LARS Information Note 032674

MAPPING A RECENT FOREST FIRE WITH ERTS-1 MSS DATA

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Purdue University, West Lafayette, Indiana

1974

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Abstract

Accurate fire boundary delineation provides essential information to forest managers in allocating suppression costs and planning regeneration efforts. The objective of this study was to test the capability of computer-aided analysis of ERTS-1 MSS data to accurately define the boundary of a recent forest fire and to discriminate spectral classes within the perimeter. Two frames of ERTS-1 MSS data were selected for analysis of the Moccasin Mesa Fire in Mesa Verde National Park. Data sets were collected one-half growing season and one full growing season after the fire. Results indicate that computer-aided analysis of ERTS-1 MSS data has the capability for accurately delineating fire boundaries and determining acreage of the burned area. Distinct spectral classes may also be defined within the fire perimeter.

This work was sponsored by the National Aeronautics and Space Administration (NASA) under Grant Nos. [redacted] and NGL 15-005-112.

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Introduction

Accurate forest fire mapping plays an important role in forest management decision making. When a fire involves the land of two or more agencies, suppression costs may be proportioned on the basis of relative areas burned. Proper planning of regeneration efforts may be dependent on accurate information concerning acreages involved and extent of damage. Estimates of burned acreage also aid in estimating regional as well as local costs in timber volume losses, and in litigations.

Lauer and Krumpe indicated that analysis of ERTS-1 imagery obtained shortly after a fire had a 10:1 cost advantage over conventional methods for mapping burned areas.[1] Seevers and Drew reported that range fires in Nebraska over 4 months old could be detected by only Band 7 of ERTS-1 imagery.[2]

The current study involved computer analysis of two ERTS-1 data sets, one of which was obtained one-half growing season after the fire, and the other obtained the following summer, after a full growing season.

Objectives

A relatively small area within the Mesa Verde National Park in southwestern Colorado was used to test the capabilities of computer-aided analysis of ERTS multispectral scanner (MSS) data in mapping certain features of recent forest fires. The specific objectives of the analysis were: (1) to determine the capability for accurately defining fire boundaries after the area has a period of time to recover slightly, and (2) to determine the capability for separating distinct spectral classes within those boundaries. These objectives were realized by comparing various methods of estimating burned acreage. [redacted]

Data Acquistion and Processing

Two sets of ERTS-1 MSS data were used in the analysis sequence: (1) Frame 1317-17204; June 5, 1973 and (2) Frame 1066-17254; September 27, 1972. Four channel digital MSS data were analyzed. The spectral bands for each channel were: Channel 4, 0.50-0.60 μm; Channel 5, 0.60-0.70 μm; Channel 6, 0.70-0.80 μm; and Channel 7, 0.80-1.10 μm. The LARSYS software system of computer programs designed to analyze and display remotely sensed multispectral data was used for this analysis. Both data sets were rotated and geometrically corrected to 1:24,000 scale.[3]

Seven processing functions were used in the study: (1) CLUSTER, (2) STATISTICS, (3) MERGESTATISTICS, (4) SEPARABILITY, (5) CLASSIFYPOINTS, (6) PRINTRESULTS, and (7) PHOTO. The CLUSTER function uses an unsupervised classification (clustering) algorithm to group data vectors into a predetermined number of spectral classes.[4] A modified version of CLUSTER may also simultaneously calculate mean vectors and covariance matrices for each class, similar to the STATISTICS processor.

MERGESTATISTICS is used to merge two or more sets of statistics, if desired, for use by the CLASSIFYPOINTS processor which classifies each scanner resolution element, or remote sensing unit (RSU), utilizing a pattern recognition algorithm involving a Gaussian maximum likelihood scheme.[5] Classification results may be displayed either as alphanumeric maps through PRINTRESULTS or on a video digital display with the PHOTO processor. Black and white or color photographs are options available with PHOTO.

All data analysis was done at the Laboratory for the Applications of Remote Sensing (LARS/Purdue) using the LARSYS software system.[3,4,5,6,7]

Site Selection

An initial non-supervised classification of the Mesa Verde National Park and immediate area (Fig. 1) indicated a relatively small area on the southeastern edge of the park to be spectrally unique. This area was identified as the Moccasin Mesa Fire of July 11, 1972. An approximately 20,000 acre area containing the burn was selected as a study site for detailed analysis.

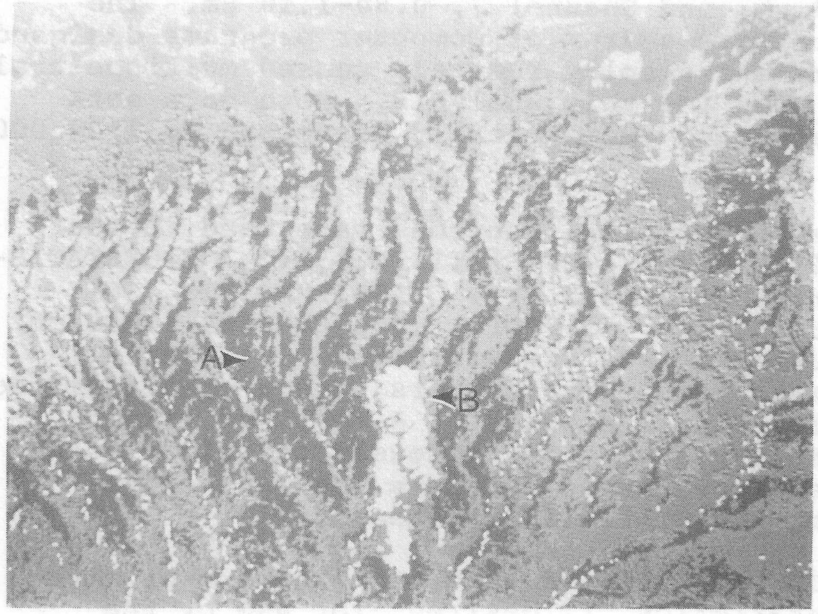


Figure 1. Computer-aided classification of Mesa Verde National Park from ERTS-1 MSS data, June 5, 1973 as displayed on a video CRT. Mesa-canyon patterns (A) and the Moccasin Mesa Fire (B) are evident.

Fire History and Ground Truth

Mesa Verde National Park is on a highly dissected plateau with canyons oriented North-South. The park comprises 50,275 acres and has 2000 feet relative relief. Vegetation types are primarily pinyon-juniper and chaparral. Some larger vegetation may be found in the canyons and at higher elevations.[8]

The Moccasin Mesa Fire originated near Little Moccasin Canyon July 11, 1972 and burned south for about 5 miles, consuming approximately 2000 acres. The fire was limited primarily to Moccasin Mesa with some damage to Moccasin Canyon. It was unique in that it burned in both the National Park and the Ute Mountain Indian Reservation.

Park personnel mapped the fire boundaries at a 1:24,000 scale from infrared scanner imagery collected July 16, 1972. Subsequent plainmetering of the map at LARS provided the acreage estimates in Table 1.

Table 1. Burned Acreage Estimated from NPS Map.

	Acres Burned	Percent
Mesa Verde Nat. Park	854	37
Ute Mountain Ind. Reservation	1455	63
TOTALS	2309	100

The National Park Service Map and total acreage estimate, along with a USGS 1:24,000 topographic map were used as reference data for evaluating the study results.

Procedure

An unsupervised classification was performed on both sets of data involved. The first classification was performed on the small study area using data from Frame 1317-17204, June 5, 1973. This date was selected for the initial classification because photographic data obtained the same day from SKYLAB was available for the Mesa Verde area.

Twelve spectral classes defined by the CLUSTER processor were pooled, based on separability, into six classes for classification. Two of these could be further combined, allowing five display classes. A 1:24,000 overlay of stream courses indicated two of these spectral classes corresponded to actual canyon-mesa patterns (Fig. 2) and were assigned the appropriate class names. The three remaining classes were, for the most part, contained within the fire perimeter defined by the NPS map and were arbitrarily assigned class names of BURN 1, BURN 2, and BURN 3, based on their respective distances from the fire origin. (Fig. 3A)

In order to look at temporal effects upon the classification procedure, ERTS frame 1066-17254, September 27, 1972 was also analyzed. These data were collected only 3 months after the fire (compared to 11 months after the fire for data used in the previous classification). Twelve spectral classes defined by the CLUSTER processor were pooled, based on separability, into 5 classes for classification. Two of these could be further combined, allowing 4 display classes (Fig. 3B). Canyon-mesa patterns were again evident. In this classification, however, the statistics indicated that only two burn classes could be separated.

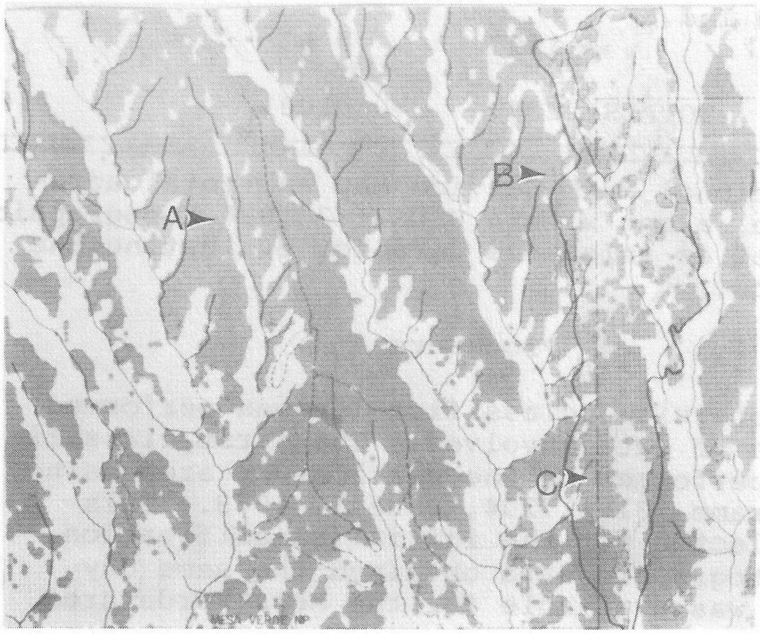
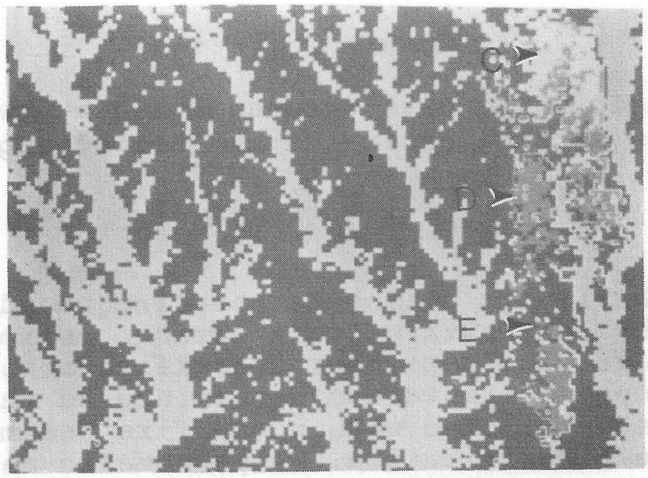
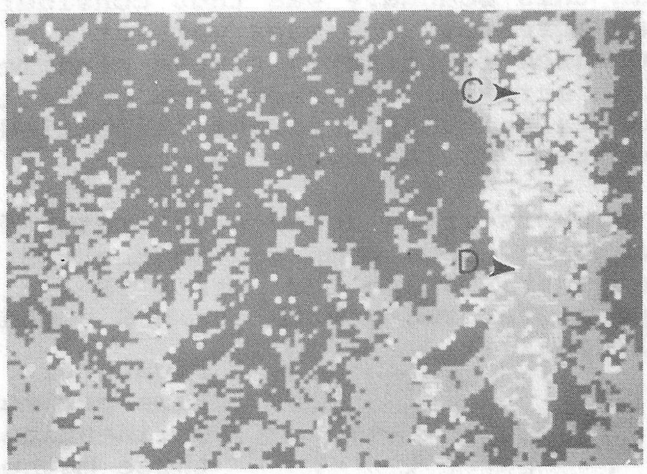


Figure 2. Computer-printout of classification results for ERTS-1 MSS data June 5, 1973. Printout has been colored to accent the grey scale. Locations of canyons (A), fire boundary (B), and National Park Boundary (C) are shown.

Both of the above sequences classified some points outside the fire perimeter as one or another of the burn classes. Many of these points were near canyon rims and other locations known to be unburned. Since shadow areas have a low spectral response believed to be similar to that of burned areas, these misclassified points were assigned the name shadowpoints. Initial attempts to eliminate these shadowpoints without affecting the classification of the burned area have had some success, but additional work is required.



A.



B.

Figure 3. Comparison of classification results for two sets of ERTS MSS data: (A) June 5, 1973, with 3 burn classes (C,D,E) and (B) September 27, 1973, with 2 burn classes (C,D).

Results

Classification results were analyzed by two methods: gross acreage estimated and net acreage estimated.

Gross Acreage

The capability to delineate the fire boundary was assessed by contrasting gross acreage estimates for both the June and September classifications. The gross acreage estimate was determined as that area, in acres, contained within the fire perimeter defined by the classification. Alphanumeric maps were produced by the PRINTRESULTS processor for both classifications. A smoothed line was then drawn around the apparent edge of the burned area. The area within this boundary was thus considered as gross burned acreage. The maps were at a 1:24,000 scale which facilitated simple planimetering to determine acreage. It should be noted that the area did contain isolated points classified as unburned in addition to the burned areas.

Figure 4 depicts gross acreage estimates for the ERTS-1 classifications compared to the NPS base map data. The general shape for both ERTS-1 classifications compares favorably with the NPS boundary, though slightly smaller.

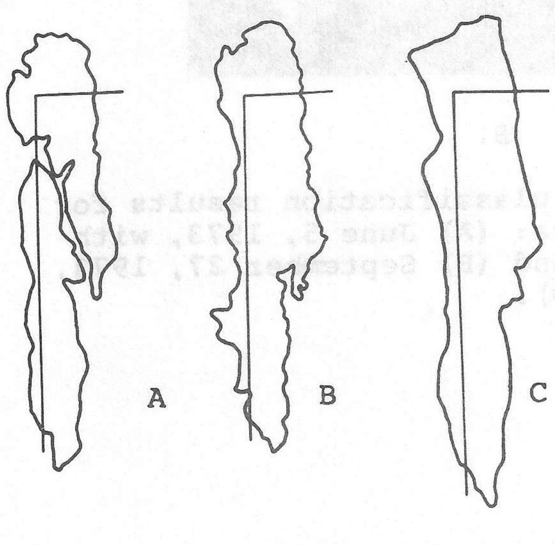


Figure 4. Fire perimeter delineations by three methods: (A) Computer-aided classification of June 5 1973 ERTS-1 MSS data, (B) Computer-aided classification of Sept. 27,1972 ERTS-1 MSS data, and (C) National Park Service map produced from thermal scanner imagery by conventional methods.

The gross acreage estimates were subdivided into acreage burned within the National Park and acreage burned within the Ute Mountain Indian Reservation. Acreages obtained were expressed as percentages as well as absolute values. Table 2 shows these gross acreage estimates obtained by classification of ERTS-1 data, as well as the acreage estimates obtained from the official NPS base map.

Table 2. Gross Acreage Estimates for two ERTS-1 classifications, contrasted with NPS base map estimates.

	Burned Acreage (and % of Total)		
Classification	Park	Ute Res.	Total
June 5, 1973	561 (32%)	1194 (68%)	1755 (100%)
Sept. 27, 1972	602 (34%)	1196 (66%)	1798 (100%)
NPS Base Map	854 (37%)	1455 (63%)	2309 (100%)

Acreage estimates for both ERTS-1 classifications are very similar, but are significantly lower than the acreage estimates derived from the National Park Service base map.

It is important to note that the <u>percentages</u> of area burned in the Mesa Verde Park and in the Ute Indian Reservation are approximately the same for both ERTS-1 classifications and also for the NPS base map data. Thus, there is little question about the relative areas involved, but the total acreage of the fire requires further examination. Key questions might involve the differences in photogrammetric characteristics of the data sources, and the data analysis techniques utilized. Since the NPS base map was prepared from thermal infrared scanner imagery, and data from such scanner systems can contain considerable geometric distortions, it was thought that the original NPS map could be in error due to distortions in the original data source. Inspection of the original NPS infrared imagery (Fig. 5) revealed such distortion around the fire perimeter. Since mechanical techniques

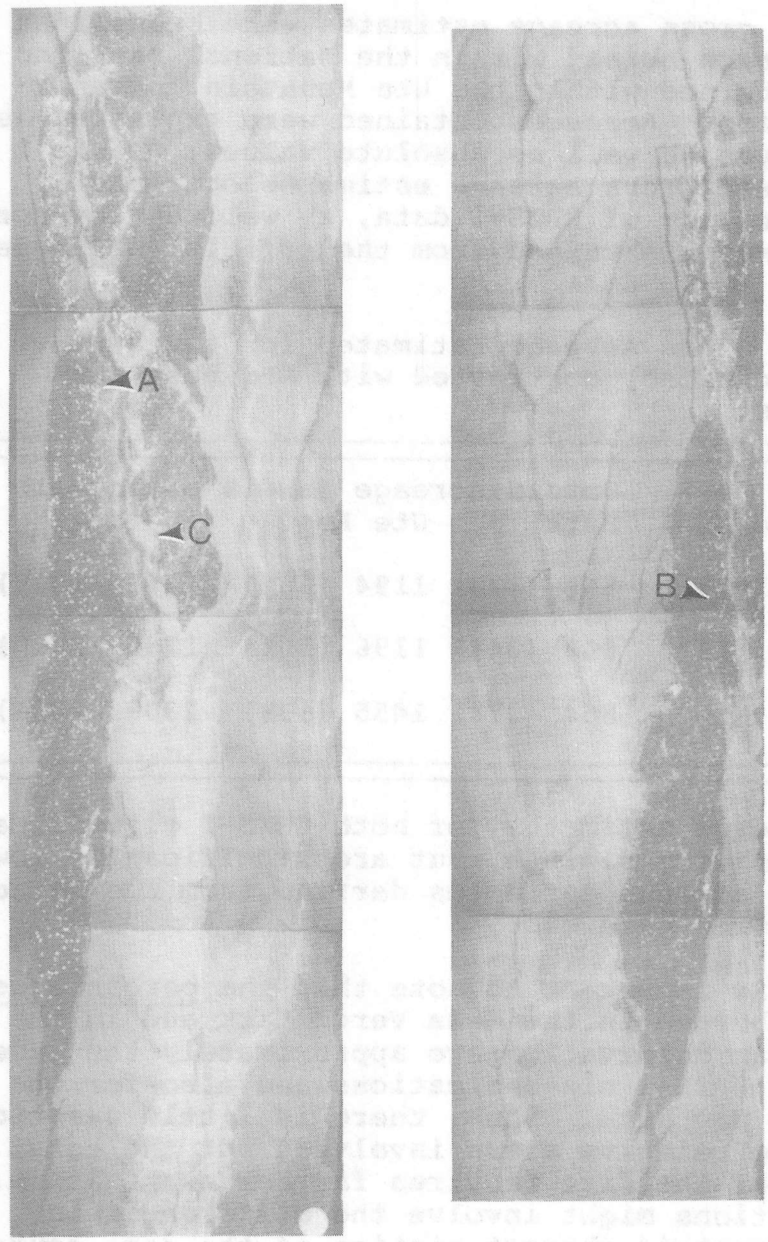


Figure 5. Thermal scanner imagery of the Moccasin Mesa Fire obtained at 0250 MST, July 16, 1972. Bright area (A) are hot spots. Note severe distortion (B) near the edges compared to the same area (C) near the center.

were used to construct the map, distortions inherent in the imagery would also be present in the fire map. This could explain the differences shown in Table 2 between the NPS base map and either of the ERTS-1 classification results.

Net Acreage

The capability to separate distinct spectral classes within the fire boundary was assessed by contrasting net acreage estimated for each classification. Net acreage was defined as the sum total of all resolution elements classified as burn within the fire perimeter, expressed in acres. Each RSU of ERTS-1 data was determined to represent 1.08 acres. The PRINTRESULTS processor listed the total RSU's, within the burned area, which were then converted to acres. (Table 3)

Table 3. Net acreage estimates of the Moccasin Mesa Fire listed by spectral class, and compared with NPS base map.

Net Acreage Estimates				
Classification	Spectral Class			
	Burn 1	Burn 2	Burn 3	Total
June 5, 1973	274 (18%)	651 (43%)	596 (39%)	1520
Sept. 27, 1972	693 (52%)	643 (48%)	--	1336
NPS Base Map	--	--	--	2309

Conclusions and Recommendations

Accurate boundary delineation of recent forest fires may be accomplished utilizing computer-aided analysis of ERTS MSS data. Spectral differences between burned areas and adjacent cover types may largely be a function of residual burned materials. Results of this study suggest that such boundary delineation may be achieved more accurately through use of ERTS-1 and SKYLAB satellite data than by more conventional techniques currently being utilized.

Distinct spectral classes within a burn may be discriminated by computer-aided analysis. These classes may be indicative of burn severity, stage of revegetation, original cover type, or a combination of the three. These results suggest the possibility of using satellite data, available at various intervals after a forest fire, to monitor regeneration of the area.

This study also indicates that further work is needed in an attempt to define cause-and-effect relationships in the spectral characteristics of a burned forest area. This work should also be directed toward quantitatively determining expected classification accuracies.

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