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REFLECTANCE OF VEGETATION, SOIL, AND WATER

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16. Abstract

    One set of aircraft support data was received late in this reporting period. CCT from ERTS-1 have not yet been received because the test county has been clouded over until the Dec. 16, 1972, overflight. The ground truth obtained contains much useful information; it consists of several interpenetrating samples representing about 4% of the land area in the county.

    One question dealt with in detail in this report is that of selecting the best channels from the 24-channel aircraft data to represent crop and soil conditions. A three-step procedure has been developed. It involves using univariate statistics and an F-ratio test to indicate the best 14 channels. From the 14, the 10 best channels are selected by a multivariate stocastic process. The third step involves the pattern recognition procedures described in our data analysis plan.

    Indications are that the procedures in use are satisfactory and will extract the desired information from the data.

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INTRODUCTION

The work planned under this contract had three stated objectives. These objectives were:

1. To compare experimental results using ERTS-1 data with predictions of analytical models for interaction of light with vegetation.

2. To determine the seasonal changes of the various crops and soils in Hidalgo County, Texas and discriminate them by means of reflectance measured from ERTS-1.

3. To gain experience developing an operational system of satellite data analysis tailored to the needs of the U.S. Department of Agriculture.

These objectives can be logically grouped into substudies in the following categories:

1. Crop vigor and potential crop yield
   a. Relation to leaf area index (LAI)
   b. Iron deficiency detection
   c. Crop vigor categories within crops and their relation to yield

2. Crop discrimination
   a. Cotton versus sorghum
   b. Among vegetables
   c. Optimum time of year to discriminate citrus
   d. Dominant rangeland plants
   e. Rangeland condition

3. Soil
   a. Bare versus cropped land
   b. Major soil types
   c. Spectral contrast between freshly irrigated and nonirrigated soil
   d. Spectrum of saline soil and distribution of salt-affected soil.

A three-phase scientific approach was adopted in this project. The first phase consisted of a theoretical investigation into the interaction of light with a plant canopy. The second phase involved correlation of these theoretical results with measurements on a plant canopy obtained from aircraft. The third and final phase is implementation of an operational system based on ERTS-1 data to monitor crops for vigor and maturity.

The first phase, performed in the laboratory, established that reflectance of a typical leaf can be simulated by a model specified by two geometrical and two optical parameters. The geometrical parameters specify the amount of water and intercellular air that exists in a leaf. One optical parameter is the mean index of refraction of the external and internal surfaces of the leaf. The other optical parameter is the leaf absorption coefficient. Typically, the absorption coefficient of a leaf is a superposition of chlorophyll and water effects. The optical parameters are functions of wavelength, while the geometrical parameters consist of two numbers. The theory has been developed to predict reflectance of a plant canopy superimposed upon a soil background of known reflectance if the optical and geometrical properties of a single leaf are known and if the LAI of the canopy has been determined. The first phase is now virtually complete. The results of phase one already have led to application of derived theoretical results to field conditions.

The second phase of research was based on utilization of multi-spectral scanner imagery obtained from aircraft and upon determination of corresponding ground truth for various fields selected as training samples randomly located throughout the test area. This second phase entailed considerable effort in the area of ground truth collection. Phase 2 was a feasibility and simulation period preparatory to the utilization of ERTS data.

Ground observations continued and medium altitude multispectral scanner aircraft (NASA C130) and high altitude aircraft (RB 57F) overflights of the study area were obtained in advance of the ERTS-A launch. These were used to establish spectral signatures of crop and soil conditions of interest and to develop data handling experience and analysis procedures capability by the time ERTS-A was launched.

The aircraft phase and the satellite phase are not mutually exclusive but will be complimentary. The mechanics of phase 2 have already been utilized in past, present, and planned work that deals with discrimination between different crops based upon computer identification procedures. These identification procedures developed with the use of aircraft imagery, will be refined and applied to ERTS-1 data.

DATA COLLECTION

Hidalgo County, Texas has been chosen as the base area from which data are collected and analyzed. The complete county was chosen as the base unit because this is the governmental unit by which agricultural census data are collected and summarized, and is the unit by which crop allotment and acreage restrictions are most commonly administered.

Although Hidalgo County is not a rectangle the whole county can be contained in an area 49 nautical (56 statute) miles by 47 nautical (54 statute) miles. Collecting complete ground truth data, or analyzing all ERTS-1 data from an area this large is beyond the scope of the contract and beyond the ability of USDA resources at Weslaco. Statisticians of the Statistical Reporting Service, USDA, were asked to develop a sound sampling program which would allow a valid summary of data for the county from a sample of the county. Hidalgo County contains three major agricultural areas which may be designated as Northern, Central, and Southern. The Northern region is mainly pasture and rangeland with a little irrigated farming located around local water supplies. The central region is practically all under irrigation. The cultivated land is generally

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broken into small fields, of typically medium-textured terrace soils devoted to mixed field and vegetable row-crops, citrus, and miscellaneous farm enterprises. The southern region of Hidalgo County is generally fine-textured soil that is used extensively for winter vegetable production. The majority of land in the southern region is irrigated. Urban and other non-agricultural areas are found mainly in the central region. The urban areas are not included in the survey.

The sampling procedure used was to divide the county into approximately 160-acre segments and assign each segment a number. By the random start and increment method, four interpenetrating samples of 43 segments each were selected. These were distributed through all three regions. Four more interpenetrating samples were selected, but only the segments located in the southern region were designated as sampling sites. These 25 additional segments in the southern region were chosen because of the concentration of winter vegetables in the southern region when few crops are growing in the other regions. A total of 197 sampling segments were chosen from the 3,927 segments listed for the county. The sampling area is thus approximately 4% of the total area.

Each of the 197 segments were located on a base aerial map of the county and assigned a unique number designation. Each field in each segment is being ground-truthed so a reliable data base will be available for the analyses required of ERTS-1 data. Continuous ground truth is required because it takes the ground truth team approximately 10 working days to visit each field. Major changes in ground cover and conditions can occur in 10 days if the visits were made only after it was apparent the sky was clear at the time of any ERTS pass.

The huge amount of ground truth data necessary for the successful completion of this study, made it mandatory that data be stored, edited and retrieved automatically. All crops, soils and the various descriptive parameters needed to characterize field appearances have been coded. Also, computer card formats have been devised for entry of all data into a computer for editing, and storage on magnetic tape. About 60 different parameters had to be coded. Considerable effort was made to code parameters in such a way that they are easily remembered and read.

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Before actual field visits could be made the sample segments had
to be transferred from the 1:90,000 scale mosaic produced from RB 57F
photography, to 1:40,000 scale field sheets of the RB 57F imagery
purchased from the ASCS Western Aerial Photography Laboratory at Salt
Lake City. This was done to facilitate ease and accuracy of sample
segment location in the landscape. Also, during this time period
1:120,000 scale aerial photography was used to make 1:2,000 scale prints
of each sample segment.

The ground truth personnel, using the 1:40,000 scale mosaics,
located each sample segment and outlined the segment on the 1:2,000
scale prints. Each field in every segment was given a number.

Each time the satellite is due to pass over the test county, each
field is visited for ground truth purposes. The percent crop cover,
percent weed cover, crop maturity, plant height, plant condition, soil
surface condition, plant nutrient deficiency, irrigation and date of
irrigation, and other information as well as the date of the visit are
recorded for each field. During this reporting period each segment
has been visited on 6 different occasions. Fields are, by definition,
plots of land devoted to the same crop or use. The number of fields
fluctuates slightly. The total number of fields being ground-truthed
each satellite pass is approximately 1,300.

After each sample segment has been visited, the field information
is coded by the technician in charge of ground-truthing and recorded
on 80-column computer punch cards. The data on the computer cards is
later edited and stored on magnetic tape for use in the analysis of
the satellite data. A print-out of these tapes is given to the ground
truth personnel. The magnetic tapes and computer cards are stored in
separate buildings to minimize the chances of data loss.

The farmable acreages for some fields were obtained from the county
Agricultural Conservation and Stabilization Service office. However,
the main thrust in this area will be made in the next reporting period.
These actual acreages of fields are needed to provide the acreages
involved in the statistical estimates, since total acreage devoted to a
given crop is more meaningful than the number of fields. These data
will also be used for determining the distribution of field sizes in
the county and for comparing the acreage of given classification cate-
gories in the training sample by computer and by direct observation.

Each set of ground truth information recorded on tape is processed
by three specially written programs. Program SEPRT compares up to 8
files of ground truth information for each segment, field, and sector
listed. In those cases where the land use code is not identical in each
file, the program prints the segment, field, and sector number along
with the land use code and name for each period being compared. This
gives a current listing of land use changes and allows checking for
unreasonable or illogical changes in land use. Illogical changes
suggest possible errors in coding of land use in one or more ground
truth records.

The number of areas and number of sets of data compared in each
pass through the program are limited by the memory capacity of our CPU.
At present, the program is limited to 1,050 areas from three sets of
ground truth or to 750 areas from four sets. When the faster 2311 disc
units are installed, it will be possible to expand the number of areas
and sets that can be included in a single pass through the program.

Program COMB2 combines the ground truth data for a single orbit
with the acreage values. The output of this program is a summary of
all the land use codes included in the data file. The number of fields,
the average crop cover, the average weed cover, and the average height
of principal crop along with the number of fields for which acreage
figures are available, the total acres, and the average field size are
listed for each land use code present.

Program CROP lists all fields for which acreage figures are not included on the acreage tape. The segment, field, and sector numbers have to match exactly to avoid being listed by this program. CROP thus lists those fields which are counted in COMB2 but are not included in the acreage summary. Also listed are fields which have been divided, or combined, differently than when the acreage figures were last updated.

The procedures described above play a very significant role in the total effort on this contract. They enable checks on the manually acquired ground truth for consistency, accuracy, and completeness and they present the ground truth in a form that can be readily used in conjunction with the digital magnetic tapes of ERTS-1 data--for training field selection and for checking the accuracy of the classification assigned these fields by the pattern recognition algorithms.

Considerable information of agricultural importance can be extracted from these ground truth data; however, the main reason for collecting such a complete set of records is to have a base to compare the reliability and accuracy of interpretation of ERTS-1 data. No digital data from ERTS-1 was received at Weslaco during the period covered by this report, primarily because there was a cloud cover over most of Hidalgo County at each ERTS-1 pass until the December 16, 1972 pass.

Early in the consideration of this project it was realized that a means of displaying the CCT of ERTS-1 data in a visible form would be necessary to select the data from the fields for which the ground truth data were available, and to select training sites necessary for crop discrimination. A DICOMED Model 36 Digital Display unit was purchased and interfaced with our IBM 1800 computer. The Dicomed display is basically a storage CRT tube capable of receiving and displaying 64 levels of density on 2,048 points in 2,048 lines within a seven inch square viewing area on the face of the tube.

A System of Digital Image Display Subroutines (SODIDS) computer programs has been developed during this reporting period and is operational on sample ERTS data. The subroutines provide a tool for interaction among user, digital image display, and computer. Their use and function have been described in an in-house report.[1]

The following programs have been developed at Weslaco for image processing:

a. Program ERTS-1 - Rapidly displays any ERTS-1 MSS Channel (1-4) from any of the ERTS-1 CCT and overlays a grid that is referenced to the MSS data on the ERTS-1 CCT. (Automatic)

b. Program Quadrilateral - Displays a quadrilateral determined from coordinates taken from grid system of Prog ERTS-1 so that operator can see accuracy of area definition and make further coordinate adjustments if necessary. (Man-Machine interaction)

c. Program Select - Uses quadrilaterals to read data from ERTS-1 CCT of quadrilateral defined areas and records only these areas on a secondary tape for further processing. (Automatic)

d. Program Statistics - Prints out selected area on printer (uses secondary tape) and calculates the following basic statistics for each area and channel: mean, standard deviation, maximum, minimum, range, and distribution. (Automatic)

e. Program Preprocess 1 - Combines ERTS-1 channels according to a predefined algorithm and displays the combination. A different subroutine is used to implement any one of the following transformations: addition of channels, ratioing of channels, principal axis transformations, and other. (Automatic)

f. Program Preprocess 2 - Corrects ERTS-1 data for variations due to scan angle or scene illumination. (Automatic)

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[1] R. J. Torline. System of Digital Image Display Subroutines (SODIDS). 22 p. plus appendices. August 1972. USDA, Weslaco.

The following pattern recognition programs have been developed and tested at Weslaco:

a. Program Reformat - Reformats ERTS-1 data in all channels on secondary tape and records on temporary disk file for use with pattern recognition programs. (Automatic)

b. Factor Analysis - Reads data from temporary file and calculates principal axis factor weights that optimally represent most of the variation in the ERTS-1 data. (Automatic)

c. Factor Plot - Generates a scatter plot of the first two principal axes for study of the category data structure. (Automatic)

d. Pattern Recognition - Calculates category standards (mean vector and covariance matrix) and classifies the ERTS-1 data using the maximum likelihood ratio algorithm. (Automatic)

e. Channel Select - Selects optimum channels for pattern recognition using a step wise channel selection procedure. (Automatic)

f. Basic Statistics - Calculates means, standard deviations, correlation matrix, T-values for every category - channel combination. (Automatic)

RESULTS

Phase 1 - Theoretical investigations:

Results of studies made under the first phase of this study, that of the theoretical investigation into the interaction of light with a plant canopy, have resulted in a manuscript entitled "Willstätter-Stoll Theory of Leaf Reflectance Evaluated by Ray Tracing" by W. A. Allen, H. W. Gausman, and A. J. Richardson of the USDA staff at Weslaco. This manuscript is being submitted to the Journal of Optical Society of America for publication. The abstract of this paper follows:

The widely accepted Willstätter-Stoll (W-S) theory of leaf reflectance has been investigated by extensive ray tracing through a model (W-S model) in which the leaf cellular structure is approximated by circular arcs. Calculations were performed on an IBM 1800 computer. The W-S model is treated as a two-dimensional uncentered optical system consisting of a single medium and air. Optical properties of the medium are specified by a complex index of refraction. Given an incident ray, new reflected and transmitted rays are produced at each interface with properties determined by the laws of Snell, Fresnel, and Lambert. Calculations indicate that the W-S model, as exemplified by their artist's conception is too transparent; that is, the magnitude predicted for transmittance is too high. Transmittance is still too high if each interface is treated as a diffusive instead of a smooth surface. The W-S model can be easily improved, however, by introduction of more intercellular air spaces. The modified W-S model promises to be an excellent representation of physical reality. Accurate predictions, however, require an inordinate amount of computer time.

Phase 2 - Aircraft support data:

Work under the second phase of this study, that involving correlation of these theoretical results with measurements of a plant canopy obtained from aircraft, is continuing. The aircraft data involved are from the Bendix 24-channel scanner flown on Mission 207 on July 26, 1972. Digital tapes (25) were received December 6, 1972.

Procedures for selecting optimal channels for discrimination among crops and soils have been compared as to accuracy and computer time required. The aircraft data are broken into more bands and cover longer wavelengths than do the ERTS-1 data, but by selecting bands results similar to those expected from ERTS-1 can be obtained. (The details on the procedures developed are included in an Appendix.)

PROGRAM FOR NEXT PERIOD

Weslaco has a working arrangement with another USDA organization at Chickasha, Oklahoma whereby Weslaco furnishes the computer and certain programming and operating assistance for analysis of ERTS-1 data from the watershed area in Oklahoma. The watershed area has been cloud-free on at least two ERTS-1 passes and CCT data were received from the first of these passes on December 18. The staff at Weslaco, assisted by Chickasha personnel, will work with the CCT to gain experience working with actual ERTS-1 data. The programs and procedures will be adapted as necessary to extract the desired data from the CCT.

Because the Hidalgo County, Texas area was essentially cloud-free for the December 16, 1972 ERTS-1 pass, it is expected that data from the test area of this contract will be received for analysis during the next reporting period.

Ground-truthing will continue. Existing ground truth will be summarized up to date, checked for errors, and be stored in the computer for use in conjunction with analysis of the CCT from the December 16, 1972 ERTS-1 pass.

Work will also continue on determining the size, in acres, of each field in the sample frame. The acreage of the vegetable crops cabbage, carrots, and onions in the county will be calculated from the statistical estimating equations, so that these estimates will be available for comparison with the acreage estimates of the Crops and Livestock Reporting Service. The information for the latter estimates are determined by post card survey.

The leaf area index field determinations needed for objective 1 will be planned more thoroughly and candidate fields of corn from the sample segment will be identified. (Corn is the only major crop that will be far enough along in growth to merit field determination of leaf area index the next reporting period.)

CONCLUSIONS

Results to date indicate that the procedures and programs set up to handle ERTS-1 data are satisfactory and will extract the desired information from these data.

Because no actual CCT containing data from the area for which we have ground truth information are available it is not possible to draw definite conclusions.

RECOMMENDATIONS

None.

APPENDIX

Channel selection from the ERTS aircraft support 24 channel scanner
data.

INTRODUCTION

Using ERTS-1 satellite data only 4 channels need be considered to
find the best combination for pattern recognition investigations. There
are 6 possible pair-wise combinations, 4 possible 3 channel combinations,
and, of course, only 1 four channel combination to consider. This makes
a total of 15 ways the individual channels can be combined (4+6+4+1=15)
counting each channel by itself as a separate combination.

To find the best 2 out of 24 channels for the ERTS aircraft support
data, it is necessary to consider 276 combinations (Table 1) to find the
best 3 out of 24 there are 2168 combinations; and for the best 4 out of 24
there are 10,626 combinations to be considered. It is impractical to
consider this many combinations when a large volume of data is to be
analyzed. Therefore, some other approach to channel selection must be
devised for the ERTS aircraft support data using the 24 channel scanner.

It was decided to use data acquired from the Bendix aircraft mounted scanner in April, May, June and July of 1969 to investigate candidate procedures. These data provide a sample set to develop computer programs that approximate the best 2, 3..., 8 channels out of 8 for pattern recognition investigation. One program previously used for this work determines principal factor scores from the original data channels (Richardson, 1971).[1] This program has several disadvantages. One disadvantage is that computer capacity limits the number of channels that can be considered to 14. Another limitation is that 24 channels would mean inverting a 24X24 matrix, which is difficult to do in single precision mode and computer memory requirements discourage the use of extended precision mode. From an interpretative standpoint, it is sometimes difficult to give physical meaning to the principal factor scores (linear combinations of the original channels) that are determined from the program. These disadvantages made it desirable to devise another method of channel selection when confronted with the 24 channel ERTS aircraft support data.

PROCEDURE

The channel selection procedure that will be used at the USDA in Weslaco for the 24 channel ERTS aircraft support data will have three phases. Data collected in the spring and summer of 1969 using the Bendix 9-channel scanner were used to develop these procedures.

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[1] Richardson, A. J., Torline, R. J., and Allen, W. A. 1971. Computer identification of ground patterns from aerial photographs. Proc. 7th Internatl. Symp. Remote Sens. Environ., Univ. Mich., Ann Arbor. May 17-21, p. 1357-1376.

The first phase (P1) of the procedure will be a cursory look at the data using basic univariate statistics. A computer program has been developed that will calculate the following statistics for each channel and land use studied:

        (1)   Means

        (2)   Standard deviation

        (3)   Correlation matrix

        (4)   Multiple comparison T-test

        (5)   F-Ratio test

The F-Ratio is a test of the hypothesis of no difference among the land use categories for each channel. The channels can be ranked according to their ability to distinguish among the land use categories as measured by the F-Ratio statistics. The best 14 channels can then be judged as the 14 top ranking channels in a univariate sense.

The second phase (P2) uses a multivariate approach to determine the best 10 out of 14 channels. The computer program for this phase determines the average pair-wise probability of misclassifications (Freese, 1964)[2] among the land use category studied for different channel combinations. The program reads the data once and calculates the mean vector and covariant matrix for each land use category. Using this statistical information about each category, it then determines the average pair-wise probability of misclassification among land use categories for all possible pair-wise combinations of 14 channels (91 possible combinations, Table 1). The best 2 channels (lowest average pair-wise probability of misclassification) will be selected from the initial process and saved. Each of the remaining 12 unselected channels will be used in combination with the best 2 channels one at a time (12 trials). The best 3 channels are then selected from this process. The best 4, best 5, and so on can be selected in a manner similar to the best 3. At the end of this phase the best single channel, best two channels, best three channels, and so on can be selected in a multivariate stochastic sense until the best 10 channels have been identified.

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[2]   Freese, Frank, "Linear Regression Methods for Forest Research," U. S. Forest Service Research Paper, 17 Dec 1964.

Table 1. Selected combinations ($_nC_r$) of n channels taken r at a time. Calculations are based on the formula

$$_nC_r = \frac{n!}{n!(n-r)!}$$

taken from Middlemiss,[1] 1952.

Total number of channels (n)	Channels taken r at a time					
	1	2	3	4	5	6
	– – – – – – – – Total number of combinations – – – – – – – –					
1	1	–	–	–	–	–
2	2	1	–	–	–	–
3	3	3	1	–	–	–
4	4	6	4	1	–	–
5	5	10	10	5	1	–
6	6	15	20	15	6	1
7	7	21	35	35	21	7
10	10	45	120	210	252	210
14	14	91	364	1001	2002	3003
20	20	190	1140	4845	15504	38760
24	24	276	2024	10626	42504	134596

[1] Middlemiss, Ross R. "College Algebra," New York, McGraw-Hill Book Co., Inc. 1952.

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The third phase (P3) involves all the pattern recognition programs listed in the data analysis plan submitted by Weslaco. One of these programs is a channel selection process similar to phase two. It determines the actual overall percent correct recognition among the land use categories studied rather than an average pair-wise probability of misclassification. Its obvious disadvantage is the amount of computer time used as it reads through all the data for each channel combination considered (45 pair-wise combinations out of 10 channels).

RESULTS

Table 2 is a comparison of the channel selection process represented by the three phases (P1, P2, and P3) previously described. Channel 9 was not operative for any of the Bendix 4 overflights and does not appear in Table 2. The eight available channels are ranked by discriminating ability as measured by each of the 3 phases for each of the four Bendix overflights. The P1 column ranks the channels by the univariate F-Ratio statistic. The P2 column ranks the channels by the multivariate average probability of misclassification. The P3 column ranks the channels by their actual overall percent correct classification using the maximum likelihood ratio pattern recognition algorithm. There are no figures in the last part of the P3 columns because of difficulty in inverting the covariate matrix for some of the land use categories.

Table 2. Bendix multispectral scanner channel rankings according to methods P1, P2, and P3 for the 1969 April, May, June, and July aircraft overflights.

	Channel Rankings											
April			May			June			July		
P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
1	6	6	5	6	6	5	5	5	1	1	1
8	2	7	6	8	7	2	6	6	2	7	5
2	1	2	3	1	8	8	3	2	7	5	7
7	8	1	8	7	3	7	2	7	8	8	2
5	3	5	4	5	4	3	8	1	3	3	3
3	4	3	2	4	5	4	7	*	5	6	*
4	7	*	1	3	*	6	1	*	4	4	*
6	5	*	7	2	*	1	4	*	6	2	*

* The P3 method could not continue beyond these points because of difficulty inverting some of the land use covariate matrices.

Table 3 shows the actual overall percent correct classification results obtained using the selected channels from Table 2. In April the best single channel, according to the P3 method, is channel 6 which gives a percent overall correct classification result of 48% (Table 3). The best two channels are 6 and 7 which give 69%; the best three channels are 6, 7, and 2 for 70%; channels 6, 7, 2, 1, 5, and 3 yield 86%. Recognition results are better as more channels are added in for any one of the three methods or 4 overflights.

The bottom line of Table 3 gives the average overall percent recognition for each of the three methods. As can be seen the ranking of methods is P3 best; P2 better than P1, and P1 poorest for all 4 overflights. These three approaches have the opposite ranking (P1, P2, and P3) when considering computer run time.

CONCLUSIONS

On the basis of these evaluations it was decided that the P1 method could be used as a first look at the ERTS aircraft 24 channel scanner data. The best 14 out of 24 channels can be selected using the F-Ratios determined by the P1 method using relatively little computer time. Computer limitations when using method P2 determined that 14 channels be selected from the 24. The best 10 out of 14 channels can then be determined using method P2 and an acceptable amount of computer time. It then becomes reasonable, from the standpoint of computer time, to use method P3 to select the best 4 out of 10 or 8 channels. These last 4 channels can then be used for further pattern recognition investigations.

Table 3. Overall percent classification result using the channel rankings
determined from Table 2 for each method (P1, P2, and P3) for the
1969 April, May, June, and July aircraft overflights.

- - - - - - - - - - - Overall percent classification - - - - - - - - - - -

April			May			June			July		
P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
45	48	48	52	54	54	51	51	51	70	70	70
66	58	69	59	66	66	67	71	71	75	84	89
66	73	70	63	75	73	76	80	87	91	96	97
73	76	80	72	79	83	91	87	96	91	96	98
79	78	83	80	80	89	*	100	100	91	98	98
*	83	86	85	86	96	*	*	*	98	*	*
*	*	*	90	92	*	*	*	*	*	*	*
*	*	*	*	*	*	*	*	*	*	*	*

- - - - - - - - - Average Percent Correct Classification - - - - - - - - -

| 65 | 69 | 73 | 72 | 76 | 77 | 71 | 78 | 81 | 86 | 89 | 91 |

* It was not possible to determine the overall percent classification
because of difficulty inverting some of the land use covariate matrices.