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Comparison of Sampling Procedures and Data Analysis for a Land-Use and Land-Cover Map

The results of a computer-based automated sample selection were more comprehensive than the results of a manual sample selection in estimating the accuracy of the Tampa, Florida land-use and land-cover map.

ABSTRACT: *The accuracy of the Tampa, Florida Land-Use and Land-Cover Map, produced by the U.S. Geological Survey at a scale of 1:250,000, was estimated by using two separate sample selections, a manual sample selection and a computer automated sample selection. A comparison of these two methods favors the second. The manual sample selection used a stratified systematic unaligned sampling technique. The computer based automated sample selection first used a stratified systematic unaligned sampling technique followed by a random selection stratified by category to assure that all categories were adequately sampled. With the manual sample selection only six of the 26 categories were adequately represented and nine were not represented at all. Using the computer based sample selection, all 26 categories were represented; and at least a minimum number of sample points were selected for each category unless there were too few polygons of the category to achieve the minimum number. In this case, at least as many sample points as there were polygons were selected. The results of the computer-based automated sample selection were more comprehensive than the results of the manual sample selection.*

INTRODUCTION

THE U.S. GEOLOGICAL SURVEY (USGS) is currently engaged in the National Land Use and Land Cover Mapping Program to produce a nationwide series of land-use and land-cover maps at scales of 1:100,000 and 1:250,000. The land-use and land-cover information for these maps is obtained by interpretation from remotely sensed data. In addition to the maps, the Program includes producing statewide statistics on land use and land cover from a digital record of the mapped information. The classification system (see Table 1) developed by the USGS for this Program states that "the minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should be at least 85 percent" (Anderson *et al.*, 1976, p. 5). The digitized information is recorded in a digital base formatted and controlled by the Geographic Information Retrieval and Analysis System (GIRAS) (Mitchell *et al.*, 1977). As part of this mapping effort, the USGS has been conducting research on methods of determining the accuracy of these maps with respect to this criterion.

Previous methods of analyzing the accuracy of the land-use and land-cover maps involved a manual selection of sample points from the map for verification of the interpretation. There was no way to assure that all categories were sampled, only that all parts of the map received equal consideration. Recent developments in geographic information systems have made it possible to

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TABLE 1. U.S. GEOLOGICAL SURVEY LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

LEVEL I	LEVEL II
1 Urban or Built-up Land	11 Residential
	12 Commerical and Services
	13 Industrial
	14 Transportation, Communications, and Utilities
	15 Industrial and Commericial Complexes
	16 Mixed Urban or Built-up Land
	17 Other Urban or Built-up Land
2 Agricultural Land	21 Cropland and Pasture
	22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
	23 Confined Feeding Operations
	24 Other Agricultural Land
3 Rangeland	31 Herbaceous Rangeland
	32 Shrub-Brushland Rangeland
	33 Mixed Rangeland
4 Forest Land	41 Deciduous Forest Land
	42 Evergreen Forest Land
	43 Mixed Forest Land
5 Water	51 Streams and Canals
	52 Lakes
	53 Reservoirs
	54 Bays and Estuaries
6 Wetland	61 Forested Wetland
	62 Nonforested Wetlands
7 Barren Land	71 Dry Salt Flats
	72 Beaches
	73 Sandy Areas Other than Beaches
	74 Bare Exposed Rock
	75 Strip Mines, Quarries, and Gravel Pits
	76 Transitional Areas
	77 Mixed Barren Land
8 Tundra	81 Shrub and Brush Tundra
	82 Herbaceous Tundra
	83 Bare Ground Tundra
	84 Wet Tundra
	85 Mixed Tundra
9 Perennial Snow or Ice	91 Perennial Snowfields
	92 Glaciers

From U.S. Geological Survey Professional Paper 964 (Anderson *et al.*, 1976).

select the sample from the computer file following digitization of the map rather than from the actual map, and to assure that all categories on the map are sampled with at least a minimum number of points. An algorithm has been developed (Rosenfield *et al.*, 1981) for selecting the sample to include all categories and for analyzing the results after the verification process. The purpose of this study is to compare the results of this computer based sampling technique with the results of the previous manual sampling technique.

The map selected for this study was the Tampa, Florida Land Use and Land Cover Map. The primary reason for this selection was that the completed map had been digitized and the data were available in the GIRAS geographic information system.

The Tampa, Florida Land Use and Land Cover Map was produced at the same scale and format as the 1:250,000 scale topographic map base. The area depicted on the map is approximately 8,980 square kilometres, extending from the city of Tampa to south of Sanibel Island, and including the metropolitan areas of Tampa, St. Petersburg, Sarasota, and Bradenton. The source material for the compilation was 1:80,000-scale black-and-white transparencies copied from quad-centered, color-infrared, high-altitude aerial photographs. Compilers mapped the land use and land cover at 1:125,000 scale using an enlarged copy of the topographic map as a base with copies of the black-and-white transparencies also at 1:125,000 scale. The size of the minimum mapping unit was 16 hectares for most categories and 4 hectares for urban and such selected categories as Confined Feeding Operations (23); Other Agricultural Land (24); Water (51-54); Strip Mines, Quarries, and Gravel Pits (75); and Transitional Land if urban (76) (Loelkes, 1977, p. 18).

MANUAL SAMPLE SELECTION

SAMPLE SELECTION TECHNIQUES

The initial concern in the task of assessing the accuracy of the land-use and land-cover maps was the selection of a sample that would give reliable results applicable both to the whole map, and to the individual land-use and land-cover categories on the map. The most important considerations were (1) that a large enough sample be selected to provide precision at a specified significance level, and (2) that the selection of the sample points not be biased in any way. The first attempts at sampling were done by hand. The maps were stratified into a grid of 10-km blocks, and one point at the intersection of a 1-km UTM grid was selected for each block following a stratified systematic unaligned technique. This technique has been found to be the most bias-free sampling design (Berry and Baker, 1968) and has been recommended by Berry for use by the USGS. A large sample size of three or four hundred points was selected to insure adequate coverage of most categories and a precise accuracy statement at the 95-percent confidence level for the map (Fitzpatrick-Lins, 1980).

The equation for the approximate sample size, N, was taken as

$$N = Z^2\, pq/E^2, \qquad Z = 2 \tag{1}$$

Where p is the expected percent accuracy, $q = 100 - p$, and E is the allowable error (Snedecor and Cochran, 1967, p. 517). The value for $Z = 2$ is generalized from the standard normal deviate of 1.96 for the 95-percent two-sided confidence level.

For a map with the expected accuracy of 85 percent and an allowable error E of 4 percent (2 standard deviations of 2 percent), the number of sample points necessary for a 95-percent two-sided confidence probability would be

$$N = \frac{4(85 \times 15)}{4^2} = 319. \tag{2}$$

Fewer sample points could have been used if the accuracy was assumed to be greater than 85 percent or if the standard deviation acceptable was larger. The 85 percent expected accuracy value was selected because the land-use classification system specifies that each category should be mapped to at least 85 percent accuracy. The narrow limits for allowable error of 2 percent standard deviation were selected because the methods of sampling involved very little field work and, therefore, should be as precise as possible to offset any procedural errors. Costs were minimal, and a large sample increased the possibility of obtaining an adequate number of points to evaluate the major categories of the map. With a wider confidence interval fewer points could be used.

The sample accuracy, $\hat{p}$, for the map was expressed as the ratio of correctly interpreted points, r, to the total number of points evaluated, n, expressed as a percent, $\hat{p} = r/n \times 100$. The lower limit of the true accuracy of the map was then obtained by using the 95-percent one-tailed lower confidence limit from the formula

$$p_L = \hat{p} - \left\{1.645 \sqrt{\hat{p}\hat{q}/n} + 50/n\right\} \tag{3}$$

where p_L = the lower limit of the accuracy of the map expressed as a percent,
$\hat{p}$ = r/n expressed as a percent,
$\hat{q}$ = $100 - \hat{p}$, and
n = the sample size (Snedecor and Cochran, 1967, p. 211).

No estimate of the upper limits was made, because the errors of omission were not considered in this analysis.

SAMPLE SIZE AND DISTRIBUTION

The original sample for the Tampa land-use and land-cover map included 354 points selected according to a stratified systematic unaligned sampling technique. The number of points per category was proportional to the area of each category on the map and is equivalent to proportional allocation. A comparison of the percent of area for each category with the percent of points selected appears in Table 2. The Spearman Rank Correlation Test (Gibbons, 1976, p. 276-284) for association analysis of two related samples applied to the data in Table 2 indicated direct association between the number of points sampled and the area for each category, and supported the hypothesis that stratified systematic unaligned samples are area weighted for points selected in each category.

DATA VERIFICATION

The map verification process for the 354 points involved rechecking the photographs to determine if the interpretation was correct. Where questions existed, the site was field verified. Approximately one-third of the points were field checked. The results were tabulated and compared to the original interpretation.

ACCURACY ANALYSIS

This sample provided a reliable estimate of the map accuracy as a whole. The accuracy result was the ratio of 329 points correct to a total of 354 points, or 93 percent, having a one-tailed 95-

TABLE 2. THE PERCENTAGE OF AREA FOR EACH CATEGORY ON THE TAMPA LAND-USE AND LAND-COVER MAP, 1972 WITH THE NUMBER OF SAMPLE POINTS SELECTED AND THE PERCENTAGE OF POINTS

Category	Percent of Total Area Mapped	Number of Points	Percent of Total Points Sampled
11	9.14	29	9.3
12	1.39	4	1.3
13	0.42	2	0.6
14	0.72	2	0.6
15	0.10	—	—
16	0.07	—	—
17	0.82	3	1.0
21	19.75	42	13.5
22	3.47	13	4.2
23	0.02	1	0.3
24	0.16	—	—
31	23.19	90	28.9
32	0.12	—	—
33	0.03	—	—
42	6.21	16	5.1
43	0.02	—	—
51	0.62	—	—
52	0.43	—	—
53	0.23	—	—
54	19.72	60	19.3
61	7.49	27	8.7
62	1.40	2	0.6
72	0.32	1	0.3
73	0.11	1	0.3
75	0.65	2	0.6
76	3.38	16	5.1

percent lower confidence limit of 91 percent. This means that there is 95-percent confidence that the accuracy of the map was at least 91 percent or better. The results of this test are displayed as a classification error matrix in Figure 1.

Obtaining a valid estimate of the accuracy of the individual categories depends more on the size of the sample within each category that it does on the percent correct of data sampled. According to Van Genderen and Lock (1977), there is a threshold number of points that must be sampled, even if the sample is error-free, to indicate whether a map meets or exceeds a given accuracy criterion. For the criterion of 85-percent accuracy, they state that threshold value is 20 points. This manual sample provided an excess of 20 points for only six of the 26 categories on the map, and nine categories were not samples at all. For the six categories having this threshold number, a reliable estimate of the true percentage correct together with the 95-percent lower one-tailed confidence limits are given in Table 3. Of these categories, only four provided an estimate of the true percent correct with 95-percent lower confidence limits within 10 percent of the true value, these were: category 21, Cropland and Pasture; category 31, Herbaceous Rangeland; category 42, Evergreen Forest; and category 54, Bays and Estuaries. All of these categories were at least 85 percent accurate. Values with 95-percent confidence limits greater than 10 percent were not considered precise enough to give a valid estimate.

ALGORITHM FOR SAMPLE SELECTION FROM COMPUTERIZED DATA

SAMPLE SELECTION TECHNIQUES

Once a map was digitized, it became possible to select a sample that would include every category on the map. For each map digitized, there exists a computer file of all map categories in the geographic information system. It was therefore possible to prepare a computer program to select a representative sample from each category directly from the geographic information system. It was also possible to include in the computer program the procedure for making the analysis of the test data.

In order to obtain reliable results for each category, a minimum number of points had to be selected for all categories. The small threshold number of Van Genderen and Lock (1977) is useful only if the sample is error-free. For the case where errors are expected, a minimum number of points, n, can be selected, as shown in Table 4, in order that the sample mean will estimate the accu-

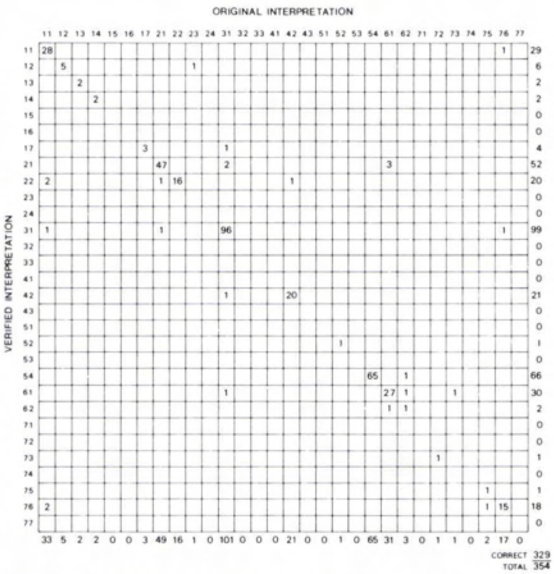

FIG. 1. Classification error matrix of the Tampa, Florida Land Use and Land Cover Map, determined from a manual selection of points.

racy value, p, with 95-percent confidence with no more than a fixed error, E, of 10 percent.

For the number of points selected, a minimum required number of points correct, the critical number, was necessary to accept the hypothesis at the 95-percent level that the category was mapped with at least 85 or 90-percent accuracy, as shown in Table 5.

An algorithm for point selection from the digitized maps was developed for use with the GIRAS information system. The algorithm was developed to provide for a stratified systematic unaligned sample of a given number of points, and a second stratification by category to achieve a selection of at least a minimum number of points for each category at a given confidence level (i.e., 95-percent) and a given accuracy criterion (Rosenfield *et al.*, 1981). The algorithm assured that there were at least a minimum number of sample points per category. Where there were less than that number of polygons for a category, interior points were selected from all polygons so there were at least as many points selected as polygons. Categories were not limited to the minimum points. Where a larger sample was selected initially, such as for the major categories on the map, this larger number of points was retained.

SAMPLE SIZE AND DISTRIBUTION

An initial point selection using this algorithm was made for the Tampa land-use and land-cover map, with the program calling for 400 points to be selected by the stratified systematic unaligned sampling technique, and a minimum number of 45 sample points for each category, based on an expected accuracy of at least 85 percent. The total number of points selected was 894. Because this many points would have required a major effort to evaluate the map accuracy, it was decided that a smaller sample size should be used.

The earlier accuracy evaluation based on the manual sample selection had indicated an overall map accuracy of at least 91 percent or better. Accordingly, it was decided to enter Table 4 with an estimated accuracy, p, of 90 percent, in order to obtain a minimum sample size for each category of 34 points. Accordingly, a computer sample calling for 400 points was used with a minimum of 35 sample points per category. The computer selection was made, resulting in a total sample size of 737 points, a more feasible number than before. Table 6 shows the number of points selected for each category, both before and after the augmentation using a minimum of 35 points.

DATA VERIFICATION

The selected sample of 737 points was plotted by the GIRAS system on the Tampa map. The verification procedures were the same as they had

TABLE 3. ANALYSIS OF ACCURACY FOR LAND-USE AND LAND-COVER CATEGORIES ON THE TAMPA MAP REPRESENTED BY MORE THAN 20 POINTS

	Points Correct	Points Total	Percent Correct	95% Lower Confidence Limits
11 Residential	28	33	85	73
21 Cropland and Pasture	47	49	96	90
31 Herbaceous Rangeland	96	101	95	91
42 Evergreen Forest	20	21	95	85
54 Bays and Estuaries	65	65	100	97
61 Forested Wetland	27	31	87	75

TABLE 4. MINIMUM SAMPLE SIZE, n, TO ESTIMATE THE GIVEN ACCURACY, p, AT 95-PERCENT CONFIDENCE LEVEL WITH AN ACCEPTABLE ERROR, E, OF 10 PERCENT OR LESS

$E = 10\%$	
p	n
0.50	77
0.70	66
0.80	53
0.85	45
0.90	34
0.95	22
0.97	16

Source: Rosenfield *et al.*, 1981.

been with the manual sample selection. The verified interpretation of the points was entered into the computer program for comparison with the map interpretation. Figure 2 represents the classification error matrix resulting from the automatic selection algorithm.

ACCURACY ANALYSIS

Accuracy of the Map. The problem, then, was to establish the accuracy of the whole map. Because the data were no longer area weighted, but category weighted, it was necessary to reintroduce weights by area. The true accuracy of the map considered as a whole would be calculated using the estimate appropriate to stratified sampling (Snedecor and Cochran, 1967, pp. 526-527), i.e.,

$$P_{st} = \sum W_h p_h \quad (4)$$

where p_h is the sample mean of the n_h observations from the h-th category, W_h is the percent area of the h-th category, and the subscript st is for the stratified sample. The one-sided lower confidence limit is calculated by the formula

$$p_L = \hat{p} - (1.645 \sqrt{\sigma_{st}^2} + 50/n) \quad (5)$$

$$\text{where } \sigma_{st}^2 = \sum W_h^2\, p_h q_h / n_h \quad (6)$$

Table 7 lists for each category the percent area, the percent accurate, the weighted accuracy value, and the number of points sampled. After summation, the sample accuracy is 97.3 percent. The lower one-sided confidence level calculated by the formulas above is 95.9 percent.

Accuracy of Categories. The hypothesis tested was that each category was mapped at an accuracy of 90 percent or better. Table 5 shows that, for a sample of 35 points for each category, a critical number of 29 points or more correct would have a lower 95-percent confidence limit of 80 percent or results having an error value of 10 percent. Calculations for the category data were made to test whether each category was mapped at 90 percent accuracy. The results for the hypothesis that $p \geq 90$ percent are shown in Table 8. From these results, it appears that of those categories with at least 35 points sampled, all but categories 13, Industrial, and 17, Urban Open land, were accepted as 90 percent accurate or better.

In addition to testing whether or not the true accuracy of each category met the criterion of 90 percent accuracy, the estimated value of each category was determined. Table 8 also shows the percent accuracy for each category with the one-tailed 95-percent lower confidence limits determined from the formula in Equation 3. The values from Table 8 are of interest to the user who needs to know the lower limit of accuracy of any given category. No lower confidence limits are shown for samples less than 20 because the values have very little statistical significance.

COMPARISON OF DATA ANALYSIS TECHNIQUES

In the manually selected sample, the lower confidence limits of the sample mean for each cat-

TABLE 5. THE CRITICAL NUMBER OF CORRECTLY IDENTIFIED SAMPLE POINTS NEEDED TO ACCEPT THE HYPOTHESIS WITH 95-PERCENT CONFIDENCE THAT THE CATEGORY WAS MAPPED WITH AT LEAST 85 OR 90 PERCENT ACCURACY

Sample Size n	The number of correctly identified sample points to accept H_0 with 95% confidence		Lower Confidence Limits at 5% level	
	$P_0 = 85\%$	$P_0 = 90\%$	$P_0 = 85\%$	$P_0 = 90\%$
10	7 or more	8 or more	0.70	0.80
15	11 or more	12 or more	0.73	0.80
20	14 or more	16 or more	0.70	0.80
25	18 or more	20 or more	0.72	0.80
30	22 or more	24 or more	0.73	0.80
35	26 or more	29 or more	0.74	0.83
40	30 or more	33 or more	0.75	0.83
45	34 or more	37 or more	0.75	0.82
50	38 or more	42 or more	0.76	0.84

Source: Rosenfield *et al.*, 1980.

TABLE 6. LIST OF SAMPLE POINTS BY CATEGORY FOR THE TAMPA LAND USE AND LAND COVER MAP WITH THE MINIMUM NUMBER SET FOR AT LEAST 35 POINTS

Category	1st Stratification	2nd Stratification
11 Residential	16	35
12 Commercial and Services	3	35
13 Industrial	1	35
14 Transportation, etc.	1	35
15 Industrial and Commericial Complexes	2	6
16 Mixed Urban and Built-up Land	0	11
17 Other Urban or Built-up Land	5	35
21 Cropland and Pasture	25	35
22 Orchards, etc.	6	35
23 Confined Feeding Operation	0	6
24 Other Agricultural Land	1	35
31 Herbaceous Rangeland	48	48
32 Shrub and Brush Rangeland	0	12
33 Mixed Rangeland	0	6
42 Evergreen Forest Land	12	35
43 Mixed Forest land	0	4
51 Streams and Canals	1	33
52 Lakes	0	35
53 Reservoirs	0	35
54 Bays and Estuaries	37	37
61 Forested Wetland	14	35
62 Nonforested Wetland	3	35
72 Beaches	0	35
73 Sandy Areas other than Beaches	1	17
75 Strip Mines, etc.	2	32
76 Transitional Areas	4	35
Total	182	737

ORIGINAL INTERPRETATION

VERIFIED INTERPRETATION

	11	12	13	14	15	16	17	21	22	23	24	31	32	33	41	42	43	51	52	53	54	61	62	71	72	73	74	75	76	77	
11	33	1				2	1																					1			38
12		32	4	1			1				1																				39
13			25																												25
14			3	33																						1					37
15					6																										6
16		1				7																									8
17							28	1														1						2	1		33
21						1	1	34	3																						39
22						1			32	2			1																		36
23										3																					3
24				1						1	34																				36
31												48	3	1								1				1					54
32													8	1																	9
33														3																	3
41																															0
42														1		33	4														38
43																															0
51																		31													31
52																			32	1											33
53																			2	32											34
54																		2			37				1						40
61																2						31									33
62																			1			2	35			2					40
71																															0
72																									34	1					35
73							2																			10					12
74																															0
75			2																	2								28			42
76	2	1	1				2																			2		1	34		43
77																															0
	35	35	35	35	6	11	35	35	35	6	35	48	12	6	0	35	4	33	35	35	37	35	35	0	35	17	0	32	35	0	

TOTAL 737

FIG. 2. Classification error matrix of the Tampa, Florida Land Use and Land Cover Map, selection of points from the geographic information system.

egory were taken as the accuracy criterion. Where the lower confidence limit was less than 85 percent, the premise that the category was mapped at or greater than 85 percent accuracy was rejected.

In the computer selected sample, the lower confidence limit for the *expected* value of 90 percent, based on the number of points sampled for each category, was considered crucial. The critical number of points correct necessary to meet this lower confidence level was computed, and the number correct in the sample must exceed this critical value in order to accept the hypothesis that the accuracy of 90 percent had been met at the 95-percent confidence level. The statement to be made was whether the category was accepted or rejected as being at least 90-percent accurate at the 95-percent confidence level. In addition, the lower one-sided confidence limit about the sample mean for each category was computed, although it was not considered necessary because of the criterion for rejection or acceptance.

The superiority of the computer based sample was that it was easier to select, it included all categories, and it assessed for each category whether the criterion of 90 percent was met or not.

TABLE 7. WEIGHTED ACCURACIES OF THE LAND-USE AND LAND-COVER MAP OF TAMPA, FLORIDA

Category	W_h % Area	Sample Mean (p_h) Expressed as a Percent	Weighted Accuracy	Number of Sample Points
11	9.14	94.3	8.62	35
12	1.39	91.4	1.27	35
13	0.42	71.4	0.30	35
14	0.72	94.3	0.68	35
15	0.10	100.0	0.10	6
16	0.07	63.6	0.64	11
17	0.82	80.0	0.66	35
21	19.75	97.1	19.18	35
22	3.47	91.4	3.37	35
23	0.02	50.0	0.01	6
24	0.16	97.1	0.16	35
31	23.19	100.0	23.19	48
32	0.12	66.7	0.08	12
33	0.03	50.0	0.02	6
42	6.21	94.3	5.86	35
43	0.02	0.0	0.00	4
51	0.62	93.9	0.58	33
52	0.43	91.4	0.39	35
53	0.23	91.4	0.21	35
54	19.72	100.0	19.72	37
61	7.49	88.6	6.64	35
62	1.40	100.0	1.40	35
72	0.32	97.1	0.31	35
73	0.11	58.8	0.06	17
75	0.65	87.5	0.57	32
76	3.38	97.1	3.28	35
			97.30%	

If a comparison between categories were desired, there are sufficient data to analyze the sample accuracy of each category.

In the manual sample the accuracy of the map was expressed as the percentage value for the ratio of the number correct to the total number of points on the map. In the computer based sample, weighting was used to determine the overall accuracy of the map because the area weighted sample was destroyed by the category stratification for the less frequent categories. The category accuracies were weighted by the percent area of each category.

FINAL COMPARISON AND CONCLUSIONS

The manual sample technique yielded a smaller and more manageable sample than either selection using the sampling algorithm based on a minimum of 35 or 45 points per category. However, the advantages of selecting and plotting points, including all categories across the map, by computer more than compensates for the added complexity of a larger sample. Another advantage is that the computer can perform the lengthy computations for analyzing the data once the verification process is complete.

The greater superiority of the computer based sampling technique over the manual sampling was in the analysis. Whereas the manual sample only allows for evaluating those categories sampled by chance, the computer sample assures that all categories on the map were selected, and selected with a minimum number of points, where possible, for a valid analysis, something nearly impossible to do manually. Because all categories were represented, the area weighted accuracy determination for the complete map was more representative of its true accuracy than than the accuracy determination from the stratified systematic unaligned sample alone.

Once a map has been digitized and the data entered into a geographic information system, a sample selection using a dual stratification—first a geographic stratification followed by a category stratification—is superior to the simpler manual sample selections.

RECOMMENDATIONS

All of the possible categories in the land classification system (Anderson *et al.*, 1976) were not represented in the map used in this study. It is expected that maps of different parts of the country would have differing land-use patterns and categories. For these reasons, the recommenda-

TABLE 8. RESULTS OF SAMPLE ACCURACY TEST BY CATEGORY FOR THE TAMPA LAND USE AND LAND COVER MAP

Category	Number of points Sampled	Number Correct	hypothesis that $p \geqslant 90$ percent for each category: Critical Value to accept	hypothesis that $p \geqslant 90$ percent for each category: Accept or Reject	Percent Correct	95 Lower one-sided Confidence Limits*
11	35	33	29	Accept	94.3	86
12	35	32	29	Accept	91.4	82
13	35	25	29	Reject	71.4	57
14	35	33	29	Accept	94.3	86
15	6	6	5	Accept	100.0	—
16	11	7	6	Accept	63.6	—
17	35	28	29	Reject	80.0	67
21	35	34	29	Accept	97.1	91
22	35	32	29	Accept	91.4	82
23	6	3	5	Reject	50.0	—
24	35	34	29	Accept	97.1	91
31	48	48	39	Accept	100.0	97
32	12	8	9	Reject	66.7	—
33	6	3	5	Reject	50.0	—
42	35	33	29	Accept	94.3	86
43	4	0	4	Reject	0.0	—
51	33	31	26	Accept	93.9	86
52	35	32	29	Accept	91.4	82
53	35	32	29	Accept	91.4	81
54	37	37	30	Accept	100.0	96
61	35	31	29	Accept	88.6	79
62	35	35	29	Accept	100.0	97
72	35	34	29	Accept	97.1	91
73	17	10	11	Reject	58.8	—
75	32	28	25	Accept	87.5	76
76	35	34	29	Accept	97.1	91

* Confidence limits were not computed for samples of less than 20 points.

tion is to test systematically the accuracy of the land-use and land-cover maps on a continuing basis. Once the maps are digitized and the data are in the GIRAS system, the procedure for determining if the maps meet the 85-percent stated accuracy is greatly facilitated. The computer program for this analysis has been tested and documented and can easily be applied to any map in the GIRAS system.

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