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The Analysis of Areal Data in Thematic Mapping Experiments

The use of several nonparametric methods of statistical inference is demonstrated.

Abstract: *Several techniques of nonparametric statistics are applicable to the analysis of areal data in thematic mapping experiments: for the analysis of multiple related samples—Kendall's coefficient of concordance test and Freedman's method of ranks test; and for the analysis of paired samples—the Kendall tau statistic test and the Wilcoxon signed rank test. In each case, these tests examine the shape of two curves, and the separation between them, to determine if there are significant differences. The application of these tests is illustrated with two examples from the remote sensing literature. By using this paper as a tutorial, these tests are made available to the remote sensing researcher.*

In a multiple sample experiment of Level II land-use and land-cover classification at three scales (1:24,000; 1:100,000; and 1:250,000), the area of individual categories delineated at 1:250,000-scale was determined to be significantly different from the other two scales. In a paired sample experiment of Level III land-use and land-cover classification at 1:24,000 scale from both high-altitude aerial photographs and Skylab S-190B aerial photographs, there was no significant difference, as determined by area.

Introduction

Background

The acquisition of areal data for experimentation in thematic mapping, such as land-use and land-cover classification, is a common practice. Fitzpatrick-Lins (1978, p. 28) compares the area for various categories of land use and land cover for three scales of mapping (1:24,000; 1:100,000; and 1:250,000) from high-altitude aerial photographs. The total area at each scale that differs in land-use and land-cover classification from the next larger scale is calculated.

Lins (1976, p. 306) compares the areas for various categories of land-use and land-cover mapping from two sources of imagery: high-altitude aerial photographs (U2-RC10) and Skylab S-190B aerial photographs, both enlarged to 1:24,000 scale. Differences or similarities in the areas of certain land-use and land-cover categories as interpreted from each of the two sources of photographs are detected.

Henderson (1980) compares several techniques for measuring area of land-use and land-cover categories for three different regions. Ratings for the various techniques are determined by closeness of agreement to the area established as a measurement standard.

Purpose and Scope

The purpose of this study is to illustrate that existing techniques of nonparametric statistics can be applied to area data of thematic categories that have been obtained from remote sensing experiments. These nonparametric techniques allow probability-based conclusions to be drawn concerning the variables under study. Such variables include scale (Fitzpatrick-Lins, 1978), source of imagery (Lins, 1976), measuring practices (Henderson, 1980), and others. The data of Fitzpatrick-Lins and Lins will be used as examples to illustrate the nonparametric techniques selected and the statistical conclusions that can be drawn from these examples. By using this paper as a

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TABLE 1. AREA DATA, IN HECTARES,[1] FOR LEVEL II LAND-USE AND LAND-COVER CATEGORIES FOR THREE SCALES OF AERIAL PHOTOGRAPHS

$i = 22$ Category	$j = 1$ 1:24,000	$j = 2$ 1:100,000	$j = 3$ 1:250,000
11	4,069	3,441	4,950
12	340	464	300
13	38	48	0
14	33	112	0
15	259	132	225
16	961	1,289	875
17	60	48	0
18	0	16	0
19	409	400	325
21	21,544	23,156	23,875
22	10	404	0
24	95	92	0
41	33,740	31,550	30,950
42	1,217	1,906	1,900
51	334	404	75
52	0	108	0
53	224	92	125
54	9,316	9,150	8,850
61	3,273	3,088	3,500
72	6	0	0
74	10	0	0
75	62	100	50
Total	76,000	76,000	76,000

[1] Fitzpatrick-Lins (1978, p. 29)

tutorial, these tests are made available to the remote sensing researcher.

Non-parametric techniques (as the name implies) as a class make fewer assumptions than conventional statistical approaches. In this sense, they are quite general and more widely applicable. In statistical parlance, they are "robust." However, there is a penalty paid for robustness, a loss in efficiency. That is, the correct parametric probability model will be more powerful, i.e., able to detect smaller differences than a non-parametric alternative. Thus, non-parametric tests are best used in cases where there is uncertainty about the appropriate probabilistic assumptions—a fairly common state of affairs. As more is learned, improved parametric alternatives can be developed and employed.

The nonparametric techniques selected are used in a two-test procedure to determine the technological conclusion. The criteria of the two tests must be considered to determine whether or not a significant difference exists in the effects of the variables under study in the remote sensing experiment. These are the tests of association and of central location. Tests of association measure the degree of independence between the data sets, and tests of central location measure the "sameness" of median values among the data sets. This is analogous to testing the shape of two curves and the separation between them, in order to determine whether the curves are statistically different. A different set of tests have been selected for each set of data, since the Fitzpatrick-Lins data represent a multiple related sample case, and the Lins data represent a paired sample case.

ANALYSIS

MULTIPLE RELATED SAMPLE ANALYSIS

Previous analysis of data. The area data acquired by Fitzpatrick-Lins (1978, p. 29), by category, from three scales of land-use and land-cover classification mapping, represent a multiple related sample case for statistical inference. The purpose of statistical analysis of these data is to determine whether or not a significant difference exists between the ability of an interpreter to classify various categories at each scale, as determined by area measurement. The area data are given in Table 1 by category code for each of the three scales. The data analysis developed by Fitzpatrick-Lins is based on the absolute values of the differences in area measurements between each pair of scales, by category code.

The area difference values, and the percent of area difference value to total area, based on a total area in each case of 76,000 hectares, are summarized below as

Scales of Comparison	Area Difference* Value	Percentage of area Difference values
1:24,000 − 1:100,000	3,468	4.56
1:100,000 − 1:250,000	2,766	3.64
1:24,000 − 1:250,000	4,122	5.42

* Computed in the manner: $\sum|A_{ij} - A_{ik}|/2$, where A_{ij} = area for category i for scale j, and A_{ik} = area for category i for scale k.

It is noted that the largest differences and percent differences are between the scales of 1:24,000 to 1:250,000; and the smallest differences are between the scales of 1:100,000 to 1:250,000. Thus, it can be concluded from this test that the closest agreements in interpretation are between the scales of 1:24,000 to 1:100,000 and 1:100,000 to 1:250,000; while the largest difference in interpretation is between the scales of 1:24,000 and 1:250,000 as determined by area. The unanswered

TABLE 2. RANKS OF THE LAND AREAS SHOWN IN THE COLUMNS OF TABLE 1 (TRANSPOSED)

Category	Area Rank in Each Scale*			Sum of Ranks in each category j
	1:24,000	1:100,000	1:250,000	R_j
11	19	19	19	57
12	14	15	14	43
13	7	4.5	4.5	16
14	6	10	4.5	20.5
15	12	11	13	36
16	16	16	16	48
17	8	4.5	4.5	17
18	1.5	3	4.5	9
19	15	12	15	42
21	21	21	21	63
22	4.5	13.5	4.5	22.5
24	10	6.5	4.5	21
41	22	22	22	66
42	17	17	17	51
51	13	13.5	11	37.5
52	1.5	9	4.5	15
53	11	6.5	12	29.5
54	20	20	20	60
61	18	18	18	54
72	3	1.5	4.5	9
74	4.5	1.5	4.5	10.5
75	9	8	10	27

R_j represents the rank sum for each column.
* rank 1 = smallest, rank 22 = largest, midrank value for ties.

question in this analysis is: Are the differences in interpretation between the three scales of mapping statistically significant, as determined by area—and, hence, must cost/precision trade-offs be made in the choice of scale, or could these differences arise from chance alone?

Kendall's coefficient of concordance test. Kendall's coefficient of concordance test (Gibbons, 1976, pp. 301-310) is a nonparametric statistical test which will measure the association between variables for multiple related samples to determine their independence. The Fitzpatrick-Lins data consist of the area measurements for all 22 interpreted categories from each of the three scales of mapping. The comparisons are to be made on rankings made separately on the 22 categories for each scale. These ranks are recorded as rows in Table 2, together with the column sums R_j. (Note that the rows and columns are transposed.) Thus, a matrix is formed with $k = 3$ sets of rankings as rows, and $n = 22$ columns.

The computed value of Kendall's coefficient of concordance, W, will lie within the range $0 < W < 1$, with the value 1 indicating perfect agreement, and 0 for no agreement. Kendall's coefficient is computed by

$$W = 12 \sum_{j=1}^{n} \left[R_j - \frac{k(n+1)}{2} \right]^2 / k^2 n(n^2 - 1)$$

where R_j is the rank sum for each column.

If the number of ties within the sets of rankings is extensive, the denominator in the equation for W is replaced by

$$k^2 n(n^2 - 1) - k(\sum t^3 - \sum t)^*$$

"where t is the number of observations tied at any rank in any set of rankings, and the summation is over all sets of t tied ranks and all k sets of rankings" (Gibbons, 1976, p. 305).

The Kendall coefficient may be given probabilistic values using the Q statistic from Friedman's test (Gibbons, 1976, p. 310-317), computed by

$$Q = k(n - 1)W.$$

The null hypothesis for this test is that there is no association or relationship among the three scales for classifying land-use and land-cover categories as determined by area. The alternate hypothesis is that association exists. The statistic Q has a chi-square distribution.

* For example: in Table 2 at 1:24,000 scale there are two values tied at 1.5, and two values tied at 4.5; at 1:100,000 scale there are two values tied at 1.5, two values tied at 4.5, two values tied at 6.5, and two values tied at 13.5; at 1:250,000 scale there are nine values tied at 4.5. Thus, t_i = 2,2,2,2,2,2,9; and $\sum t = 21$. t_i^3 = 8,8,8,8,8,8,729; and $\sum t^3 = 777$.

The values for W and Q have been calculated with the accommodation for ties:

$$W = 0.957$$
$$Q = 60.29.$$

The Q statistic is compared to a critical value of the chi-square distribution with $n - 1$ degrees of freedom, or 21 degrees of freedom in this case. From tables of the chi-square distribution, the right-tail probability is found to be smaller than 0.001 (less than the α value of 0.05), and the null hypothesis is rejected. The conclusion is that there *is* association among the category classifications of the three scales, as determined by area. This result is compatible with the high relative measure of agreement indicated by Kendall's coefficient, W; i.e., they "agree" well.

Since the test for association has been met, it is appropriate to investigate the "sameness" of these data sets. The next test will determine this, measuring "sameness" in terms of median values.

Friedman's method of ranks test. Friedman's method of ranks test (Gibbons, 1976, pp. 310-317), also called Friedman's chi-square test, is a non-parametric statistical procedure which will test the equality of the median values for multiple related samples. The methodology of Friedman's test is identical to that of Kendall's coefficient of concordance test, but the inference concerns "homogeneity of ranked objects rather than independence of rankings" (Gibbons, 1976, p. 310). The Fitzpatrick-Lins data here consist of the area measurements for each interpreted category matched as a unit among all three scales of mapping. The comparisons are to be made on rankings made separately on the three scales for each category. These ranks are recorded in Table 3 with $k = 22$ sets of rankings as rows, $n = 3$ columns, and the column sums R_j. This test, when applied to this inference situation and to data obtained in this manner, is known as Friedman's two-way analysis of variance by ranks.

The Friedman's Q statistic is computed by the same formula used in Kendall's coefficient of concordance test. However, for Friedman's test the coefficient W has no meaning by itself whereas it does for Kendall's coefficient of concordance test.

The null hypothesis for this test is that there are no differences in the median values of the three scales for classification into land-use and land-cover categories, as determined by area. The alternate hypothesis is that the median effects of at least two of the classifications differ from each other. This is a one-tailed test employing the chi-square distribution.

The value for Q has been calculated with the accommodation for ties:

$$Q = 8.67.$$

The Q statistic is compared to a critical value of the chi-square distribution with $n - 1 = 2$ degrees of freedom. The right-tail probability is found to be smaller than 0.02 (less than the α value of 0.05) and the null hypothesis is rejected. The conclusion is that at least two of the median values of the area measurements for the three scales differ from each other, as determined by area. Indeed, inspection of Table 3 suggests that the area rank associated with the 1:250,000 scale is consistently the smallest. It is the smallest in more than the one-third of the categories that would have been expected under the null hypothesis. The multiple comparisons test shown below determines whether this discrepancy could arise from chance alone.

TABLE 3. RANKS OF THE LAND AREAS SHOWN IN THE ROWS OF TABLE 1*

Category	1:24,000	1:100,000	1:250,000
11	2	1	3
12	2	3	1
13	2	3	1
14	2	3	1
15	3	1	2
16	2	3	1
17	3	2	1
18	1.5	3	1.5
19	3	2	1
21	1	2	3
22	2	3	1
24	3	2	1
41	3	2	1
42	1	3	2
51	2	3	1
52	1.5	3	1.5
53	3	1	2
54	3	2	1
61	2	1	3
72	3	1.5	1.5
74	3	1.5	1.5
75	2	3	1
R_j	50	49	33

R_j represents the rank sum for each column.
* Rank 1 = smallest, rank 3 = largest, midrank value for ties.

Multiple comparisons test. A multiple comparisons test for k related samples is given by Gibbons (1976, pp. 313-317) for use if the differences among the median values from the Friedman's test are significant, and it is desired to know which values differ significantly from which others. Given Table 3 of $k = 22$ rows and $n = 3$ columns from Friedman's test, and the column sums, R_j, the test statistic for the absolute value of the differences in the column sums is based on the equation:

$$|R_i - R_j| \leq Z \sqrt{\left[\frac{kn(n+1)}{6} \right]},$$

where Z is the standard normal deviate.

For multiple comparisons tests, it is common practice to use a higher level of significance, e.g., $\alpha = 0.20$ (Gibbons, 1976, pp. 182, 316). Then Z = 1.843, and the test statistic for comparison is 12.165. The three differences in rank sums R_j are

$$R_{50} - R_{49} = 1$$
$$R_{49} - R_{33} = 16\dagger$$
$$R_{50} - R_{33} = 17\dagger$$

The results of the multiple comparisons test are represented by

$$\underline{50 \quad 49} \quad 33,$$

indicating that the rank sums 50 and 49 are not significantly different from each other, and both are significantly different from 33.

The conclusion is that the differences among median values of the area measurements from 1:24,000 and 1:100,000 scales could have arisen by chance, while both differ significantly from the median value of the area measurements for the 1:250,000 scale.

Results. The result of Kendall's coefficient of concordance test is that there is association between the area data from the three scales. That is, that the general trend of category classification as indicated by area measurements is the same for the three scales of mapping. However, Friedman's method of ranks test indicates that the trend curves are not all coincident with each other at their medians. Specifically, the category classifications interpreted for the 1:24,000- and 1:100,000-scale mapping were not significantly different from each other, while they were both different from those interpreted for the 1:250,000-scale mapping as determined by area. Thus, though the pattern of land-use and land-cover category classification at a scale of 1:250,000 is broadly similar to those of the other two scales, as determined by area measurement, details such as boundary determination, minimum mapping size, etc., are lost in the generalization due to smallness of scale. Therefore, the final conclusion is that land-use and land-cover classification at 1:250,000 scale results in significantly smaller areas for more of the categories than the other two scales (1:24,000 and 1:100,000), as determined by area measurement.

The above two tests have been used to illustrate the analysis for a multiple related sample case. Although these same two tests can also be used for only two samples, more simplified tests are available. The following is an example illustrating the two tests for the paired sample case.

PAIRED SAMPLE ANALYSIS

Previous analysis of data. The area data acquired by Lins (1976, p. 306) by category, from two sources of aerial photographs for land-use and land-cover classification mapping, represent a paired sample case for statistical analysis. The purpose of statistical analysis of these data is to determine whether or not a significant difference exists between the ability of an interpreter to classify various categories from each source as determined by area measurement.

† represents a significant difference.

TABLE 4. AREA DATA, IN HECTARES,[1] FOR LEVEL III LAND USE AND LAND COVER CATEGORIES FOR TWO SOURCES OF PHOTOGRAPHS

Category	U-2	Skylab
111	780.4	657.3
112	32.2	26.4
120	7.4	0.0
121	3.4	0.0
122	166.3	166.4
123	3.6	1.4
124	0.8	0.0
125	60.7	99.8
127	2.8	1.9
129	5.1	1.1
136	32.1	23.7
141	6.9	7.2
146	0.0	4.8
150	12.1	4.5
171	54.4	39.6
172	128.2	152.9
411	215.2	339.5
412	5.6	0.0
431	16.2	0.0
760	20.6	27.5
Total	1,554	1,554

[1] Lins (1976, p. 306)

The area data are given in Table 4 by category code for both the U-2 and Skylab aerial photographs. The Lins data analysis concerns only the apparent discrepancy between certain pairs of data and states either a relative discrepancy or similarity.

The Kendall tau statistic test. The Kendall tau statistic (Gibbons, 1976, pp. 284-300) is a nonparametric statistic which measures the association between two related samples. The Lins data here consist of the area measurements for all 20 interpreted categories from each of the two sources of aerial photographs. The comparisons are to be made on rankings made separately on the 20 categories for each source. These ranks are recorded as rows in Table 5. (Note that the rows and columns are transposed.) Thus, a matrix is formed with $n = 20$ sets of data.

The computed value of the τ statistic will lie within the range $-1 \leq \tau \leq 1$, with the value 0 for no association, +1 for direct association, and −1 for inverse association. The Kendall tau statistic is computed by

$$\tau = 2S/n(n - 1)$$

TABLE 5. RANKS FOR KENDALL TAU STATISTIC TEST FROM THE AREAS SHOWN IN COLUMNS OF TABLE 4 (TRANSPOSED)

Category	U-2	Skylab	U*	V*
146	1	10	10	9
124	2	3	14	0
127	3	8	11	6
121	4	3	13	0
123	5	7	11	4
129	6	6	11	3
412	7	3	11	0
141	8	11	9	3
120	9	3	10	0
150	10	9	9	1
431	11	3	9	0
760	12	14	6	2
136	13	12	7	0
112	14	13	6	0
171	15	15	5	0
125	16	16	4	0
172	17	17	3	0
122	18	18	2	0
411	19	19	1	0
111	20	20	0	0
			$\sum = 152$	$\sum = 28$

* Values of U and V for use in illustration of method.

where S is computed per Gibbons (1976, pp. 286-287): i.e.,

$$S = U - V$$

U is the sum of the numbers of ranks that are greater than and to the right of each successive rank,‡ and V is the total number of ranks that are smaller than and to the right of each successive rank,‡ except that a score of zero is given when a tie occurs in either set of the pair.

If there are many ties, Gibbons (1976, pp. 288-290) suggests using the equation

$$\tau = \frac{S}{\sqrt{\binom{n}{2} - u'}\sqrt{\binom{n}{2} - v'}}$$

"where $u' = \sum(u/2)$ for u the number of observations in the X sample that are tied at a given rank and the sum is over all sets of u tied ranks, and similarly $v' = \sum(v/2)$ for the sets of v tied ranks in the Y sample."

$\binom{n}{2}$ is the combination equation: $\frac{n!}{2!(n-2)!}$

‡ The sum of the numbers of ranks that are greater than and to the right of 10 for Skylab is 10, for 3 is 14, . . ., etc. The total numbers of ranks that are smaller than and to the right of 10 for Skylab is 9, for 3 is 0, . . ., etc. (see Table 5 for values of U and V). Since Table 5 is transposed, to the right means beneath.

The null hypothesis for this test is that there is no association or relationship between the two sources of aerial photographs for classifying land-use and land-cover categories as determined by area. Since the purpose of the test concerns only agreement between the areas for the categories, the alternate hypothesis is that there is direct (+) association between the sets of rankings. This is a one-tailed test.

Because there are ranking ties for zero area using the Skylab aerial photographs, the τ value was computed with the equation for ties (Gibbons, 1976, p. 288). The computed value is

$$\tau = 0.671 \text{ with } n = 20.$$

The probability value of τ is computed from Gibbons (1976, Table J, p. 420) (cumulative probability for the Kendall tau statistic). The right-tail probability is found to be smaller than 0.005 (less than the α value of 0.05), and the hypothesis is rejected. The conclusion is that there is direct association between the category classifications from the two sources of aerial photographs, as determined by areas. As before, because the test for association has been met, it is also appropriate to measure the "sameness" of the median values among the data sets. The next test will determine this.

The Wilcoxon signed rank test. The Wilcoxon signed rank test (Gibbons, 1976, pp. 123-141) is a nonparametric statistical test which will test the median value of the differences between paired samples. The observations arise from two nonindependent samples, i.e., the same category areas being interpreted from the two sources of aerial photographs.

The Lins data also consist of the area measurements for all $n = 20$ interpreted categories from each of the two sources of aerial photographs. The test is to be made on rankings made from the differences between the areas of each category for the two sources. These differences and their ranks are recorded in Table 6. The sign of the differences is given as the sign of the ranks.

The Wilcoxon signed rank test statistic is defined as either $T+$, the sum of the positive ranks, or $T-$, the sum of the negative ranks. For values of n from 2 to 15, Gibbons' (1976, p. 406) Table G gives the right-tail probabilities for $T+$ or $T-$. The probability value for the two-sided alternative is twice the right-tailed probability for the larger of $T+$ or $T-$. Gibbons (1976, p. 126) gives the method and equations for computing the asymptotic approximate P-values for $n > 15$. These equations follow the normal approximation for right-tail probabilities and include the correction for continuity: i.e.,

$$Z_{+,R} = \frac{T+ - 0.5 - n(n+1)/4}{\sqrt{[n(n+1)(2n+1)/24]}},$$

$$Z_{-,R} = \frac{T- - 0.5 - n(n + 1)/4}{\sqrt{[n(n + 1)(2n + 1)/24]}},$$

where Z is the standard normal deviate. The recommended procedure for accomodating zeros and ties is also given by Gibbons (1976, pp. 127-128).

The null hypothesis for this test is that there is no difference between the median values of the two sources of aerial photographs for classification into land-use and land-cover categories, as determined by area. The alternate hypothesis is that the median values of the two classifications differ from each other. This is a two-tailed test.

There are no zeros or ties, and the values for the ranks are

$$T+ = 133, T- = 77.$$

Since $n = 20$, the value of $Z+$ computed as per Gibbons (1976, p. 126) is 1.027. The probability value is computed from Gibbons (1976, Table A, p. 385—cumulative probability for the normal distribution) as twice the right tail probability for the larger of $Z+$ and $Z-$, as $P > 2\ (0.1515) > 0.303$ (greater than a value of 0.05), and there is no basis to reject the null hypothesis. The conclusion is that the observed differences between the median area measurements for the two sources of aerial photographs could have arisen by chance.

Results. The result of the Kendall tau statistic test is that there is direct association between the area data from the two photographic sources. That is, that the general trend of category classification as indicated by area measurements is the same for both photographic sources. The results of the Wilcoxon signed rank test indicates that the trend curves are coincident with each other at the medians. Therefore, the final conclusion is that both sources of aerial photographs generally lead to the same land-use and land-cover category classification, as determined by area measurement.

TABLE 6. DIFFERENCES FOR THE AREAS, IN HECTARES, SHOWN IN TABLE 4 AND RANKS OF THE DIFFERENCES FOR WILCOXON SIGNED RANK TEST

Category	Δ	Rank
122	−0.1	−1
141	−0.3	−2
124	0.8	3
127	0.9	4
123	2.2	5
121	3.4	6
129	4.0	7
146	−4.8	−8
412	5.6	9
112	5.8	10
760	−6.9	−11
120	7.4	12
150	7.6	13
136	8.4	14
171	14.8	15
431	16.2	16
172	−24.7	−17
125	−39.1	−18
111	123.1	19
411	−124.3	−20

Δ represents the differences in area.

DISCUSSION

It is evident that nonparametric statistical tests allow certain probability statements to be made about the results of these experiments. For the Fitzpatrick-Lins study: the probability is less than 0.001 that there is independence between the category classifications of the three scales, as determined by area; and the probability is less than 0.02 that the median values are equal for the category classifications of the three scales, as determined by area. This means that the area data are comparable in trend but not coincident in value, with accepted statistical significance, say at the 0.05 level. It is also evident, from the multiple comparisons test, that it is the 1:250,000-scale data which are different from the data of the other two scales.

For the Lins study: the probability is less than 0.005 that there is independence between the category classifications of the two sources of aerial photographs, as determined by area; and the probability is greater than 0.303 that the observed differences between the median values could be due to chance alone for the category classifications of the two sources of aerial photographs, as determined by area. This means that the area data are comparable in trend and reasonably coincident in value, with specified statistical significance.

The major purpose of this report has been to demonstrate the use of some nonparametric methods of statistical inference for comparing area data from thematic classification.

CONCLUSIONS

- In this one example, the generalization for Level II land-use and land-cover classification at 1:250,000 scale leads to significantly different results than does the land-use and land-cover classification at the larger scales of 1:24,000 and 1:100,000, as determined by area. This difference is indicated by the larger number of categories with area values smaller than would have been expected by chance alone. Accordingly, if 1:250,000-scale imagery is to be used for Level II land-use and land-cover mapping, it must be realized that the area delineated for most categories will tend to be underestimated, as determined by area measurement from this single experiment.
- In this one example, there is no significant difference in Level III land-use and land-cover clas-

sification between high-altitude U-2 and Skylab aerial photographs, when both are brought to the same scale of 1:24,000, as determined by area. Therefore, the Skylab S-190B aerial photography, when available, can be used for Level III land-use and land-cover classification with equivalent results as with U2-RC10 high-altitude aerial photographs when enlarged to a scale of 1:24,000, as determined by area measurement from this single experiment.

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The flight department is equipped with a dual-camera, turbo charged, Cessna 310; a turbo charged Cessna 206; Wild RC10 and RC8 cameras; as well as several specialized cameras of varying focal lengths and formats.

First class equipment is necessary, but we believe the greatness of a company comes from the greatness of the people within.

Our chief pilot, Mike Chatterton, with us since our inception, is an excellent example. He and his crew are among the best in the industry, consistantly providing our customers with photography of the highest quality.

Maintaining the excellence of the flight department is an alert, progressive, and enthusiastic team of lab technicians.

In our modern 7,000 square foot photo lab you will find well-known names such as Millington, Durst, Saltzman, Zeiss, LogEtronic, Houston Feerless, Richards, DuPont, and Kodak. Most notable are the Kodak Color and Black-and-White Versamat aerial film processors. Color and black-and-white aerial film processing is a fast-growing part of I. K. Curtis Services, Inc.

The good reputation of our photo lab is well established and provides services for many customers other than our own flight department.

We understand the needs and requirements of aerial photographers as only aerial photographers can.

Close proximity to Hollywood/Burbank Airport and Los Angeles International makes shipping fast and convenient from virtually anywhere in the world.

Remember the name, I. K. Curtis Services, Inc., near beautiful downtown Burbank. For more information call (213) 842-5127. Ask for Ivan Curtis, Joan Curtis, or Mike Chatterton.

Great Basin Aerial Surveys

956 Industrial Way, Sparks, NV 89431; (702) 359-7242

GREAT BASIN AERIAL SURVEYS is located in the rain shadow of the Sierra Nevada where aircraft mobilization to California, Idaho, Utah, Arizona and Nevada is an all-year possibility. The firm maintains a turbocharged aircraft and a Wild RC-10 camera. Complete photo lab services are available with Versamat processing, LogE printing, and Robertson copy camera services.

Photogrammetric mapping capabilities are built around the firm's Wild B-8S stereoplotters, which are

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