# Evaluation of Thematic Map Accuracy in a Land-Use and Land-Cover Mapping Program

*Steven E. Dicks* and *Thomas H. C. Lo*
Mapping and GIS Section, Southwest Florida Water Management District, 2379 Broad Street, Brooksville, FL 34609-6899

ABSTRACT: The widespread use by governmental agencies and private firms of Geographic Information Systems (GIS) for planning, regulatory, or facilities management purposes has led to an increased demand for thematic maps depicting land use and land cover (LU/LC). Because of inadequate funding, time, or training, these maps are often produced with inadequate quantification and documentation of their thematic accuracy. The Southwest Florida Water Management District is currently in the process of developing LU/LC maps as part of its GIS database development effort. Presented here is a description of automated sample generation methods developed at the District using GIS techniques, results of statistical evaluation of these sample data, and the field experiences and person-hour requirements associated with the accuracy assessment of the LU/LC data. The methodology presented here, though applied to LU/LC maps photo interpreted from color infrared photography, is equally applicable to many other types of thematic mapping.

## INTRODUCTION

THE GROWING USE BY GOVERNMENTAL AGENCIES of geographic information systems (GIS) for planning, regulatory, or facilities management purposes has led to an increased demand for digital thematic maps depicting land use/cover (LU/LC). Often, because of inadequate funding, time, or training, these maps are produced with little consideration given to the quantification and documentation of their accuracy. This problem has become particularly evident since the advent of "user-friendly" inexpensive image processing systems that allow relatively untrained users to generate "accurate looking" LU/LC maps in a relatively short period of time and with minimal effort.

Given that an increasing number of groups are producing and sharing digital LU/LC maps, it is important that the thematic accuracy of these maps be documented and passed along with the digital data. The Proposed Standard for Digital Cartographic Data presents three options for accuracy assessments to be included in a lineage report: deductive estimates, tests based on polygon overlays, and tests based on independent samples (NCDCDS, 1988).

The first option, deductive estimates, is little more than an educated guess about the accuracy of the map. As such, it is the least quantitative approach and gives the poorest estimate of how accurate an LU/LC map is. The second approach, tests based on polygon overlays, involves a polygon-by-polygon comparison of the map in question with a reference map. Though this approach is an improvement over the use of deductive estimates, it is plagued by several problems. The reference map must be of a higher and known accuracy than the map being evaluated, both maps must have been compiled using similar procedures, and both maps must have similar minimum mapping units and classification schemes. These conditions can rarely be met, except when a map is being updated. In the case of map undating, false errors may occur wherever LU/LC has changed between the two mapping dates. The last method, comparison based on independent samples, is, in the opinion of these authors, the preferred method for assessing the accuracy of an LU/LC map.

Presented here is a methodology being developed at the Southwest Florida Water Management District (District) for assessing the accuracy of LU/LC maps produced from aerial photographs. The methodology was designed to make maximum use of the fact that the data are in a digital format and to minimize the costs associated with map validation. The method discussed here utilizes comparison based on independent samples. Though developed for use with LU/LC maps, with minor modifications the accuracy assessment procedures presented here can be applied to any thematic map.

## ACCURACY ASSESSMENT PROCEDURES

Maps are simply models of the actual features found on the Earth's surface, with their accuracies varying depending on the methods and care used in producing them (Maling, 1989). The thematic accuracy of an LU/LC map is constrained by several factors, including the LU/LC classification scheme, quality of imagery, size of minimum mapping unit, scale of presentation, and expertise of the photointerpreters or imagery analysts producing the map. As with all maps, LU/LC maps contain errors that should be quantified before they can be used with certainty.

The quantification of mapping errors requires that appropriate sampling techniques and sample units be utilized, sample data be compared to the actual LU/LC, and appropriate statistics be applied to determine map accuracy within specified confidence limits. The sampling technique and acceptance/rejection criteria selected should satisfy the following criteria (Ginevan, 1979):

- It should have a low probability of accepting a map of low accuracy;
- It should have a high probability of accepting a map of high accuracy; and
- It should require a minimum number of on-site verification samples.

### SAMPLING TECHNIQUES

In designing an accuracy assessment, one must determine sample size, sample selection strategy, and the measures of accuracies to be used for evaluating the samples. The first of these, sample size, has the most significant impact on the cost of accuracy assessment and, therefore, it should be chosen with care. Prior to determining sample size, one must consider whether an overall or per-class accuracy value is required for a map, with the latter being the most desirable. Hay (1979) suggested that a minimum of 50 samples be collected for each class of interest, while Fitzpatrick-Lins (1981) calculated a minimum per-class sample size using the cumulative binomial probability distribution (Aronoff and Fitzpatrick-Lins, 1981). Ginevan (1979) and Aronoff (1985) have likewise utilized binomial probabilities to generate tables of sample sizes and allowable errors that minimize the risks to both the map producer and consumer. In

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general, the larger the sample size, the greater the confidence one can have in assessments based on that sample; and, therefore, a balance must be made between the cost of sampling and the confidence one has in a classification.

Common sample selection methodologies applied to thematic maps are simple and stratified random sampling, cluster sampling, and systematic and stratified systematic unaligned sampling (Congalton, 1988; Maling, 1989). Arguments for and against each of these strategies can be made, and the decision as to which method to use is often application and data dependent. The sample procedure utilized should minimize the effects of spatial autocorrelation as well as ensure that all classes of interest are adequately sampled. Simple random and stratified random samples are utilized here because they are easily generated using standard raster and vector GIS software packages and simple computer programs.

### Sample Unit

Typical sampling units applied to the accuracy testing of maps include points, transects, and areas. The sampling unit must be chosen with care because it is the inspection of these features that introduces the greatest degree of subjectivity into sample evaluation. It is important that sample units can be accurately located on both the map and the verification data, a task that can be particularly difficult in the field. Most commonly, areas are used as the sampling units for evaluating LU/LC map accuracy.

### Sample Evaluation

The reporting and evaluation of the comparison of the classified data to verification data should include the generation of an error matrix and statistical evaluation of that matrix. The error matrix provides a concise means of examining per class map errors and should include both errors of commission and errors of omission (Aronoff, 1982b). Errors of commission occur when a point is identified as being in class A when, in fact, it is not. Errors of omission occur when a point is identified as being a member of another category when it is, in fact, a member of class A.

The two most common measures of accuracy applied to the accuracy assessment of thematic maps utilize binomial probabilities or Kappa coefficients of agreement. Binomial probabilities are commonly used in acceptance sampling and can readily be computed for even relatively large samples using personal computers or can be read from published tables (Ginevan, 1979; Hay, 1979; Aronoff, 1982a; 1982b; 1985). Binomial probabilities can be used to test the accuracy of the classification as a whole; but, if the accuracy of a particular class is of interest, these probabilities must be calculated for each class. A primary disadvantage of the use of binomial probabilities is that they are based on the percent correct, and therefore do not account for errors of commission or of omission.

Programs for computing Kappa coefficients are likewise available for personal computers. The Kappa coefficient provides a measure of difference between the observed agreement between two maps and agreement that is contributed by chance (Congalton and Mead, 1983; Rosenfeld and Fitzpatrick-Lins, 1986; Rosenfeld, 1986; Hudson and Ramm, 1987). A Kappa coefficient of 0.90 means that a classification is 90 percent better than what would be expected if polygons were randomly assigned to LU/LC classes. Advantages of Kappa are that its calculation takes into consideration off-diagonal elements of the error matrix, or errors of omission or of commission, and that conditional Kappa coefficients may be calculated for individual LU/LC categories.

## STUDY AREA AND DATA

The District is responsible for managing the water resources within an approximately 26,000 sq km area along the west-central coast of peninsular Florida (Figure 1). Recently the District has begun the development of a GIS to assist its planning, environmental, and regulatory efforts. Prior to developing the digital database for the entire District, the following six 7.5-minute USGS quadrangles were selected to test mapping and data automation methodologies, database design, and accuracy assessment procedures: Plant City East, Plant City West, Socrum, Ehren, Tampa, and Zephyrhills. These quadrangles were selected because they contained LU/LCs that are typical of much of the District and were all within one-hour travel time of the District's headquarters.

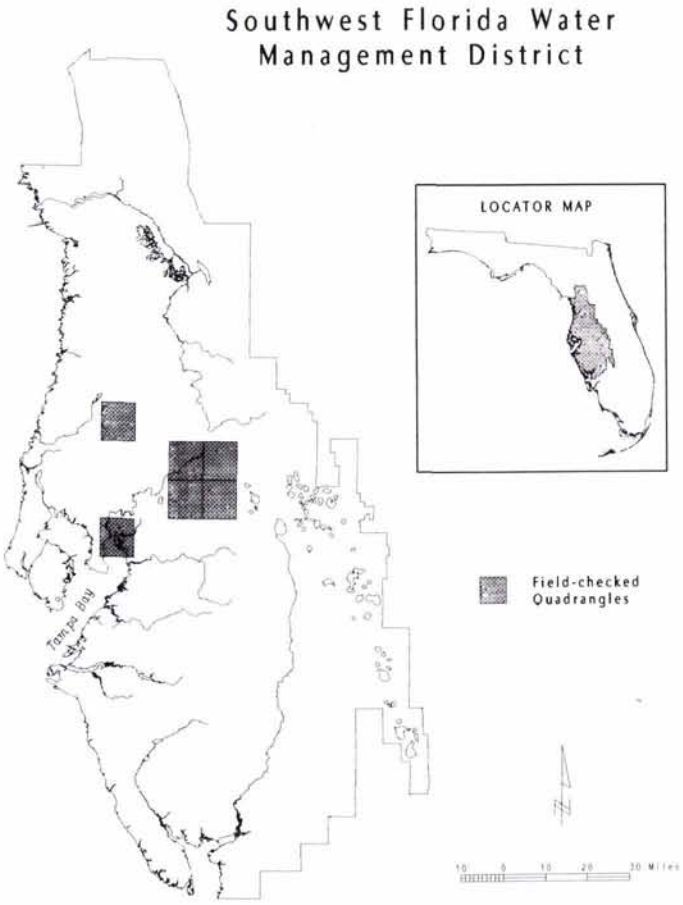


FIG. 1. Study area.

As with many natural resource-based geographic databases, LU/LC was identified as one of the primary layers of interest to potential GIS users. The LU/LC classification scheme chosen for this project is the Florida Land Use and Cover Classification System (FLUCCS). FLUCCS is a modification of the USGS Level II system developed by the Florida Department of Transportation (Table 1) (FDOT, 1985). Because many of the FLUCCS Level II categories reflect land use rather than land cover, it was felt that the best results would be obtained from photointerpretation rather than the digital classification of satellite data. All mapping was completed by an outside contractor using 1984-85 NHAP color infrared transparencies. Minimum mapping units are 2.5 acres (1.01 ha) for water bodies and wetlands and 5 acres (2.02 ha) for upland categories.

Products delivered to the District included fully attributed and edge-matched Environmental Systems Research Institute (ESRI) Arc/Info digital files corresponding to USGS quadrangles (Figure 2). Though database design considerations favored quadrangle-referenced maps, contract specifications required the

TABLE 1. FLORIDA LAND-USE AND LAND-COVER CLASSIFICATION SCHEME.

100 URBAN AND BUILT-UP
- 110 Residential, Low Density <less than two dwelling units per acre>
- 120 Residential, Medium Density <Two-five dwelling units per acre>
- 130 Residential, High Density
- 140 Commercial and Services
- 150 Industrial
- 160 Extractive
- 170 Institutional
- 180 Recreational
- 190 Open Land

200 AGRICULTURE
- 210 Cropland and Pasture
- 220 Tree Crops
- 230 Feeding Operations
- 240 Nurseries and Vineyards
- 250 Specialty Farms
- 260 Other Open Lands <Rural>

300 RANGELAND
- 310 Herbaceous
- 320 Shrub and Brushland
- 330 Mixed Rangeland

400 UPLAND FORESTS
- 410 Upland Coniferous Forests
- 420 Upland Hardwood Forests
- 450 Mixed Coniferous/Hardwood

500 WATER
- 510 Streams and Waterways
- 520 Lakes
- 530 Reservoirs
- 540 Bays and Estuaries

600 WETLANDS
- 610 Wetland Hardwood Forests
- 620 Wetland Coniferou Forests
- 630 Wetland Forested Mixed
- 640 Vegetated Non-forested Wetlands

700 BARREN LAND
- 710 Beaches
- 720 Sand Other Than Beaches
- 730 Exposed Rock
- 740 Disturbed Land

800 TRANSPORTATION, COMMUNICATIONS AND UTILITIES

LU/LC maps be capable of being merged to produce a seamless digital map of the entire study area.

## SAMPLING STRATEGY

The sampling strategy was designed to meet the following objectives:

- Provide a means of determining whether or not the LU/LC map met contract specifications;
- Widely accepted measures of accuracy should be utilized because a wide variety of potential users of the data had been identified;
- Automate the methodology as much as possible, thereby minimizing personnel requirements;
- Minimize field time, and therefore expense, involved in verifying map accuracy; and
- Test the data of acceptance/rejection in a manner that provided a means of entering the LU/LC maps into the GIS database in an orderly manner.

Given these goals, four basic decisions were made regarding the accuracy assessment procedures to be employed. First, each quadrangle would be tested individually for acceptance/rejection. Second, only overall map accuracy would be tested using binomial and Kappa statistics, with classification errors for individual classes reported in the error matrix. Third, random sampling would be used. Lastly, homogeneous area sampling units were

FIG. 2. Land use/cover for Ehren, Florida quadrangle.

utilized. Preliminary work indicated that because of the "fuzzy" nature of many 1:24,000-scale LU/LC boundaries, the greatest amount of subjectivity encountered in both the original mapping and verification occurred in the location of polygon boundaries, and therefore such boundaries were avoided, where possible.

ARC/INFO Arc Macro Language (AML) and FORTRAN programs were developed to run in a batch environment on a DEC 8550 to automatically select samples for each 7.5-minute digital file in the following manner:

(1) A 5-acre grid was generated using the Arc/Info software. This provided sampling units with a size corresponding to the minimum mapping unit for upland categories. The grid was created as a topologically correct polygon coverage, allowing its use in Arc/Info overlay and database routines. This grid was oriented north-south with its origin at the bottom left-hand corner of each quadrangle to be sampled. It was assumed that, because the latitude-longitude grid of quadrangles is an artificial construction, there would be little systematic correspondence between LU/LC and the grid. Because Florida is a Public Land Survey State, there may be a tendency towards an east-west orientation of property lines following Section-Township-Range lines and therefore potentially the spatial patterns of LU/LC. A random orientation of the grid was considered, but a visual inspection of the photography and LU/LC maps showed no such correlation and therefore no re-orientation of the grid was done.

(2) The 5-acre grid was topologically overlaid with the LU/LC data to produce a combined digital file (Figure 3). Using the relational database capabilities of ARC/INFO, all homogeneous grid cells were reselected and the grid-cell identifiers (sequential numbers ranging from 1 to $n$, where $n$ is the total number of polygons within the digital map) were written to a data file. The sample units corresponding to homogeneous grid cells are termed Type A samples.

(3) The above gridding scheme neglected two types of LU/LC polygons found in the maps, those with shape characteristics that preclude the inclusion of a homogeneous grid cell within their boundary, and those whose minimum mapping unit is below the 5-acre grid cell size (water bodies and wetlands). To ensure that these

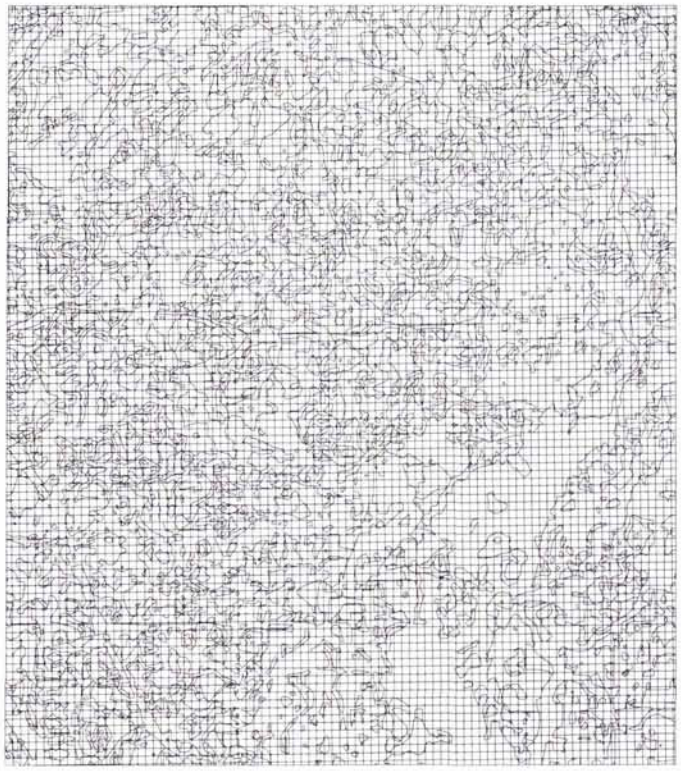

FIG. 3. Merged grid and land-use/cover map.

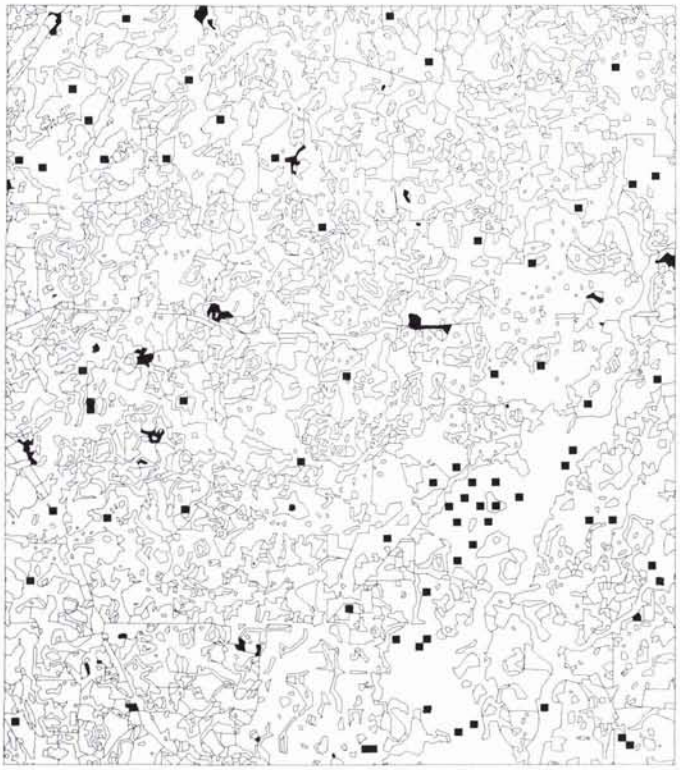

FIG. 4. Sample sites for gridded and non-gridded data.

features were sampled, an INFO program was written to determine which polygons did not contain at least one homogeneous grid cell and to write their polygon identifiers to a data file. The sample units resulting from this procedure are termed Type B samples.

(4) The data files created in steps 2 and 3 were read into a FORTRAN program that used the polygon identifiers for the Type A and Type B samples to select a random sample without replacement. The sample identifiers selected by this program were written to a data file for later entry into ARC/INFO. Samples were proportioned between the Type A and Type B sample units on the basis of total area represented by LU/LC polygons falling into each category.

The approximate sample size was determined using the following equation:

$$N = Z2pq/E2,$$

where $N$ is the total number of samples, $p$ is the expected percent accuracy, $q = 100 - p$, $Z = 1.96$ is the standard normal deviate for the 95 percent two-sided confidence level, and $E$ is the allowable error (Fitzpatrick Lins, 1981; Snedecor and Cochran, 1967). For $p = 90$ (the accuracy required under contract specifications) and an allowable error of four percent, an estimated minimum sample size of 216 was calculated. It was decided that because sampling would not be stratified by LU/LC categories, and that one of the goals of this project was to determine personnel requirements, the total sample size could be greatly increased. For contractual and project management purposes, 175 samples were selected for the first quadrangle inspected and 100 for each of the remaining five. Two samples were rejected during the inspection stage, resulting in a total of 673 samples.

(5) The sample identifiers selected in step 4 were used to create 1:24,000-scale plots in which the selected Type A and B sample sites were highlighted and the FLUCCS categories for all polygons were labeled (Figure 4). These maps were then used in the subsequent photointerpretation and field inspections. The use of 1:24,000-scale plots ensured that they could be readily used in conjunction with standard USGS quadrangles for locational purposes.

## VERIFICATION PROCEDURES

The verification of the LU/LC map was accomplished in two steps. The first step, photo verification, involved comparing the photo interpreted LU/LC maps provided by the outside contractor with the results interpreted by a District photointerpreter. The second step, field verification, was to perform field inspections of those samples where photo verification alone was felt to be inadequate.

In the photo verification step, the NHAP photographs used to produce the classification map were set up on a Zoom Transfer Scope (ZTS) so that the stereo model registered to the appropriate 7.5-minute quadrangle. The 1:24,000-scale sample polygon plot described above and plotted on transparent media was overlaid on top of the quadrangle. The photo interpreter was then able to view the photo model and the sample polygon plot simultaneously.

Features on the photo model corresponding to the sample polygons were interpreted according to the following guidelines:

- Any sample site with less than 90 percent of its area correctly classified was rejected as being incorrect (majority rule criteria). This percentage was chosen because project specifications called for a 90 percent accurate map.
- Any time a wetland or water body below 5 acres was not mapped and it was determined from the photography that this polygon intersected a sample site, that sample site was rejected as being incorrect.

Following these guidelines, a tick, cross, or question mark was placed next to each selected polygon to indicate whether the feature was correctly interpreted, incorrectly interpreted, or undecided. Those with question marks required additional field verification. In addition to checking sample sites, an overall scan of the maps was done to detect gross positional errors, and all edgematching with adjacent map sheets was examined.

The second step, field verification, began with the development of a field work plan. The shortest route required to visit all the

sites in question was determined and marked on the quadrangle. When examining the sites, the field crew had to keep in mind that the on-site verification reflects the current LU/LC, and therefore a judgment call had to be made on the LU/LC existing when the photographs were taken in 1984/85. This type of subjective judgement was unavoidable under some circumstances. Those sites that were inaccessible from the ground were to be subtracted from the total sample population if other means of observation (such as a fixed-wing overflight) were not available. In this study, no sites were unobservable on the ground and therefore none were rejected for this reason. Two sites were inadvertently not inspected and were therefore left out of the sample.

### Accuracy Reporting

Upon the completion of photo and field verification efforts, the results were tallied and entered into a personal computer-based spread sheet that produced error matrices. Matrices and statistics were produced for both FLUCCS Level I and II LU/LC categories to allow increased flexibility in the use of the maps because many times only the more generalized LU/LC data are used. For space considerations only, the Level I matrix is presented here (Table 2). The sample results were evaluated for both Level I and Level II LU/LC categories using both binomial and Kappa coefficients calculated using FORTRAN programs.

## DISCUSSION

The primary purpose of this study was to develop accuracy assessment procedures and to estimate personnel requirements necessary to utilize these procedures. Based on the examination of six quadrangles, this process required approximately 11.5 person-hours per quadrangle from receipt of a digital file from the contractor to completion of all accuracy assessment procedures described here (Table 3). As expected, the greatest amount of time was spent in field verification. It is felt that this time could be decreased if larger scale photographs were available for verification purposes. Larger scale photographs should improve the accuracy of photo verification and decrease the number of questionable photo verification sites. The drawbacks of increasing photo scale include increased imagery costs (estimated to be a two to three fold difference between 1:58,000- and 1:24,000-scale photos), increased contractor mapping costs, and possibly increased photo verification times because more stereo models would have to be set up. Computer usage times were not considered in detail because of the difficulty in tracking CPU times for the multiple sub-processes created by the ARC/INFO AML programs. The most CPU-intensive task involved overlaying the grid with LU/LC, requiring in excess of 30 minutes of CPU time for a quadrangle containing approximately 2200 polygons.

The major difficulty in conducting an effective accuracy assessment is overcoming the problem of subjectivity encountered during field and photo verification. In this study it was found that the majority of the subjectivity encountered occurred during the evaluation of LU/LC polygon boundaries. Two types of boundary location errors are common in photo interpreted LU/LC maps. The first are gross positional errors caused by improper photo-to-map registration, while the second are the result of improper class delineation. The former errors are evident when the LU/LC maps are compared to the USGS basemaps; for the purposes of this project, such errors were considered to make further accuracy assessment procedures unworkable, and therefore the entire map sheet would be rejected. No such cases occurred during this project.

The second type of boundary error, that of improper class delineation, is more difficult to avoid. In the interest of reducing subjectivity and personnel requirements encountered when attempting to resolve boundary problems, it was decided to select only homogeneous areas from the LU/LC maps for verification. For two reasons this approach minimized but did not entirely eliminate boundary problems. First, Type B samples were not subsets of mapped polygons, but were entire polygons themselves, and therefore boundary checking could not be avoided. Second, both Type A and Type B samples that were mapped as homogeneous areas may or may not be homogeneous when compared to the photographs, and therefore it was possible that unmapped polygon boundaries would be found. These mapping discrepancies may be caused by minor positional errors, by the existence of LU/LC types smaller than the minimum mapping unit that were not mapped, or by photointerpretation errors. The use of only homogeneous sample units may potentially bias against the detection of some misclassifications along boundaries, but it was felt that the extra effort in resolving such cases was not justified for this study.

During photo verification, it was found that the majority of the Type A samples were homogenous, and the interpreters had no difficulty verifying their accuracy. This did not prove to be the case with the Type B samples, several of which exhibited mixed LU/LCs. The more common occurrence of mixed LU/LCs within Type B samples is most likely attributable to two factors. First, the majority of Type B samples were wetlands, and these categories, particularly for smaller polygons, were often difficult to map accurately from the NHAP photography. Second, the fact

TABLE 2. ERROR MATRIX AND STATISTICAL RESULTS.

| | | Level I Error Matrix Verified | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | Total | %Correct | |
| %Commission | | | | | | | | | | | | |
| O | 100 | 148 | 5 | | | | | | | 153 | 96.7 | 3.3 |
| B | 200 | 3 | 213 | | | 3 | 1 | | | 220 | 96.8 | 3.2 |
| S | 300 | | | 55 | 2 | | | | | 57 | 96.5 | 3.5 |
| V | 400 | 1 | 1 | | 26 | | | | | 28 | 92.9 | 7.1 |
| E | 500 | | | | | 54 | | | | 54 | 100.0 | 0.0 |
| R | 600 | | 1 | 10 | 1 | 1 | 139 | | | 152 | 91.4 | 8.6 |
| E | 700 | | | | | | | 1 | | 1 | 100.0 | 0.0 |
| D | 800 | | | | | | | | 8 | 8 | 100.0 | 0.0 |
| | Total | 152 | 220 | 65 | 29 | 58 | 140 | 1 | 8 | 673 | | |
| | %Omission | 2.6 | 3.8 | 15.3 | 10.3 | 6.9 | 0.7 | 0.0 | 0.0 | 100.0 | | |

| | |
|---|---|
| Points Sampled | 673 |
| Observed Misclassification | 29 |
| Map Accuracy (.05 confidence level) | 95.6 ± 1.2% |
| Kappa | 94.5 ± 1.9 |
| Level II Statistics | |
| Points Sampled | 673 |
| Observed Misclassification | 34 |
| Map Accuracy (.05 confidence level) | 94.9 ± 1.5% |
| Kappa | 94.1 ± 1.7 |

TABLE 3. AVERAGE PER QUADRANGLE PERSON-HOUR REQUIREMENTS FOR ACCURACY ASSESSMENT (APPROXIMATELY 2800 POLYGONS PER QUADRANGLE).

| Task | Time (Hours) | Comments |
|---|---|---|
| Photo verification | 4.0 | Includes 112 sample sites per quad plus total map scan and visual edgematch inspection. |
| Field verification | 6.0 | Average of 12 sites per quad; excludes travel time to and from study area. |
| Statistical Analysis | 1.5 | Includes running sample generation programs, inputting verification data into spreadsheet, running binomial and Kappa statistics. |
| Total | 11.5 | |

that Type B samples were entire polygons meant that border identification played a large part in determining whether a sample was correctly classified. The majority rule criteria provided a fairly good guideline for evaluating these samples, though subjectivity in their evaluation was undoubtedly higher than for Type A samples.

Subjectivity was also a problem during field verification. Judgments had to be made not only as to the identification of the specific categories, but also as to the location of the sample sites in question. The latter difficulty was mostly found with Type A samples because their shapes had no correspondence to natural features.

## CONCLUSIONS

The accuracy assessment methodology described here provides a means of quantitatively determining the accuracy of an LU/LC map that can be readily implemented on most raster and vector GIS systems. The methodology emphasizes the utilization of automated techniques for sample generation, thereby minimizing the personnel required to evaluate a map.

The authors feel that the time estimates presented here for evaluating quadrangle-based LU/LC maps are realistic and therefore are suitable for project planning purposes. Based on this preliminary study, it is estimated that approximately 1.4 person-days are required to evaluate each quadrangle for a total of 259 days to evaluate the 185 quadrangles to be mapped in the District. This large personnel requirement dictates that certain modifications be made to our sampling strategy prior to expanding our mapping program to the remainder of the District. The problem of subjectivity in sample evaluation can only be overcome by increasing the expertise and experience of field- and photo-verification personnel. Given these problems, the following project guidelines are being established:

- Digital data files will be delivered in files containing multiple quadrangles. This will decrease the time spent in handling individual data files and checking for edgematch errors between quadrangles.
- Use of current 1:40,000-scale color infrared photographs rather than 1:58,000-scale NHAP photographs. This should improve mapping accuracy and eliminate virtually all mapping errors caused by land-use change over time.
- Use stratified random sampling to ensure that per-class accuracies will be met. Classes will be stratified according to FLUCCS Level I categories.
- Decrease the total number of samples from the current number of 100 per quadrangle. A District-wide minimum of 500 samples per FLUCCS Level I category will be selected, with actual number of samples per quadrangle varying depending on the LU/LCs existing in an area. It is anticipated that wetland categories will be oversampled because of their importance to District regulatory, planning, and environmental activities.
- Establish a four person field- and photo-verification team. The use of a small number of individuals to carry out verification work should improve consistency and minimize subjectivity in sample inspection. Members of the team will cross-check the others work.

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## ERRATA

In the article, "A Spatial Database fro Ecological Land Classification," by Frank W. Davis and Jeff Dozier, which appeared on pages 605-613 of the May issue of PE&RS, plate 2 on page 610 was printed upside down.

In the Members listing of the May issue of PE&RS, appearing at page 653, one of our members' names was inadvertantly dropped from the listing: Majorie A. Gould, P.O. Box 33, Hope Valley, RI 02832.