Louisiana because the wetlands are not available to be lost. Consequently any future losses will probably be greatest in the areas of the country where an abundance of wetland acreage and a high potential for land use conversions overlap.

Operating on this basic assumption, if GIS data layers adequately representing the land use conversion factors above are developed, these data layers can be examined to determine where intersections with wetland complexes exist. In theory, these intersects may represent potential "hot spots" . For the purposes of this discussion, we have chosen to focus on the development oriented indicators as an example (Figure 1).

ACQUIRING REPRESENTATIVE GIS LAYERS

The obvious question is why not use remote sensing technologies to determine land use changes or "hot spots"? This is a technique that has worked well for some applications including monitoring global change (Driscoll 1991; Loveland *et al.* 1991). The problem is one of scale. Wetlands compose only five percent of the land surface of the conterminous United States. Annual losses are estimated to be less than one half of one percent of that land area or about 120-160,000 hectares (300,000-400,000 acres) per year. Wetland losses are often composed of fractional acreages piecemealed over several years to ultimately result in fairly significant cumulative losses in any particular area. Any remote sensing tool that would cost-effectively examine the conterminous U.S. with repeat coverage would have a resolution similar to that of the Advanced Very High Resolution Radiometer (AVHRR) imagery at 1.0 kilometer (Hastings and Emery 1992). This is too coarse a resolution to be useful for detecting wetland changes at the necessary scale. Examination of SPOT or LANDSAT data or acquisition of aerial photography is prohibitively expensive and universal repeat coverage on a 3-5 year cycle is not currently available. In the future, as satellite derived statewide image mosaics can

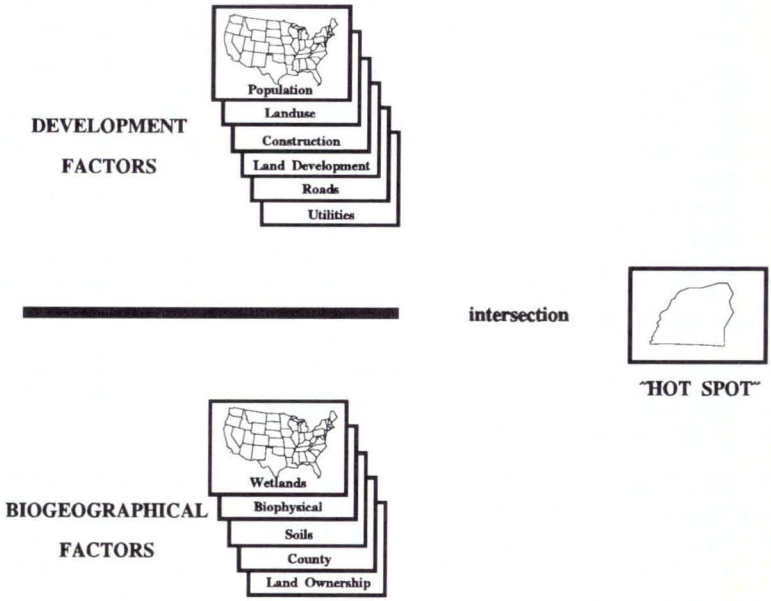

Figure 1. Conceptual strategy for using GIS layers to identify wetland "hot spot" areas.

be produced at 1:500,000 scale or larger, reconnaissance for change detection may be more realistic. The need for temporal national coverage with fine resolution of land use changes has indicated that GIS is presently better suited for this type of reconnaissance work. GIS may offer particular advantages to the study of landscape change (Hulse and Melnick 1991), however, for this study several criteria for a conceptual framework of GIS layers useful for detecting wetland losses must be met: The GIS coverages must be national in scope; coverages must be inexpensive to obtain, manipulate or assemble; and data layers must be readily available (cannot involve extensive data collection or proprietary information).

GIS layers thought to be representative of land development include those shown in Table 1. In some cases no data layers were located to correspond to the tracking indicators. In other instances surrogate data were used either as GIS information or automated data base management files were retrofitted to GIS coverages.

The Federal Geographic Data Committee (FGDC) has assembled a "Manual of Federal Geographic Data Products" compiled by the various Federal agencies generating GIS information (FGDC 1993). By the title of this publication it implies that it is a directory of GIS layers available from the Federal Government. In reality it is a listing of operational or planned geographic data assimilation efforts with only some percentage being available in digital or automated formats. This typifies the situation when trying to assemble national GIS coverages.

Table 1. Indicators of urban and rural development, corresponding GIS information and source(s).

Tracking Indicators	Representative GIS Layers	Source(s)
Land use	<not current>	---
Population immigration/emigration	Population growth	Bureau of Census
Building permits/ new construction	Development projects*	Various
Highway development/ construction	U.S.G.S. updates	U.S. Geological Survey
Land development/ speculation	Development projects*	Various
Utility construction/ expansion	<not represented>	---
Resource status	Wetland distribution Resource priorities	U.S. Fish & Wildlife Service Environmental Protection Agency
Soils	<not represented>	---
Land ownership	<not represented>	---

* Relational Data Base Management System (RDBMS)

The GIS layers that have been obtained for this exercise include several from the U.S. Geological Survey (U.S.G.S.). To date U.S.G.S. has supplied digital layers containing county boundaries, 1:24,000 scale quadrangle boundaries, forest types, land use, vegetation and climate. Each GIS coverage comes with pertinent attribute information. In addition, U.S.G.S. has provided an ASCII flat file containing information about publication and revision dates for their 1:24,000 scale quadrangle topographic maps. This information was used with the quadrangle boundaries layer to create a GIS coverage showing where and how often topographic base maps are being updated for the nation.

The Bureau of Census has also provided information in tabular format that has been used to create various GIS layers. The "USA Counties" database provides hundreds of attributes associated with each state and county in the nation. Some of this information has been extracted and used in conjunction with the national counties coverage to create GIS layers showing recent population changes; number of building permits issued; and recent changes in number of residential and commercial buildings. These types of data are ideally suited for the purposes of this study.

Beyond what is available from other agencies, Status and Trends has found it necessary to create some GIS layers. Among these, a national coverage depicting physiographic regions based on Hammond (1970) has been digitized from 1:250,000 scale base maps. A coverage showing U.S. Environmental Protection Agency (EPA) Advanced Identification (ADID)* sites was created from project documentation provided by EPA. A coverage showing National Wetlands Inventory (NWI) map sales by 1:100,000 map unit was also created using data obtained from U.S.G.S. EROS Data Center (EDC).

To assemble, view and analyze these data, Status and Trends utilizes the ARC/INFO GIS system and the ORACLE Relational Database Management System (RDBMS). Both software systems run on a network of Sun Microsystem servers and workstations. All analyses and interpolation of data layers are performed in ARC. GIS information received from outside sources is converted to ARC coverage format if necessary. Likewise, flat file data or RDBMS files other than ORACLE are converted to ORACLE tables on the main server. The amount of effort required to prepare acquired data for use ranges from very little to quite involved. Importing ARC EXPORT format files is a simple task. A more complicated process involved querying the EDC computer system via modem for NWI map sales data, KERMITing the resulting data files to the SUN network, editing the ASCII files to clean up typographic errors and creating a program to massage the data for loading into an ORACLE table. Each ORACLE table must have some geographic link that will allow the data to be tied to a GIS coverage that can then be analyzed and displayed in ARC. For this purpose, the Geographic Names Information System would be extremely useful, but is still under development at U.S.G.S. Figure 2 illustrates several representative GIS layers used by Status and Trends to isolate potential wetland loss areas.

ANALYSIS TO LOCATE RAPID CHANGE AREAS

Intersection of the assembled GIS layers is accomplished by classical GIS layering and intersecting operations. This process is fundamental to GIS (ESRI 1992) and has been described by numerous authors.

Analysis of the GIS information gathered for this study indicate a preponderance of development related indicators in the Southeastern United States. For example, Florida is a particularly good hot spot candidate when comparisons of biogeographical layers are run against tracking indicator GIS layers. This is because 1) Florida is a state with lot of wetlands and 2) development pressure within the state resulting from population growth is high.

Once a candidate region or state is filtered from the national data sets, there are other statewide databases that may be accessed and combined with the results of the national GIS information. It is anticipated that regional refinement of the information will help support the indicators provided by the national model. For the purposes of this exercise, several data sets pointed to Collier County, Florida as a likely candidate for further study. By querying state or regional data, factors

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*Advanced Identification sites are those areas the EPA considers important for wetland resource planning activities.

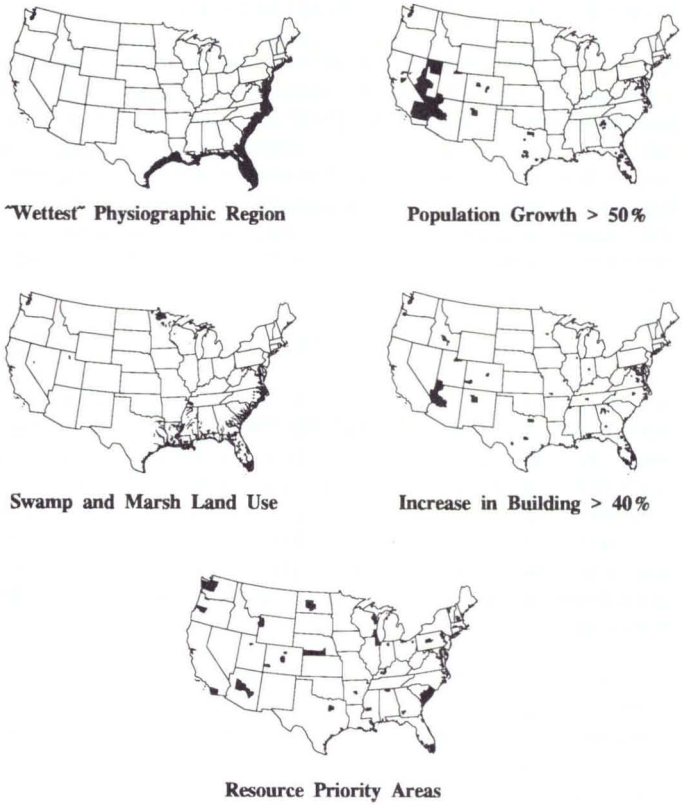

Figure 2. Representative GIS layers used in analysis of wetland "hot spot" areas.

such as the proximity of cities or towns to coastal resources or the amount of Federal land within the county can provide additional insights to characterize these candidate areas.

As with any model of this type it is necessary to make a series of judgement determinations that help differentiate change areas. Factors or layers are valued differently for their ability to distinguish potential wetland loss areas. The date of the source GIS information or how closely the GIS layer actually represents the target indicator(s) are important considerations. An example of this occurs when contrasting the population growth GIS layer with the EPA ADID GIS layer. Population growth represent census estimates as a best representation without parameter bias. EPA's ADID data layer however, may have been developed with many more internal compromises including budgetary constraints, information gaps, etc.* Consequently there is some subjective weighting of the GIS layers that occur

*This is a hypothetical example. The authors have no information to indicate EPA's information is bias.

in the analysis phase. Ideally, this should be minimized.

It should also be emphasized that intersecting a number of these national data layers is the first step to filter the available indicators. Candidate hot spots of wetland loss are derived from these data sets. These areas can be further analyzed for their appropriateness as final study sites. Matching the candidate county with information such as the availability and timeliness of aerial photography; the size of the county; the availability of collateral resource information; and the proximity to other agency resource priorities or ongoing studies helps make a final determination for suitability. Ultimately, field verification of these candidates areas is made.

CONCLUSION

GIS technology has made it possible for Wetland Status and Trends to effectively identify potential hot spots of wetland loss without reliance on expensive remote sensing techniques or the subjectivity of field reconnaissance. Using GIS layers which describe indicators of rapid land use change in potential conflict with wetlands can be identified on a national basis. Confirmation of valid hot spots can then be supported with state and regional data and verified by field reconnaissance. To date, Status and Trends has identified several counties where work is ongoing to analyze recent wetland acreage losses. The preliminary results of these studies are promising.

The process of utilizing GIS technology to accomplish this work is evolving over time. The data assimilation effort is massive and continuous. Real-time linkages between relational data base management systems and GIS graphical displays are improving. Ancillary tools such as Geographic Names Information System should ultimately make this types of work faster and better in the future.

The paramount consideration however, is the methodology described relies on the availability of timely, nationally-based GIS information to provide a cost effective approach to assessing areas of rapid wetland change. Improvement in the comprehensiveness and availability of these base layers must keep pace with the technological ability to compute and display the information.

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