Floyd M. Henderson
Department of Geography
State University of New York at Albany
Albany, NY 12222

Effects of Interpretation Techniques on Land-Use Mapping Accuracy

The method of cell mapping and the cell size employed will have an effect upon the accuracy and validity of the derived land-use information.

Abstract: *Three study areas in the southern United States were employed to examine effects of selected interpretation techniques on land-use mapping accuracy. Using the USGS hierarchial classification system (Geological Survey Professional Paper 964), nine different interpretation methods based on a grid cell matrix were used to determine which methods were most accurate and were used to pinpoint variations. Best results were not always obtained with the smallest grid cell; interpretation techniques less complex than stratified systematic unaligned sampling often produced more accurate data. It was also discovered that grid placement may not be a random decision. The optimum interpretation technique was found to vary among sites and category but not in a consistent manner.*

Inventorying and monitoring land-use change are generally considered basic to almost any resource management, planning, or land-related program—be it rural or urban, local or national in scope. Society's growing awareness of a changing environment and its consequences has generated a need to know what activities are present on the land and where and how quickly shifts in activity occur. To meet this demand for current accurate data, remote sensing systems are being employed with increasing frequency as a mapping base.

Fundamental to inventorying land-use activity is the selection of a mapping unit. Obviously, in determining the area devoted to each type of land use, the most precise method is to measure each parcel, but this procedure is also the most arduous, expensive, time-consuming, and difficult to update. As an alternative, many inventory programs employ cells or polygons as the decision unit and coordinate them with UTM or other similar map grids. While a degree of accuracy is sacrificed by recording data in artificial segments, the process of change notation and updating is more expedient and facile. The result is a relatively efficient data base from which land-use information can be derived, stored, and integrated into automated or semi-automated geographic information systems.

It is readily apparent that the particular method of cell mapping selected and the cell size utilized will have some effect on the validity and accuracy of the results. Various authors have recognized this relationship and attempted to provide guidelines for users and practitioners. Hord and Brooner (1976) described sampling strategies that could be used to assess the accuracy of classification, boundary line placement, and control point location. The effect of resolution on land-use mapping accuracy has been

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examined by Simonett and Coiner (1971). Using 106 study areas representative of the diverse environments found in the United States and overseas, they compared the number of land uses present in various size cells in order to determine the effectiveness of Landsat and other similar satellite systems. As might be expected, the authors found that the level of land-use complexity varied considerably. Wiedel and Kleckner (1974) have assembled a guide for land-use mapping via remote sensing, including procedures for recording area measurements, field checking, sampling strategies, and tables depicting the relationship of map scale to polygon area and sizes. Whereas these analyses and similar efforts have provided valuable insight to land-use mapping design and application, a related and equally critical problem has received little attention. Assuming that it is often impractical to determine land use on a parcel by parcel basis and that cells provide a viable alternative method, the question then arises as to what effect the size of the cell, the placement of the cell grid over the study area, and the interpretation strategy employed to classify land use within that cell will have on map accuracy.

In the majority of instances, imagery of the desired type and scale is obtained for the study area, appropriate land-use categories are designated, and a grid of certain cell size or dot density is specified. The size of cell selected is normally a function of the level of detail and interpretation time required, but ostensibly the principle is that the smaller the decision unit the more accurate will be the results. After selecting a cell size, the grid is placed over the imagery and land use is tabulated, most frequently by identifying the dominant land use in each cell or by employing dots in systematic aligned or stratified systematic unaligned format. Again, it is assumed that the more complex technique will produce the more accurate data. However, to date no work has specifically addressed the fidelity of land-use interpretation as a function of these decisions. This study is an initial investigation of the role and ramifications of these processes for land-use mapping efforts. Specifically, the following parameters are considered in regard to accuracy of land-use determination:

- the effect of grid placement or orientation,
- the effect of cell size, and
- the effect of method used to assign land use for each cell.

FIG. 1. *Location of study areas.*

STUDY AREA

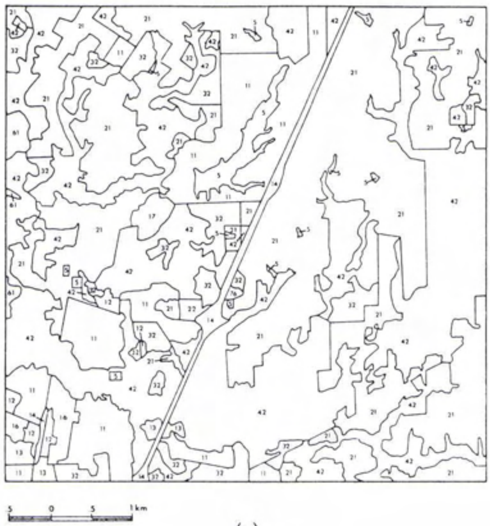
The decision was made to examine the variation in land-use interpretation accuracy within more or less homogeneous proximate areas. Three study areas in the southern United States were selected for analysis—two in southern Mississippi and the third in southern Louisiana (Figure 1). Because the study areas are located in the same general geographic area, extreme variations in topography and land use are lacking. The land-use types and patterns are similar among the three areas, being predominantly cropland and pasture with forest land and small urban areas common.

However, on an individual basis, not uncharacteristic of intra-region modulation, somewhat more distinct patterns do emerge. Study Area I (Picayune), located in the Gulf Coast lowland, contains the largest percent of forest and urban land uses and the lowest percent of land devoted to agricultural crops and pasture. The land-use pattern is the most complex and fragmented of the three areas (Figure 2a). Study Area II (Maringouin) is Mississippi Valley lowland and shares an absence of relief with Study Area I. It contains the greatest concentration of land devoted to crops and pasture activity and the least diversity (Figure 2b). The third study area (St. Elmo)* is Mississippi Valley upland and also is characterized by an absence of relief although at a slightly higher elevation. The most rural of the three study areas, St. Elmo's has a rather fragmented land-use pattern (Figure 2c). In the following paragraphs the ability to accurately inventory this land cover by selected interpretation strategies is discussed.

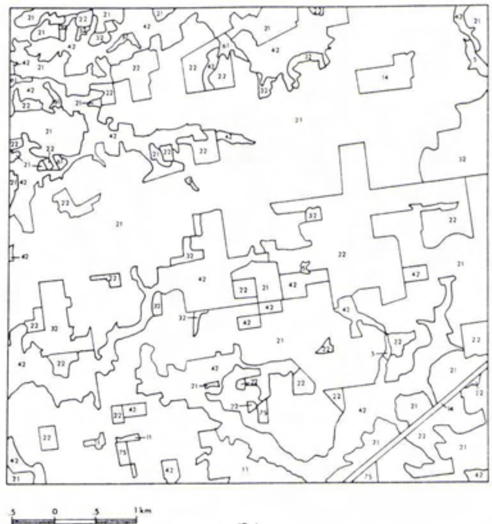
METHODOLOGY

A nine inch by nine inch frame of color infrared imagery at a scale of 1:30,000 was

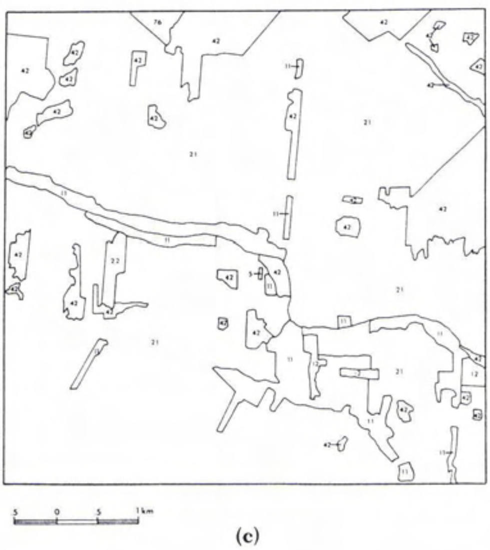
* St. Elmo is a small town near Port Gibson, Mississippi.



(a)



(b)



(c)

FIG. 2. (a) Picayune, Mississippi (Study Area 1); (b) Maringouin, Louisiana (Study Area 2); (c) St. Elmo, Mississippi (Study Area 3). Note: Numbers refer to USGS Level II land-use categories listed in methodology section.

selected for each study area. Land use was delineated and recorded by parcel on an acetate overlay at Level II detail according to Anderson *et al.* (1976). Thirteen Level II land-use categories and water were delineated:

5—Water
11—Residential
12—Commercial and Services
13—Industrial
14—Transportation, Communications, and Utilities
16—Mixed Urban or Built-up Land
17—Other Urban or Built-up Land
21—Cropland and Pasture
22—Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
32—Shrub and Brush Rangeland
42—Evergreen Forest Land
61—Forested Wetland
75—Strip Mines, Quarries, and Gravel Pits
76—Transitional Areas
(NOTE: The numbers are used to designate land use types in Figure 2 and Tables II and IV.)

The area devoted to each category within the respective study sites was calculated by planimeter and served as ground truth. Grid overlays with cell sizes if 2.5, 5, 7.5, and 10 hectares were produced for the mapping process. Placing the grids randomly over the parcel maps of each study area the land use was recorded by the following methods:

(1) Using the five hectare grid, the dominant land use in each cell was tabulated. Without moving the grid, the land use was then retabulated using: (a) a systematic aligned method (center dot within each cell representing land use of cell) and (b) a stratified systematic unaligned procedure using a 5 × 5 coordinate system for each cell (after Berry and Baker, 1968). By not moving the cell, possible vatiation owing to grid placement was eliminated.
(2) The five hectare grid was then shifted one half cell to the left and the dominant land

use for each cell noted. Returning the grid to its original position (noted by registration marks), it was then shifted one half cell up and the dominant land use by cell noted. Following this interpretation, the five hectare grid was rotated 45 degrees from the original position and, again, the dominant land use registered.

(3) Grids of 2.5, 7.5, and 10 hectare size were placed over each of the three parcel maps and the dominant land use by cell recorded.

In each instance the Level II land use was recorded by cell and by category for each of the three study sites, generating the following nine products per site:

- 5 hectare cell—dominant land use (the original position)—DLU
- 5 hectare cell—systematic aligned sampling—SAS
- 5 hectare cell—stratified systematic unaligned sampling—SSUS
- 5 hectare cell—grid shifted one half cell to the left of original position and dominant land use recorded
- 5 hectare cell—grid shifted one half cell up from original position and dominant land use recorded
- 5 hectare cell—grid shifted forty-five degrees to left of original position and dominant land use recorded
- 2.5 hectare cell—dominant land use recorded at original position
- 7.5 hectare cell—dominant land use recorded at original position
- 10 hectare cell—dominant land use recorded at original position

The first comparison tests the hypothesis that the SSUS method should yield the most accurate results followed in order by the SAS and DLU techniques. Technically, the SSUS and SAS methods measure point data while the DLU is an areal sample. In practice, foresters, planners, and others use data sampled at points to represent a specific area of data (e.g., one dot equals 40 acres) (Wiedel and Kleckner, 1974). It is frequently assumed that the stratified systematic unaligned sampling technique (SSUS) is the most accurate because it minimizes the effect of bias introduced with regular dot placement. With the SAS method spatially small and/or infrequent land-use activities as well as periodicities in the data are, theoretically, more likely to be under- or overestimated. A similar rationale is present in comparing the advantages of a systematic aligned (checkerboard) sample of dots (SAS) over inventorying activity by the dominant land use (DLU) within a cell.

The second comparison tests the hypothesis that orientation and placement of the grid over a study area is a random process and will have no bearing on interpretation accuracy. By changing the orientation of the grid, the effect on accuracy of cells not aligned parallel to field borders (i.e., North-South, East-West) is examined. By shifting the grid position but retaining a cell orientation parallel to field borders (i.e., to the left and up, respectively) the assumption of randomness in grid placement is also considered.

In the third approach land use was interpreted using cells of 2.5, 5, 7.5, and 10 hectares in size, the assumption being that the smallest cell would generate data most nearly similar to ground truth. As the cell size increased, a bias towards land use occupying the greatest portion of the study area and towards those activities found in the largest contiguous groupings should be expected.

Analysis

Two procedures were employed to examine the effects of the nine grid techniques on land-use mapping accuracy. The Mean Absolute Per Cent Error (MAPCE) was calculated for each land-use category by interpretation method for each study area using the formula

$$\text{MAPCE} = \frac{|a - b|}{A} \times 100$$

where

a = hectares of land use for category x as determined by parcel calculations;
b = hectares estimated (interpreted) for category x by method y; and
A = total hectares in study area as counted by parcel data.

For each study area, category, and technique the condition of over- or under-estimation of land-use area was also tabulated.

A necessary second step was to test for the relative magnitude in the observed differences among the interpretation strategies. To this end a series of chi-square statistics was computed. The limitations of employing such analysis with continuous data are recognized. On the other hand, normality and homoscedasticity of the data could not be assumed, thus calling for a non-parametric measure. While it would be inappropriate to apply any rigorous interpretation of the statistical significance of the results, chi-square does provide an attractive intuitive measure of the extent of differences in the interpretation techniques. Consequently, chi-square tests of the following data were completed for each of the three test sites:

- Cell orientation and placement (dominant land use with 5 hectare grid: original position, one half cell left, one half cell up, forty-five degree angle shift);
- Cell size variation (dominant land use in 2.5, 5, 7.5, and 10 hectare cells);
- SSUS, SAS, and DLU techniques (5 hectare cells);
- All techniques using a 5 hectare cell (DLU, SAS, SSUS, one half cell left, one half cell up, and a forty-five degree angle shift); and
- All nine techniques for each category to discern if some land-use types were more variable than others, thus skewing the entire data set.

Results

MEAN ABSOLUTE PER CENT ERROR (MAPCE)

Because the Picayune site contained the broadest range of land-use activities, shapes, and sizes of the three study areas (see Figure 2), it might be expected to produce the greatest range in land-use estimates with the most precise technique (SSUS) requisite for accuracy. This was not the case. The study area of intermediate land-use complexity (St. Elmo) presented far more problems regarding estimation consistency. Table 1 contains a summary of the results of this analysis. Although the overall range of percent error is small, it is readily apparent that no single technique is consistently the most accurate.

Table 1. Mean Absolute Percent Error

Method	Study Area		
	Picayune	Maringouin	St. Elmo
SAS 5h. grid	9.21	6.43	7.18
SSUS 5h. grid	9.21	6.42	6.08
DLU 5h. grid	8.14	6.63	9.08
DLU ½ left 5h. grid	6.68	8.05	8.55
DLU ½ up 5h. grid	7.28	6.48	9.28
DLU 45° 5h. grid	7.76	6.30	10.22
DLU 2.5h. grid	6.95	7.65	11.78
DLU 7.5h. grid	8.48	6.13	12.89
DLU 10h. grid	11.04	8.96	16.04
Range of Error	4.36	2.54	9.96

For the Picayune study site, the most accurate results (6.68 percent error) were obtained when the 5 hectare grid was shifted one half cell to the left of its original position and dominant land use recorded while the dominant land-use 10 hectare grid proved to be the least accurate. The Maringouin site contained the fewest land-use categories (seven) and was the least complex of the three areas. It also had the smallest range of error (2.54 percent). The most exact land-use figures for Maringouin were generated by recording the dominant land use in 7.5 hectare cells (6.13 percent error), but five other techniques were within one half percent of this figure (see Table 1). In this almost monoland-use environment the interpretation technique apparently made little difference in accuracy. The greatest range in results (9.96 percent) occurred at St. Elmo, but the SSUS procedure also produced the most precise data (6.08 percent error). Since this site is less complex (see Figure 2) and contains fewer land-use categories (nine versus thirteen) than the Picayune site, one might expect closer agreement among the nine interpretation techniques. At present no explanation can be advanced for this phenomena.

To discover if any land-use categories were repeatedly over- or under-estimated by a given interpretation technique or for more than one study area, Table 2 was constructed. A detailed comparison of these data with Figures 2a, b, and c is intriguing but perhaps tedious. For brevity, it is believed a few general comments will suffice. Urban land-use categories tended to be overestimated if contiguous and/or non-linear in shape and underestimated if fragmented, small in size, and/or linear in shape.

A lack of consistency and more complex pattern emerged when the agriculture and forest cover types were examined. Cropland and Pasture (21) was always overestimated at St. Elmo but underestimated at the other two sites except when 2.5, 7.5, and 10 hectare DLU cells were employed. No trend was observed for Shrub and Brush Rangeland (32). The interpretation methods also produced mixed results for Evergreen Forests (42) except at St. Elmo where forest was always underestimated. The remaining categories were inconsistently estimated. While no precise explanation for these phenomena can be offered at this time, the data do present a provocative enigma and suggest that further research is needed in regard to the prediction of land-use mapping accuracy.

A clearer picture of trends and results of

TABLE 2. OVER- AND UNDER-ESTIMATION OF LAND USE BY CATEGORY AND METHOD AMONG STUDY AREAS

Category Method	5	11	12	13	14	16	17	21	22	32	42	61	75	76
Picayune														
5h. SAS	–	+	+	+	+	–	–	–	–	–	–	–	NA	–
5h. SSUS	+	+	–	+	–	–	–	–	–	+	–	–	NA	–
5h. DLU	–	+	+	+	–	–	–	–	–	–	–	+	NA	–
5h. DLU ½ left	–	+	+	+	–	–	–	–	–	–	–	+	NA	+
5h. DLU ½ up	–	+	+	+	–	+	–	–	–	–	–	–	NA	–
5h. DLU 45°	–	+	+	+	–	+	+	–	–	–	–	+	NA	+
2.5h. DLU	+	+	+	+	+	+	–	+	–	+	+	–	NA	–
7.5h. DLU	–	+	+	+	–	–	–	+	–	–	–	+	NA	–
10h. DLU	–	+	–	–	–	+	–	+	–	+	+	+	NA	–
Maringouin														
5h. SAS	–	–	+	NA	NA	NA	NA	–	+	NA	–	NA	NA	+
5h. SSUS	–	–	+	NA	NA	NA	NA	–	–	NA	–	NA	NA	–
5h. DLU	–	–	+	NA	NA	NA	NA	–	+	NA	–	NA	NA	+
5h. DLU ½ left	–	+	+	NA	NA	NA	NA	–	–	NA	+	NA	NA	–
5h. DLU ½ up	–	–	+	NA	NA	NA	NA	–	–	NA	–	NA	NA	–
5h. DLU 45°	–	–	–	NA	NA	NA	NA	–	–	NA	–	NA	NA	+
2.5h. DLU	–	–	+	NA	NA	NA	NA	+	–	NA	+	NA	NA	+
7.5h. DLU	–	–	+	NA	NA	NA	NA	+	+	NA	–	NA	NA	–
10h. DLU	–	–	+	NA	NA	NA	NA	+	+	NA	+	NA	NA	+
St. Elmo														
5h. SAS	+	–	NA	NA	–	NA	NA	+	+	–	–	+	+	NA
5h. SSUS	–	–	NA	NA	–	NA	NA	+	–	–	–	+	–	NA
5h. DLU	–	–	NA	NA	–	NA	NA	+	+	–	–	–	–	NA
5h. DLU ½ left	–	–	NA	NA	–	NA	NA	+	–	–	–	–	–	NA
5h. DLU ½ up	+	–	NA	NA	–	NA	NA	+	+	–	–	+	+	NA
5h. DLU 45°	–	–	NA	NA	–	NA	NA	+	–	+	–	–	+	NA
2.5h. DLU	+	+	NA	NA	–	NA	NA	+	+	–	–	+	+	NA
7.5h. DLU	–	–	NA	NA	+	NA	NA	+	–	–	–	–	+	NA
10h. DLU	+	–	NA	NA	–	NA	NA	+	–	–	–	–	+	NA

+ = overestimation of land use category
– = underestimation of land use category
NA = not applicable, land use category absent in study area

these analyses may be possible by referring to Figure 3. Note that no single interpretation method is consistently superior, nor do the results entirely substantiate traditional or accepted guidelines. The smallest grid (2.5 hectares) never produced the best results while the most sophisticated technique (SSUS) did so only once. Both of these interpretation methods did come close to being the most accurate and the percent differences were small, but the fact remains that consistency was absent. However, there does seem to be some association between grid unit size and accuracy for the cells. Note that the 10 hectare cell is always the least accurate and the 7.5 hectare cell is the next most frequently subject to the greatest estimation error. Intriguing as such comparisons may be, the more critical parameter involves determining if these differences are significant or merely fall into the realm of random chance occurrence.

CHI-SQUARE ANALYSIS

To test for the relative magnitude of the observed differences in the data, chi-square statistics for k independent samples were computed. The rationale and acknowledged limitations of this procedure have already been discussed. Rather than calculate the chi-square value of all nine interpretations for each test site, common methods were grouped into subsets for more equitable comparisons of techniques. Calculations were made from matrices indicating hectares devoted to each land-use category according to a given interpretation technique. The null hypothesis, H_o, was that the interpretation methods do not differ in the frequency with which the various land-use types are assigned. The rejection level for H_o was set at $\alpha = 0.05$.

The first test explored the effect of cell size on mapping accuracy. It is generally assumed that the smaller the grid cells used the more accurate the land-use data will be. That is, the smallest cell will be most similar to measurements made using parcels or actual boundaries. Previous calculation of MAPCE indicated fluctuation in accuracy levels did occur. To further explore this observation, chi-square analysis of dominant

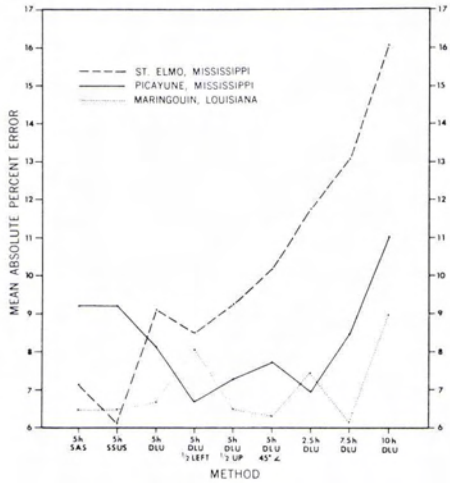


FIG. 3. Range of error by method among study areas.

land use recorded by 2.5, 5, 7.5, and 10 hectare cells for each of the three study areas was performed (Table 3). The null hypothesis was rejected. In fact for St. Elmo and Picayune the probability that the differences were due to change is <0.001.

A second analysis investigated the effect of cell orientation and placement on land-use accuracy. Column two of Table 3 shows the results of these interpretations. In two of the study areas, Maringouin and Picayune, shifting the grid produced significantly different results. At St. Elmo, however, the level of significance is much lower and the null hypothesis must be accepted. Although Picayune and St. Elmo have similar land-use patterns or divisions (Figure 2), the latter area has fewer types of land use. Initially, this suggests that fewer number of land-use categories may afford less chance of error—until one notices the highly significant difference recorded at Maringouin. Maringouin has the least complex landscape, and one would not expect that simply moving a grid would have such a striking effect. In operational situations manually moving the grid over each study area to determine the ideal orientation may prove impractical. It is suggested, however, that useful guidelines might be efficiently produced if the effects of such changes could be modeled.

Three interpretation strategies were employed to explore the role of interpretation technique. Each study area was interpreted three times using a 5 hectare cell grid and the following methods: (1) dominant land use (DLU), (2) systematic aligned sampling (SAS), and (3) stratified systematic unaligned sampling (SSUS). By referring to column three of Table 3 it can be seen that the observed differences were significant in two cases (Picayune and St. Elmo). The question arises as to why the data should be significantly different for Maringouin when the 5 hectare cell is moved (column 2 of Table 3) but not prove to be significant when the technique (SAS, SSUS, DLU) is modified. St. Elmo exhibits a similar pattern but in the reverse. Earlier, it was noted that the DLU method at St. Elmo was the most error prone of the three techniques (9.08 percent), but produced the least error (8.14 percent) at Picayune (Table 1). In short, it seems that the technique responsible for significant difference in error is DLU, but it may be more or less accurate than the SAS and SSUS techniques, depending on the environment. For example, the linear nature of certain St. Elmo categories undoubtedly has some influence. For the present, no inferences are attempted aside from acknowledging the hegemony of environmental modulation on mapping accuracy.

To discover if any specific categories or types of land use were more difficult to interpret accurately, chi-square statistics were computed for each land-use category in each of the three study areas. Again, the null hypothesis was that there was no difference in the nine techniques used. Although the rejection level for H_0 was set at $\alpha = 0.05$, the exact levels were calculated for comparative

TABLE 3. LEVELS OF SIGNIFICANCE OF CHI-SQUARE TESTS; USING COMPARABLE METHODS FOR EACH STUDY AREA

Methods Compared	Cell Size 2.5h. DLU cell 5h. DLU cell 7.5h. DLU cell 10h. DLU cell	Cell Orientation 5h.-DLU cell 5h.-½ cell left 5h.-½ cell up 5h.-45° rotation	Interpretation Method 5h. cell DLU 5h. cell SAS 5h. cell SSUS
Study Area			
Picayune	0.001	0.005	0.001
Maringouin	0.05	0.001	0.90
St. Elmo	0.001	0.20	0.05

Null Hypothesis: No difference among methods purposes. As can be seen in Table 4, the results of these tests, being almost capricious in nature, certainly reflect local environmental conditions. At Picayune, the null hypothesis was accepted for four land-use activities. Industrial (13); (17) Other Urban or Built-up Land; (22) Orchards, Groves, Vineyards, Nurseries, etc.; and (61) Forested Wetland were equally susceptible to all interpretation strategies. There was no significant difference in two of the six categories eligible for analysis at Maringouin: (11) Residential and (76) Transitional Areas. At St. Elmo there was no significant difference among techniques for four of the nine categories: (5) Water; (14) Transportation, Communications, and Utilities; (32) Shrub and Brush Rangeland; and (75) Strip Mines, Quarries, and Gravel Pits.

A characteristic shared by all the above mentioned categories is that they occupy small percentages of the respective study areas and are present in small parcel units. However, note that the same land-use category in a different study area, as well as other categories with similar areal/pattern characteristics, were found to be significantly different. This is apparent by studying the rows in Table 4. Note the variation among study areas in (11) Residential Land; (14) Transportation, Communication, and Utilities; and (32) Shrub and Brush. The dichotomy is similar but reversed, however, when (61) Forested Wetland and (22) Orchards, Groves, Vineyards, Nurseries, etc., are compared. The interpretation technique used to interpret land use was found to be consistently significantly different for three categories: Commercial and Services (12), Cropland and Pasture (21), and Evergreen Forest (42). Yet, only the latter two activities occupied extensive portions of the three study sites.

Table 4. Chi-Suare Levels of Significance Among Nine Methods for Each Category and Study Area

Category	Picayune	Study Area Maringouin	St. Elmo
5	0.001	No Data	0.10
11	0.01	0.30	0.001
12	0.001	0.05	No Data
13	0.80	No Data	No Data
14	0.001	No Data	0.30
16	0.01	No Data	No Data
17	0.30	No Data	No Data
21	0.001	0.001	0.001
22	0.20	0.05	0.01
32	0.001	No Data	0.20
42	0.001	0.001	0.01
61	0.70	No Data	0.02
75	No Data	No Data	0.95
76	No Data	0.30	No Data

Null Hypothesis: No difference among methods

Why some categories should be more subject to variations in the interpretation technique employed than others is not known. The areal extent and configuration of an activity undeniabley contribute to the phenomena, but the relationship is imprecise. Extensive contiguous land-use practices were found to be particularly susceptible to changes in interpretation methodology, but the remaining fragmented land-use segments exhibited inconsistent results. Since these latter categories did comprise a statistically small data base and some were extant in only one or two of the study sites, a definitive verdict is not warranted. Should additional areas be interpreted where these categories were more frequent in occurrence and occupied a greater percentage of the study area, the relationship might be found to more closely simulate that of the Cropland and Pasture category. Certainly the data presented here call for additional empirical evidence and research into the problem.

Conclusions and Observations

Three study areas in the southern United States were employed to examine effects of selected interpretation techniques on land-use mapping accuracy. Land use was recorded by parcel using a hierarchial classification system. These parcel maps served as ground truth. Nine different methods based on a grid cell matrix were then used to remap each area. Mean absolute percent errors (MAPCE) were calculated to determine which methods were most accurate and to pinpoint variations. To test for the relative magnitudes of the observed differences, chi-square statistics were computed and the data were compared and analyzed.

Given the nature of the data, no rigorous application of chi-square statistics could be completed, but it can be said that the differences in error noted in the MAPCE analysis were given support. Specifically: (1) the smallest cell size did not consistently generate the most exact data, (2) a more accurate estimation of the actual area devoted to land uses was possible at times by employing a less precise technique than stratified systematic unaligned sampling, (3) the best technique varied as a function of the land-use category but not in a predictable manner, (4) grid placement and orientation may not be a random decision because the subsequent land-use area classifications incorporating such changes proved to be significantly different, and (5) the best land-use interpretation technique for a land-use category varied between study sites but not in all cases. In only one study area (Picayune) was there a consistent significant difference in all interpretation technique comparisons. In this regard it should be noted that Picayune was also the most diverse environment and contained the greatest number of land-use types and most intricate land-use patterns.

Several questions and observations come to mind as a result of this study. Among the more immediately apparent is the almost omnipotent role of the environment. Variation could be expected if one were to compare strikingly diverse areas such as wheat and grain farming versus irrigated agriculture or a tobacco and cotton economy. In this study, however, significant variations in accuracy were noted using only three sites within one such general region. Admittedly important from a pure research viewpoint, a question also arises from these data in regard to application. Are these observed differences deemed critical to practitioners and users of land-use data, or are the discrepancies within some vague and imprecise but acceptable level of accuracy? Concomitantly, can a model possibly be created or a pattern discerned whereby the exact form and type of variation can be predicted for a given environment? If so, would the costs be commensurate with anticipated benefits? Answers to these questions can only come from research focussing on technology transfer and intended uses of such data. However, before a definite answer can be expected, it is logical and requisite that additional data be collected pertinent to this apparent conundrum in land-use mapping accuracies.

The results of this study are intriguing if not also perplexing. Based on the data reported above, the merit of many traditional guidelines used in selecting a specific mapping approach should be reviewed and perhaps more thoroughly examined. To name but a few: the parameters of scale, area, and interpretation method merit attention. That is, can results comparable to those produced here be expected when different scales of imagery are used and/or a more general or more detailed land-use classification system imposed? What amount and type of variation can be expected when different environments, land-use/settlement patterns, and more extensive areas are examined? The effect of an environment where commercial and service, wetlands, mining, or other land-use activity comprises a larger portion of the area also calls for examination. Finally, further investigation of cell sizes *per se* and in combination with the factors of cell placement, cell orientation, and interpretation technique (e.g., dominant land use, systematic aligned sampling) is advocated.

It is quite evident that the particular method of cell mapping and the cell size employed will have an effect upon the accuracy and validity of the derived land-use information. The role of environmental modulation has also been cited. It is hoped the present study will serve to stimulate interest and initiate research into this not infrequently overlooked problem.

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