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STRATEGIES FOR INFORMATION - DIRECTED WETLANDS

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ABSTRACT

Protection and effective management of wetlands requires information describing their type, distribution, and condition. Inventories are carried out to obtain such information. The efficiency of inventories that produce statistical information can be improved by the use of remote sensing because the synoptic observation capabilities of remote sensors, particularly Landsat, make it possible to nearly eliminate sampling error. The information furnished by inventories designed to produce maps can be extended through the use of digital data manipulation techniques to include (1) quantitative measures of the spatial arrangement of a resource and (2) detection of changes in a resource over time.

INTRODUCTION

An increasing awareness of the ecological and economic benefits of wetlands has finally fostered meaningful efforts to protect them. Before government agencies charged with this responsibility can act, however, they must have information describing the resource so that effective protective measures can be identified and plans for implementing them prioritized. Obtaining such information can be difficult for a number of reasons, including: limited funds, lack of personnel trained in resource inventory procedures, not much time to do the job, and, in the case of wetlands, the difficulty of visiting remote areas and areas with poor trafficability. Each of these constraints can severely limit the amount of useful information a decision-maker can obtain if, in attempting to gather the required information, the wrong inventory strategy is employed. With this in mind, the purpose of this paper is to review the basic issues that one needs to consider in order to design an efficient resource inventory, and then describe some new inventory design strategies involving the use of remote sensing data and digital data manipulation techniques that make it possible to extend the usefulness of traditional wetlands inventory techniques.

BACKGROUND

No one knows how many wetlands originally existed in our country, but one thing is clear -- there are a lot fewer now. Many of these lost wetlands were the victims of drainage efforts aimed at improving conditions for agriculture. These efforts began with the individual farmers who cleared the land, and continued to grow in size and popularity. In the 1930's, the Federal government became actively involved and actually subsidized programs for this purpose. Unfortunately, this practice continued until as recently as 1975. Meanwhile, other pressures also nibbled away at wetlands. The pressures of industrial, residential and recreational development caused the destruction of large numbers of wetlands along the shores and banks of lakes, rivers, and streams. The net result of these and other activities was a period of wholesale destruction of wetlands covering much of the last century. Our best estimates indicate that as a result of the effects of all these activities nationwide as much as 30-40 percent of our original wetlands may already have been lost (Stegman, 1975; Staats, 1981).

Certainly one of the main factors contributing to destruction of wetlands in the past was a lack of understanding of their inherent ecological and economic benefits. For years wetlands were regarded simply as waste spaces, unfit for habitation or the production of goods; besides which, they formed obstacles to travel, and were regarded as decidedly unpleasant and unhealthy. It is really only within the last quarter-century that the attitude of the general public has substantially changed in this regard. This change is due largely to the fact that research studies during this period identified and objectively demonstrated the many functions wetlands perform that make them valuable and worthy of preservation and protection. Among the more important of these beneficial functions that wetlands have been identified as providing are the following: serving as buffer zones to reduce the effects of coastal storms, trapping sediment, pollution filtration, flood reduction, ground water recharge, and providing essential habitat for certain species of fish and wildlife (Niering, 1978).

The realization that wetlands possess the values just mentioned has fostered a great amount of effort over the last decade aimed at obtaining protection for those wetlands that still remain. Many approaches have been tried and found effective; these include: direct acquisition, easements, tax incentives, regulation under other enabling legislation, and regulation under specific wetland legislation (Bedford, 1978).

Wetlands protection currently provided by the Federal government consists primarily of (1) acquisition and management of key habitat by the Fish and Wildlife Service, and (2) certain regulatory functions. Under Section 404 of the Clean Water Act, the Army Corps of Engineers requires permits for discharge of dredge or fill in wetlands, and under Section 10 of the River and Harbor Act of 1899 the Corps requires permits for any activities that affect wetlands located along navigable waterways. In addition, many other Federal agencies indirectly assume various levels of responsibility for wetlands protection in the process of carrying out their primary responsibilities, including the Bureau of Reclamation, the Soil Conservation Service, the Federal Power Commission, Nuclear Regulatory Commission, Forest Service, Bureau of Land Management, National Marine Fisheries Service (Stegman, 1975).

Many states have also passed legislation which provides for the protection of wetlands. Michigan, for example, which has over half of all the wetlands in the Great Lakes Basin, has three laws which regulate the uses to which certain types of wetlands may be put, and one law which gives tax breaks in return for a development right agreement with the state. Furthermore, funds for wetlands acquisition are provided through the purchase of a duck hunting stamp and the interest on a land trust fund estabished using lease fees paid for gas and oil development rights on state-owned lands.

The one thing that all of these programs of regulation and management have in common is that, in order to effectively implement them, an accurate and reliable description of the wetland resource must be available. Such information is used in several important ways. The consequences of issuing a permit for certain activities on a given wetland, cannot, for example, be assessed without consideration of how the proposed activity will affect other nearby wetlands. Also, proper management of wetlands is best accomplished when groups of similar connected wetlands are treated as a system, and the system managed as a whole. Thus, priorities for acquisition or management are difficult to establish without an overview of the extent, location, and especially the condition of the total wetland resource that is to be protected.

In spite of the obvious importance and need for good information about wetlands, such information unfortunately does not always exist. Although major efforts are being made to remedy this problem, including a new National Wetlands Inventory (Montanari and Wilen, 1978), some users will always be faced with the problem that their area has not yet been covered, or that the type of data that is available is not suited for the particular kind of analysis they require. In such cases it will be necessary for them to collect the required data on their own. Identifying the proper approach that will allow a person in this position to successfully accomplish this task is the subject of this paper.

ANALYZING INFORMATION REQUIREMENTS

Perhaps the most obvious and yet overlooked step in designing a resource inventory, regardless of the resource of interest, is deciding at the outset what constitutes the <u>minimum</u> acceptable performance in terms of accuracy, cost, reliability, and time required. Without this framework it is nearly impossible to evaluate the usefulness of a given approach or technique with regard to its suitability for the purpose at hand. The reason this step is so critical is that nearly everyone has a tendency to want to do the best job possible. As a result, attention rapidly becomes focused on the fine points of data gathering, or data analysis, or a plethora of other interesting questions. As a consequence, other very important aspects of the overall design are sometimes not given adequate attention. The results of such oversight can range from the inventory costing far too much (requiring that it be abandoned, or curtailed in size or scope), to taking so long to complete that the results are only of academic or historical interest.

Another good reason for taking the time to identify minimum acceptable performance standards for an inventory is that it forces the user to critically examine a problem and determine exactly what information is required to address it and how this information will be used. Periodic reviews of this type are desirable because as new knowledge becomes available old problems should be reexamined and the solutions to them checked for continued validity. Conducting an inventory in a particular way "just because that's the way it has always been done" is not likely to permit one to take advantage of technological advances or to incorporate better understanding of how to cope with the issue the inventory is designed to address.

A list of the factors that one should consider when developing a set of minimum acceptable inventory performance standards includes the following: (1) the size of the area to be inventoried; (2) the measurement(s) that must be made; (3) the amount of error that is tolerable; (4) the reliability which the information obtained must have; (5) the funds and personnel available to do the job; and (6) the deadline by which the information must be available.

As an example of how this review process can help focus one on the key aspects of inventory design, consider the situation of a person faced with the need to conduct an inventory where it has already been decided that a certain type of measurement is required and that a way to make it within acceptable accuracy limits is available, yet, less time and funds are available than for previous surveys. In this case, the person in charge does not need to investigate or even consider how to make a better measurement; rather, the key issue is how to either make or use the designated measurement more efficiently.

THE CHOICES OF TRADITIONAL INVENTORY DESIGN: MAPS OR STATISTICS

Once the information requirements that an inventory must fulfill are identified, it then becomes possible to determine the best way to obtain this information. Obtaining any information is based on the gathering and analysis of data, and so it is really the different ways that data can be gathered and analyzed which must be compared to determine which is best for the purpose at hand. Traditionally two basic approaches have been used to gather and analyze resource inventory data. One of these approaches is characterized by the various data gathering and analysis techniques employed when a map showing the location and abundance of a resource is desired. For example, a waterfowl biologist interested in evaluating the potential of several areas as waterfowl breeding habitat might want a map so that he can examine the arrangement of large and small wetlands in each area. The other approach is characterized by that group of data gathering and analysis techniques which rely on sampling to yield non-point-specific estimates of overall or average resource characteristics. An example of the use of this type of approach would be the annual May and July pond counts conducted by the USFWS as part of their waterfowl breeding and production surveys (Henny, et al., 1972).

Each of the two basic approaches has advantages and disadvantages with regard to providing types of information, accuracy, precision, and the generation of output products. Each approach is discussed in more detail in the material that follows.

MAP-BASED APPROACH

The common feature shared by inventories that require the analysis of a resource's spatial relationships is a depiction of the location and extent of the resource on a map. A map is defined as a representation of the earth's surface and a good map shows features of interest in the same relative position on the map as they are on the ground. Thus, a good map in an inventory sense also furnishes a complete enumeration, i.e., a census, of the resource. This fact is especially relevant to this discussion because it also means that summary statistics from this type of inventory will have no imprecision due to sampling error associated with them, a characteristic not shared by inventories based on sampling. This is not to say, however, that map-based summary statistics are more accurate than sampling-based statistics, because map-based inventories are subject to errors in measurement just as sampling inventories are, and these errors can display a particular bias. Determining the size and nature of this error can be exceedingly difficult, especially if several map categories are involved, and as a result the error of many maps is not actually known because of the difficulty required to determine it.

Because of the difficulty associated with assessing the accuracy of a map and the time required to prepare a map, some persons whose responsibility it is to make the decisions that determine how resources are managed prefer to use statistically based data because it is easier to prepare, and an objective measure of the precision of the estimate can be calculated. Yet, when dealing with the general public, many administrators find that map based inventories are more suitable for illustrating resource abundance and condition. The reason for this is that someone can examine a portion of the map covering an area with which they are personally familiar, and see if it compares with the conditions that that person knows exists in that area. If the map and the person's impressions agree, that person will have confidence in the map. This kind of comparison cannot be done with statistical data in most cases, and so persons not trained in sampling may have a hard time evaluating it in a personal context. Since they cannot personally judge its validity they may remain skeptical of its accuracy.

Another point worth mentioning is that maps can be updated by pencilling in changes and the conditions in local areas may change in the same relative way so that broad patterns in resource abundance may still be correctly portrayed on a relative basis. Statistical estimates are only valid over certain specified sample aggregation units (i.e., strata), and areas within different strata or smaller than a stratum cannot be compared or updated.

SAMPLE-BASED APPROACH

Inventories that are required to furnish an estimate of resource abundance or condition in statistical form rely on sampling techniques. Sampling is an efficient way to generate information for several reasons. Perhaps the most significant reason is that only a small percentage of the entire study area needs to be examined. Another important point is that it is sometimes possible to learn more about the resource using sampling as opposed to making a census because, even though sampling results in making fewer measurements, on a limited basis one can afford to make the type of more difficult measurements from which more is learned. On the other hand, you do not get a map to go along with the statistics that were produced, and this may make certain individuals to whom "seein' is believin'" skeptical of the results.

HOW REMOTE SENSING CAN IMPROVE INVENTORY EFFICIENCY

For a variety of reasons, many persons have fallen into the habit of thinking that any resource inventory they design must fall into one of the two types just discussed. Furthermore, they are cften frustrated when the approach they feel is most appropriate cannot provide all the information they desire. For example, many managers want a map showing the location of the resources in which they are interested. They also want to use remote sensing techniques to make the map, because such techniques are timely and relatively inexpensive compared to traditional mapping methods. But, when they assess the accuracy of their map, quite often they find that at least one, or maybe more, important categories have not been mapped with the accuracy that is desired. At this point many of these managers feel that they have only two choices: (1) live with the map as it is; or, (2) resort to a different mapping technique that is probably much more costly and time consuming. There is, however, a third alternative.

One of the major advantages of many remote sensing systems as a data gathering device is a synoptic observation capability. In essence, using these systems allows one to look at large areas at essentially the same moment in a timely and economical fashion. One of the most familiar of these systems is Landsat. As a result, almost everyone knows that Landsat can observe large areas and that maps of these areas can be made very quickly and economically. Such maps can be very useful to managers who want an estimate of resource abundance, because statistics compiled from these maps represent a complete census with no sampling error. Many investigators have also found, however, that the accuracy of these maps is lower than that of a map with comparable categories made with more conventional remote sensing techniques or field work. As a result, some individuals have concluded that Landsat cannot help them inventory the resources they are interested in, because a good map of these resources cannot be made due to the measurement error associated with Landsat data. Nevertheless, it still may be possible to use the map that can be made from Landsat in combination with various sampling techniques employing essentially no-error field measurements to yield information of value. Note, however, that while field measurements might have no error (bias) any attempt to characterize the universe using them would be prone to sampling error, because these measurements are probably so expensive to make that only a few samples can be afforded. The point here is that it is possible to effectively combine these two inventory approaches in ways that take advantage of the benefits of both approaches. To illustrate how remote sensing can facilitate combining map and sampling inventory techniques into an effective inventory procedure, a special case of a familiar inventory strategy, multiphase sampling, is discussed in more detail.

MULTIPHASE SAMPLING

The synoptic mapping capabilities of Landsat data make it possible to implement a special form of two phase or double sampling with improved estimation capabilities. This technique produces an estimate of resource abundance based on a combination of Landsat data and some low-error measurement samples (such as field data). The resulting joint estimate is called a regression estimate, and constitutes the special form of double sampling alluded to earlier, because one 'sample' or phase is the complete census provided by Landsat (Jessen, 1978).

The unique aspect of this technique that accounts for its effectiveness is the way in which the relationship between the measurements made in each phase is used. The Landsat census (100% sample) is used to characterize the sampling universe, i.e., the study area, with no sampling error (imprecision), but with some (and perhaps unknown) measurement error. This area-wide estimate of resource abundance is then modified (bias-corrected) using the regression relationship found to exist between the Landsat measurement and the field measurement which was observed when both measurements were made on a subset of sample units and compared. Note that a special condition of this approach is that the measurements that are compared must be made on the same sample units.

The specific form of the estimator is as shown:

$$y_{resource} = N[\bar{y} + b(X - \bar{x})]$$

where $y_{resource}$ = estimate of resource abundance for the area of interest (a stratum or the study area)

$\bar{y}$ = field sample mean
$\bar{x}$ = Landsat sample mean
X = Landsat census mean
N = number of "potential" sample units in the stratum or study area
b = slope of regression between field data (dependent variable) and Landsat data (independent variable)

The use of this technique was successfully demonstrated for the USFWS by ERIM as a potential method of improving the accuracy and efficiency of pond counts in North Dakota (Colwell, et al., 1978). Two pond count estimates were prepared using the double sample strategy described above for May and July of 1975 in USFWS Stratum 46, an area covering 3700 km^2. Landsat pond counts were made for both dates by thresholding MSS7 and then calculating the number of water bodies detected using a special software program called MAPSTAT. Then on a set of 18 1x6 mi sample units located along USFWS transects (approximately 1% of the study area), Landsat measurements and "phase two" measurements were made to develop the bias correction relationship for the Landsat census data. The phase two measurement consisted of a count of ponds made from largescale aircraft imagery in which there was assumed to be no error (i.e., no ponds missed and no false alarms included). It should be noted that the phase two measurements were made under the same environmental conditions (i.e., from data collected at the same time) as the Landsat measurements. Comparison of the Landsat and aircraft pond counts on the subset of 18 sample units showed a high degree of bias associated with the Landsat measurement, i.e., Landsat detected only 44% of the ponds presented in May and only 12% of the ponds present in July.

A linear regression was then calculated for each date for each set of measurements (Landsat and large-scale A/C imagery) on the subset of identical sampling units (see Figure 1). After adjusting the Landsat census data using the regressions it was found that the combined estimates for May and July were within +8% and -3%, respectively of the USFWS pond count estimates for Stratum 46.

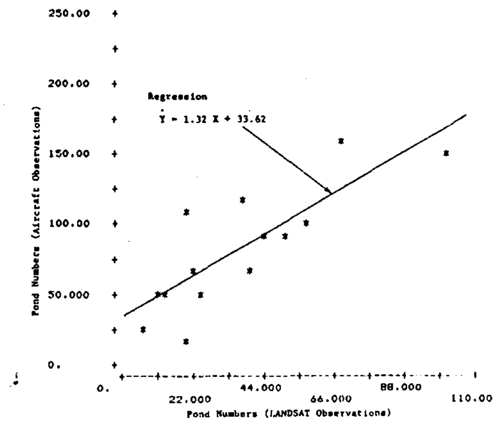


Figure 1. Sample linear regression of pond numbers (from aircraft data) on pond numbers (from LANDSAT data) for May 1975.

Thus, in spite of a large amount of bias in the Landsat census, and a relatively small phase two sample, which presumably had a significant sampling error, credible estimates were produced. It should be noted, however, that we are comparing two estimates here and so it is not clear which one is "right". The fact that they do agree, however, gives us confidence that the Landsat approach is at least capable of producing information equivalent in accuracy to traditional techniques.

TECHNIQUES FOR THE SPATIAL AND TEMPORAL ANALYSIS OF RESOURCES

As useful as sampling techniques are for gathering data efficiently and assisting in making more accurate remote sensing based estimates of resource conditions, there are some types of information that managers need which either cannot be obtained used them, or not nearly as efficiently as when another technique is used. An example of the former type of information is that which is derived from the analysis of the spatial relationships that exist between the various elements of a resource. This type of information must be derived from a map-based inventory. An example of the latter type of information is the detection of changes in a resource over time. Although sampling can be used to assess changes, it is almost always more effective to stratify an area based on a comparison of maps which indicate where the changes are occurring before doing so.

In this section of the paper strategies for using map-based inventory data to obtain the two types of information just described are presented. These strategies are based on the application of digital data manipulation techniques originally developed for the handling of remote sensing data, but which also are well suited to the more general applications discussed here.

SPATIAL ANALYSIS

Information describing the spatial relationships of a resource is important for many management purposes. As a result, a manager may be willing to accept the results of a spatial analysis based on a map of only modest accuracy if there is no other way to obtain such information. This means that although a remote sensing derived map may not be suitable for calculating the acreage associated with a given cover type, it might be perfectly acceptable for obtaining some relative information regarding the spatial arrangement of that cover type. This strategy may become even more attractive when the cost of making such measurements using traditional techniques is considered. Spatial information can be derived for relatively little cost from digital remote sensing data like Landsat when a computer is used to process the data. One area in which it is particularly important is in the evaluation of the quality of wildlife habitat.

There is more to the proper evaluation of wildlife habitat than simply summing up the relative abundance of the vegetation cover types occupying an area. This is because it is not only the presence of vegetation types that provide food and cover for wildlife that is important, but also how well these types are arranged that determines habitat quality. Biologists use the expressions interspersion and juxtaposition to describe how well vegetation cover types are arranged in terms of providing food and cover for wildlife. Measurement of these components of habitat quality requires spatial analysis of the habitat. Roller and Colwell (1978) illustrated how such measures could be incorporated into a model for evaluating waterfowl habitat in North Dakota. The measurements were made using the Wildlife Habitat Analysis and Modeling System (WHAMS) software package developed at ERIM.

Waterfowl habitat quality is a function of both water conditions and the terrain characteristics of the surrounding landscape. We have attempted to quantify these relationships and develop a mathematical model which uses cover type information as input, and provides an objective, numerical evaluation of habitat quality as output. The advantages of such a model, which combines remote sensing and computer technology to generate habitat quality ratings, is that it makes possible the rapid, objective inventory of large areas.

The habitat quality model actually consists of two submodels, one that evaluates water conditions of the habitat and another which evalutes its vegetation cover. The water conditions submodel has been designed to take into account the following factors which are important to waterfowl: pond numbers, pond area, and pond size class distribution. In practice each of these parameters is calculated by computer for each habitat unit from remote sensing data in digital format.

The presence of water bodies is only a partial indicator of waterfowl habitat quality. Other terrain features are also important. For example, the presence of upland cover has long been known to be essential to good waterfowl habitat. In addition, the spatial arrangement of various upland vegetation cover types which determines their interspersion and juxtaposition, is known to be important.

The terrain factors submodel evaluates the presence of cover types and their spatial arrangement. Although these factors could have been considered separately, we incorporate presence and spatial arrangement into a single factor represented by the amount of edge between desirable terrain types.

The individual components (scene classes) considered in our terrain factors submodel were:

(1) OW = open water

(2) WL = wetland vegetation

(3) COV = upland cover (hay, grasses and pasture)

(4) AG = upland areas providing some cover during part of the year and possibly some food in the fall (small grains, row crops)

(5) OTHER = upland areas having no particular value to waterfowl (e.g., bare soil).

The output of the terrain factor submodel was computed as the sum of the weighted proportions of all the important edge types, normalized to the average amount of desirable edge in sections considered to be good habitat.

The output of the terrain factors submodel was subsequently additively combined with the results of the water factors submodel to obtain an integrated value of waterfowl habitat quality. Since we feel that pond conditions are an essential aspect of habitat that is somewhat more important than terrain conditions we weighted the contributions of the two submodels 60%:40%.

The above model was implemented over a study area in North Dakota for the U.S. Fish and Wildlife Service, Northern Prairie Research Station. Habitat quality ratings were generated for three townships, a total of 108 sections. The results produced for one of the townships is shown in Figure 2. This area is particularly interesting because it contains a large block of agricultural land in the upper right, and an area of natural prairie in the lower left. The prairie area is, of course, better duck habitat, and in general the ratings indicate this, it being overall higher in this region. It also shows, however, that there is still considerable variability even within an area of generally good overall habitat quality.

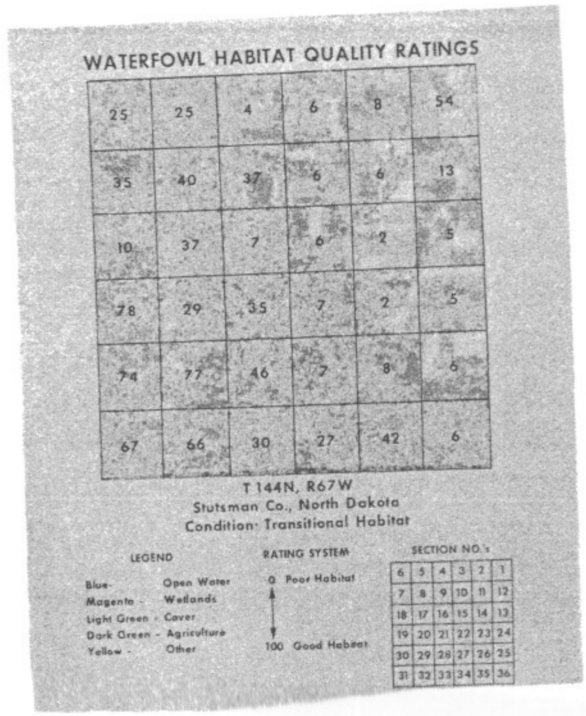


Figure 2.

The uses of habitat quality measurements are many and important. They include spotlighting priority areas for management, identifying prime areas for acquisition, prescription for treatment to improve habitat, environmental impact assessment, and mitigation.

TEMPORAL ANALYSIS

A type of temporal analysis very useful to resource managers is change detection. Map based data is often preferred for deriving this type of information because a sampling approach may not give an adequate representation of the amount of change occurring if the changes occur infrequently or in clusters and this is not known a priori. Change detection analyses can furnish several important types of information: For example, rates of vegetative successional trends, the factors responsible for changes in or losses of wetlands, and the location of sensitive or key management units. Effective use of this technique in the analysis of St. John's Marsh in southeastern Michigan made it possible to identify key wetland habitat requiring acquisition by the State to prevent it from destruction by encroaching residential development (Roller, 1977). Maps showing the wetland communities were prepared from 1937 and 1974 air photos, and then compared, and a third map generated showing the changes that had occurred in the interim (see Figure 3, next page).

Another example of where change detection has proved useful and where another form of remote sensing was used was also recently completed by ERIM. A change detection map of the coastline of Bangladesh was prepared showing where coastal wetlands were alternately being lost, due to erosion, and developing, due to accretion. The study was accomplished by preparing single date digital recognition maps of portions of five frames of Landsat data for the observation periods 1972 and 1979. The single date maps were then digitally mosaiced and registered and a cellby-cell comparison made for the 33,000 sq mi. area. The results of this study indicated a net increase in land along the coastline of 83 sq mi. (Pramanik, et al., 1981).

Both of the change detection techniques just described employed the strategy of comparing two single date categorized maps of the resource. This approach is effective, but is also subject to error if the two maps are not properly registered. In some cases this error can be considerable. For example, in a change detection analysis of forest resources in South Carolina for the USFS, (Colwell, et al., 1980) found that the amount of change indicated by a computerized cellular comparison of maps from two date was nine times greater than that detected by visual analysis of two images. Examination of an image produced from this comparison showed that much of the indicated change occurred where no changes were known to have actually occurred. Thus, these changes and the differences between the two estimates were attributed to misregistration of the original maps.

As a solution to this problem, a new method of change detection was tested in this same study called "change vector analysis" (CVA). The way this technique works is best described by example.

When a forest stand undergoes a change or disturbance, such as a clear cut, its spectral appearance in Landsat multispectral scanner data changes accordingly. If two spectral variables were measured for a stand both before and after some change occurred and then were plotted on the same graph, a diagram such as Figure 4 might result. The vector

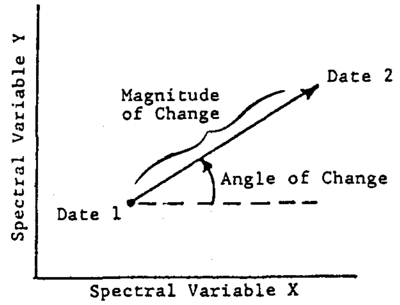


Illustration of a Spectral Change Vector

Figure 4.

describing the direction and magnitude of change from Date 1 to Date 2 is a spectral change vector.

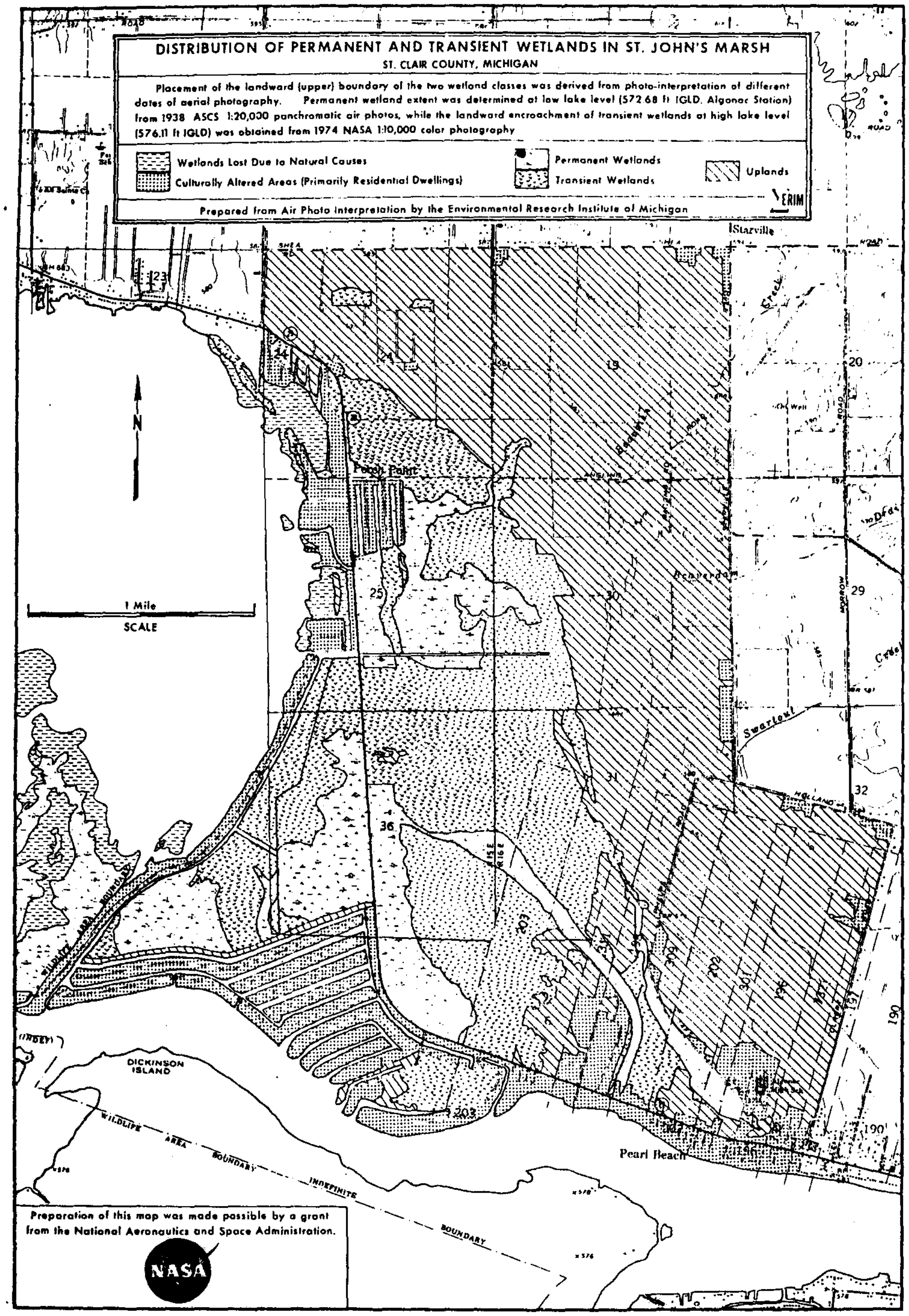
Change Vector Analysis exploits this condition in the following way. Given multi-date pairs of spectral measurements, one computes spectral change vectors and compares their magnitudes to a specified threshold criterion. The decision that a change has occurred is made if that threshold is exceeded. When the CVA procedure was applied to the same South Carolina forest area described earlier, it yielded a change detection figure within 1/2% of the visual estimate.

DATA BASES

Considerable attention has been focused on the value of geographic information systems and other types of data bases for (1) long term analysis of wetlands, and (2) reducing the need for frequent resurveying. In many cases these benefits can be realized. Some users, however, may find that data bases have become obsolete or that they are too costly to maintain and update. These persons might have been spared the time, cost and effort they put into developing a data base if they had asked themselves the following questions:

(a) Will the resource classification system being used in the present study be applicabale or still in vogue 5 or 10 years in the future? If not, then updating the data base will be difficult and change detection may not be possible.

(b) Is a computer data base really necessary, or would a good map do? Maintaining computer systems is expensive and requires staff



DISTRIBUTION OF PERMANENT AND TRANSIENT WETLANDS IN ST. JOHN'S MARSH
ST. CLAIR COUNTY, MICHIGAN
Placement of the landward (upper) boundary of the two wetland classes was derived from photo-interpretation of different dates of aerial photography. Permanent wetland extent was determined at low lake level (572.68 ft IGLD, Algonac Station) from 1938 ASCS 1:20,000 panchromatic air photos, while the landward encroachment of transient wetlands at high lake level (576.11 ft IGLD) was obtained from 1974 NASA 1:10,000 color photography
Wetlands Lost Due to Natural Causes
Culturally Altered Areas (Primarily Residential Dwellings)
Permanent Wetlands
Transient Wetlands
Uplands
ERIM
Prepared from Air Photo Interpretation by the Environmental Research Institute of Michigan
Starville
N
1 Mile
SCALE
Pearl Beach
DICKINSON ISLAND
WILDLIFE AREA BOUNDARY
INDEFINITE BOUNDARY
Preparation of this map was made possible by a grant from the National Aeronautics and Space Administration.
NASA

Figure 3.

with special skills; updating a map costs very little, and can be done by just about anyone.

(c) Assuming that it is possible to map resource categories that are of interest using Landsat data, would a technique like change vector analysis be more accurate and less costly than producing two single data classifications of an area and then comparing them?

CONCLUSIONS

- Resource inventories should be initially designed to insure that at least minimum acceptable performance standards will be met.
- Inventory design should be kept as simple as possible.
- One of the most important decisions to make is whether the information required will require generation of a map, or if statistical data is adequate.
- Landsat data can be used effectively in statistical sampling techniques to reduce imprecision and help insure optimal sample location.
- Sampling techniques can take advantage of the varying resolution, area coverage, and cost of different kinds of remote sensing systems to provide estimates of resource abundance with greater efficiency.
- Computer manipulation of map data can make complex measurements of things like interspersion and juxtaposition available at a reasonable cost.

REFERENCES

1. Anderson, R.R. and F.J. Wobber. 1973. Wetlands mapping in New Jersey, P.E.
2. Bedford, B. 1978. Wetlands Protection Efforts, Needs, and Priorities in Wisconsin. In Proceedings of the National Wetland Protection Symposium FWS/OBS-78/97.
3. Colwell, J., G. Davis, and F. Thomson, 1980. Detection and Measurement of Changes in the Production and Quality of Renewable Resources. ERIM Report No. 145300-4-F.
4. Colwell, J., D. Gilmer, E. Work, Jr., D. Rebel, and N. Roller. Use of Landsat data to assess waterfowl habitat quality. ERIM Report 120000-15-F, Ann Arbor, Michigan.
5. Henny, C.D., D.R. Anderson, R.S. Pospahala. 1972. Aerial surveys of waterfowl production in North America, 1955-71. Special Scientific Rep., Wildlife No. 160, USFWS, Washington, D.C., 48 pp.
6. Jessen, R. 1978. Statistical Survey Techniques. John Wiley & Sons, NY.
7. Montanari, J. and B. Wilen. 1978. Techniques developed and presently being used to conduct the National Wetland Inventory Project, in Proceedings of the National Wetland Protection Symposium FWS/OBS-78/97.
8. Niering, W. 1978. Wetland values. In Proceedings of the National Wetland Protection Symposium, FWS/OBS-78/97.
9. Pramanik, M., F. Polcyn and N. Roller, 1981. Assessment of change in Bangladesh coastal regions. Fifteenth International Symposium on Remote Sensing of Environment, ERIM, May 1981.
10. Roller, N. 1977. Remote sensing of wetlands. ERIM Report No. 193400-14-T, ERIM, Ann Arbor, Michigan.
11. Roller, N. and J. Colwell. 1978. Wetland inventory and condition evaluation techniques in Proceedings of Pecora IV Symposium. Application of remote sensing data to wildlife management. Nat. Wildl. Fed. Sci. and Tech. Series 3.
12. Staats, D. 1981. Wetlands: the destruction continues, but protection is growing. Great Lakes Communicator 11(9):1-3.
13. Stegman, J. 1976. Overview of current wetland classifications and inventories of the U.S. Fish and Wildlife Service, Second General Session, Part A in Proceedings of the National Wetland Classification and Inventory Workshop, USFWS.