MAPPING OF THE WILDLAND FUEL CHARACTERISTICS OF THE SANTA MONICA MOUNTAINS OF SOUTHERN CALIFORNIA

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By J. D. Nichols,* University oi California, Berkeley, California

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ABSTRACT

LANDSAT digital MSS data was successfully used to map and evaluate the wildland fuels of the Santa Monica Mountains in Southern California. A mixed classification scheme was used where training areas of known vegetation types were entered and the maximum likelihood classifier run, followed by an evaluation of the results and an unsupervised retraining of the classifier using an image of the probability of misclassification.

Estimation of maturity class and crown closure percents of the major cover types were assigned to each computer class by associating the photo interpretation of 159 large scale photo samples with the resultant computer classes using analysis of variance and analysis of categorized data. The result of the computer classification and statistical analysis were then transformed from the LANDSAT Coordinate California State Plane Coordinate system for use in a digital format in the FIRESCOPE data retrieval and fire modeling system.

OBJECTIVE

The primary objective of this FIRESCOPE funded study was to determine the potential of LANDSAT digital multispectral scanner data for meeting the requirements for identification and mapping of surface characteristics necessary for forest fire management in the Santa Monica mountain areas in Southern California. This required a determination of the adequacy of the spectral, spatial and multi-date capabilities of the LANDSAT MSS scanner, and the investigation of an integrated LANDSAT, photographic and ground data collection system for use in the operational mapping of wildland fuels. The major factor to be determined in the study was the usefulness of LANDSAT-derived data as an input to the information system being developed under project FIRESCOPE.[1] A secondary objective was to devise an operational procedure for the mapping of wildland fuels.

APPROACH

Supervised computer classification of LANDSAT digital multispectral scanner data was done using initial training from 28 areas selected from LANDSAT photographic products, high flight photography and large scale photography (See Table I). Retraining of areas with a low probability of correct classification was accomplished through use of the classification results and an image of a histogram of the probability of correct classification. The results were verified by precisely locating large scale photographs in the LANDSAT classification results and comparing LANDSAT

* Former Director of the Remote Sensing Research Program; currently Head of Earth Resources Technology Applications, Electromagnetic Systems Labs., ESL Incorporated, Sunnyvale, CA.

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classes with the vegetation fuel types identified on the large scale photos. The LANDSAT results were then mapped to the fire model coordinate system through the use of common control points in the LANDSAT imagery and in the ground coordinate system. The transformation was obtained using least square estimation procedures.

TABLE I.

	Class Name	Symbol	Description
1.	URNE	.	Urban
2.	URN	,	Urban
3.	BR. -4	-	Predominantly immature brush with patches of mature brush
4.	GRB1	/	Barren land with some grass associated with urban development
5.	GRB2	(	Barren land associated with new housing
6.	BR-SWS	]	Predominantly mature brush, patches of immature brush, found on Southwest slopes
7.	BR-5	∷	Immature brush with grass understory - 50% crown closure of brush
8.	GRC	≠	Barren land associated with new housing, very sparse grass cover
9.	BR-NE	≡	Mature brush found on northeastern slopes
10.	OPEN2A	I	Grass with riparian vegetation (willow)
11.		0	Open grassland
12.	BR-1-25	8	Mature brush mixed with live oak of 30-50% crown cover
13.	OPEN-1	×	Oak grassland with 40-60% crown closure of oak
14.	OPEN-3	W	Oak grassland with 20-40% crown closure of oak
15.	OPEN-4	4	Grassland
16.	BR-1-19	?	Mature brush mixed with live oak; average 50% crown closure
17.	UR-5	→	Training from developed area but class is basically mature brush similar to class #16
18.	BURNER	v	Immature brush with some mature patches - grass understory present
19.	B.S. -1	↑	Barren area - no grass
20.	URN 2A	<	Developed area with no vegetation
21.	URN2B	≥	Developed area with no vegetation
22.	URD1B	¬	Developed area with no vegetation
23.	BR. -1	;	Mature brush with sparse live oak
24.	URD	H	Urban development

TABLE I. -- Continued.

	Class Name	Symbol	Description
25.	OCEAN	J	Water - fresh and ocean
26.	UR-B	G	Urban
27.	SAND	9	Beach sand
28.	NEWHO	7	New Housing (Barren land)
29.	OPEN6	A	Oak grassland
30.	OPEN7	B	Oak grassland

The final classes selected for the supervised classification are shown here. The columns represent the computer class number, class name, class symbol and a general class description. The description is a result of the correlation of interpretation of large scale photos (1:1000 color) and high flight photo (1:30,000 color infrared) with discriminant analysis classes.

PROCESSING STEPS USED IN THE DISCRIMINANT ANALYSIS AND MAPPING OF WILDLAND FUELS IN THE SANTA MONICA MOUNTAINS

The following individual steps were used in the extraction, discriminant analysis, verification and mapping of the wildland fuels of the Santa Monica Mountains.

1. The LANDSAT multispectral scanner computer compatible tapes were reformatted to make them compatible with the local automatic data processing system.
2. The area of interest was then extracted from the reformatted tapes and placed on a separate tape to reduce the cost of further processing.
3. Due to the improper calibration between the individual sensors in each of the four bands, the tapes were recalibrated to minimize errors from this source.
4. Large scale stereo pairs were acquired at approximately 1/8 mile intervals over 11 flight lines distributed throughout the Santa Monica Mountains. The photos were at an average scale of 1:1000 with simultaneous medium scale photos acquired to aid in the interpretation and location of the large scale photo pairs.
5. The large scale and medium scale photos were annotated, mounted, and interpreted to determine crown cover, species composition, and general vegetation condition.
6. Through use of the large and medium scale photos, the X, Y, coordinates of each training area were located in the LANDSAT computer compatible tapes.
7. Points that could be easily located in the LANDSAT computer compatible tapes were also identified and located on 7-1/2 minute quadrangles. The tape X, Y, coordinates and the corresponding map UTM coordinates of these control points were then determined.
8. Least squares estimation procedures were used to determine the coefficients of the transformation equations necessary to map the LANDSAT data to the UTM coordinates to LANDSAT data. This data base was also used to determine the LANDSAT-to-LANDSAT

multidate transformation for four dates. (This was part of another study to investigate the geometric fidelity of the LANDSAT data for multidate ov- -ay.)

9. A LANDSAT-to-LANDSAT multidate tape was made and training areas extracted to determine the value of multidate imagery in the fuel mapping process.

10. From the four dates available for computer processing, the optimum date was selected. This selection was based on the uniformity of illumination, vegetation condition, atmospheric conditions, and quality of the digital tape data.

11. The raw data obtained from the training areas were processed in the statistical subroutine of the discriminant analysis package to determine the uniqueness of the various classes and to allocate further training of the classifier as needed.

12. The UTM coordinates of each of the large scale photo plots were obtained by first locating the plots on 7-1/2 minute quadrangles and then measuring their UTM coordinates. The LANDSAT coordinates of each of these photo plots were then computed using the UTM-to-LANDSAT transform.

13. The existing fuel classification, as completed by manual photo interpretation, was compared with the interpretation of the large scale photographs to determine the relationship between the two fuel classification procedures.

14. The "maximum likelihood" classifier was run repeatedly until an adequate separation of the various vegetation types was obtained. The discriminant analysis results and probability map were used in combination to locate areas where new training was needed and determine the exact X, Y, coordinates of these new training areas.

15. The discriminant analysis results were then run through the reclassification program. In this step each picture element was reclassified to the class that occupied the most points in the eight points surrounding the picture element being reclassified plus the central picture element. This procedure produced a map similar to the map produced by a photo interpreter when the interpreter is restricted to a 10-acre mapping minimum.

16. The LANDSAT coordinates of the photo plots were used to obtain the raw LANDSAT classification and the reclassification results of each of the photo plots. The relationship between the LANDSAT classification results and the photo interpreted results for the large number of large scale photos was then determined.

17. A summary was made of the acreages of the various fuel classes.

18. A dot count method was then used to determine the percentage of trees, brush, grass and barren area on the photo plots that had been precisely located in the LANDSAT discriminant analysis process. Each of the plots was also assigned one of the maturity classes, viz: barren, pioneer, immature or mature.

19. Four one-way analyses of variance runs were made to determine whether the discriminant analysis results explained the differences in tree cover, brush cover, grassy areas and bare soils. The procedure also ranked each of the discriminant analysis classes by the percent trees, brush, grass and bare soil (See Table II).

20. Several high resolution color coded maps were then made using the optical mechanical image reproducer. The colors represented such factors as maturity, density, and cover type.

The major product of this study is a discriminant analysis of vegetation for the Santa Monica Mountains. From this basic product a transformed image is produced that fits the ground coordinate system used in the fire modeling. A hard copy map product will be generated from the transform results and summary statistics thereby providing information on acreage by fuel type.

TABLE II

CLASS NUMBER	% TREES	% BRUSH	% GRASS	% BARE SOIL
12	86.9	9.5	2.2	1.4
23	67.2	24.7	8.5	1.0
9	55.9	35.1	5.7	2.1
16	55.9	34.4	6.3	3.2
17	52.3	47.6	0.0	0.0
6	47.8	40.0	8.9	3.2
13	41.2	21.0	28.9	7.9
30	30.0	11.9	18.2	5.0
3	29.9	37.4	24.3	9.5
18	24.1	45.0	21.4	8.7
14	21.0	20.1	56.3	2.0
15	19.3	28.5	42.6	10.6
7	17.0	50.4	27.0	5.6
AVERAGE PERCENTAGE COVER	45.3	34.7	15.3	4.8

This table gives the percent composition of trees, brush, grass and bare soil for each of the discriminant analysis classes for which photo plots were obtained. The estimates of the percentage cover are based on a least squares procedure. Each of the large scale photo plots was assigned to the computer class for that ground location. The average percent cover for each computer class was then computed for each of the four cover types.

EVALUATION OF CLASSIFICATION ACCURACY

Three major comparisons were made in evaluating results of discriminant analysis and comparing those results with the results of existing vegetation mapping for fuel type. First, the percentage correct classification within each of the training fields was computed as a normal product of the classifier (See Table III). The percentage correct by common subclasses also was computed for the mature brush, immature brush, pioneer, grassland and urban categories. The percentage correct as determined within these training fields only, did not provide a rigorous evaluation of the classifier for the entire study area. Therefore, the large scale flight lines were flown and the photo plots precisely located in the discriminant analysis results. The computer classification results, as applied to each of the p[illegible] separated the photo plots according to the classification results and provided an independent check of the classification accuracy and consistency for the entire study area.

TABLE III. SUMMARY OF STATISTICS OBTAINED IN CLASSIFYING LANDSAT DATA.

Class No.	Class Name	Class Symbol	Mean for Training Area				Percent Correct Within Training Area		Classification		
			500-600nm Ch 1	600-700nm Ch 2	700-800nm Ch 3	800-1100nm Ch 4	Class	Recl.	No. of Pixels	% of Total	Acres
1	URNE	.	40.37	39.47	48.21	23.16	95	100	4407	2.39	4803.6
2	URN	,	39.24	35.88	43.40	20.36	68	100	11242	6.09	12253.8
3	BR.-4	-	36.17	35.17	39.50	18.17	100	100	14470	7.84	15772.3
4	GRB1	/	47.83	52.67	49.67	20.67	100	67	384	0.21	418.6
5	GRB2	(	47.33	55.50	56.17	25.67	100	67	1073	0.58	1169.6
6	BR-SWS	]	31.40	26.60	33.50	16.60	100	100	12067	6.83	13741.6
7	BR-5	=	32.00	28.87	30.12	14.87	88	88	5027	2.73	5479.4
8	GRC	≠	50.73	56.82	55.18	24.64	91	91	5013	2.72	5464.2
9	BR-NE	≡	30.16	25.16	36.32	19.16	68	95	25994	14.09	28333.5
10	OPEN2A	I	40.75	48.50	51.75	25.00	88	88	1816	0.98	1979.4
11	OPEN2B	0	37.40	43.90	46.40	22.60	70	90	4832	2.62	5266.9
12	BR-1-25	8	27.67	22.56	32.44	17.44	100	100	4988	2.70	5436.9
13	OPEN-1	×	37.78	39.78	44.22	21.67	56	56	5051	2.74	5505.6
14	OPEN-3	W	36.69	39.94	42.56	21.12	69	75	5822	3.16	6346.0
15	OPEN-4	4	40.14	46.02	47.71	23.21	48	81	14173	7.68	15448.6
16	BR-1-19	?	28.94	25.74	32.37	17.20	80	100	14892	8.07	16232.3
17	UR-5	→	29.25	24.50	31.25	16.25	100	75	1882	1.02	2051.4

TABLE III. -- Continued.

Class No.	Class Name	Class Symbol	Mean for Training Area 500-600nm Ch 1	600-700nm Ch 2	700-800nm Ch 3	800-1100nm Ch 4	Percent Correct Within Training Area Class	Recl.	Classification No. of Pixels	% of Total	Acres
18	BURNER	v	32.40	30.40	31.65	15.25	80	100	13572	7.36	14793.5
19	B.S.-1	↑	50.67	56.92	55.33	23.00	58	75	1232	0.67	1342.9
20	URN2A	<	69.67	68.00	67.83	31.00	100	100	512	0.28	558.1
21	URN2B	≥	58.75	54.75	58.50	26.00	100	25	138	0.07	150.4
22	URD1B	¬	83.50	85.37	82.50	35.00	100	100	235	0.13	256.1
23	BR.-1	;	28.34	42.06	28.48	14.28	72	92	11356	6.16	12378.0
24	URD	H	45.32	42.88	45.60	20.84	96	100	10658	5.78	11617.3
25	OCEAN	J	30.56	20.30	13.64	3.91	100	100	53533	--	58351.0
26	UR-8	G	44.87	41.88	37.87	15.75	100	100	1466	0.79	1597.9
27	SAND	9	57.09	59.91	52.73	21.09	100	100	356	0.19	388.0
28	NEWHO	7	51.85	57.42	53.75	22.42	75	75	1673	0.91	1823.6
29	OPEN6	A	38.50	42.00	45.08	21.92	83	91	2551	1.38	2780.6
30	OPEN7	B	37.73	40.53	43.20	21.27	20	20	7051	3.82	7685.6

COORDINATE TRANSFORMATION

Three basic coordinate transforms were needed to complete this study. First, to compare the statistics from the multidate aspects of LANDSAT, a LANDSAT-to-LANDSAT coordinate transform was necessary. Second, to locate photo plots in the LANDSAT tape data, UTM-to-LANDSAT transformation was necessary, and third, to map the LANDSAT coordinate system to a ground coordinate system, LANDSAT-to-UTM transformation was necessary. Additionally, a LANDSAT-to-California plane coordinate system transform was necessary to permit the data to be used in the fire model. In general, each coordinate transformation is in error by less than one picture element for all control points. When the large scale photo plots are located on the maps and then transformed to the LANDSAT coordinates and the results of the discriminant analysis classification observed, it becomes very apparent that the LANDSAT-to-UTM and UTM-to-LANDSAT transformations were very accurate over the entire scene. In all cases checked, the features immediately surrounding the photo centers can easily seen and the results of the classification verified through the use of a minimal amount of photo interpretation of the large and medium scale photos.

SUMMARY OF SIGNIFICANT RESULTS

1. It was anticipated that the computer would correctly classify 85% ± 10% of the picture elements within the computer training areas. The observed percentage correct was 82.7%. When training areas that represented equivalent fuel types were pooled, the percentage correct rose to 95.0%.
2. Trees, brush, grass, and bare soil are adequately separated by discriminant analysis of the LANDSAT multispectral scanner data as evidenced by results obtained in attempting to determine the percentage cover of each.
3. The raw (initial) classification results are more accurate than the reclassification results.
4. The four maturity classes (barren, pioneer, immature and mature) are adequately separated by the discriminant analysis
5. When broad and environmentally based delineations are made, separating the area into relatively homogeneous types, the discriminant analysis procedure appears to adequately separate types by species composition.

The results of this study and other wildland studies indicate that the discriminant analysis of LANDSAT data provides a cost-effective base for sample allocation. This data base, when used to allocate large photo flight lines, which in turn are used to allocate ground samples, significantly increases the precision of resource estimates over that obtainable by conventional techniques. The integrated procedure reduces the cost of inplace mapping, inventory, and assessment from 2:1 to 20:1 depending on the complexity of the problem and the relative amount of information obtained from the LANDSAT discriminant analysis.