Microdensitometry to Identify Plant Communities and Components on Color Infrared Aerial Photos

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Highlight: *Image density differences in color infrared aerial photos can be used to discriminate individual shrub and tree species of a pinyon pine-juniper plant community. In addition, image density was used successfully to identify six general plant communities: ponderosa pine, spruce-fir, aspen, big sagebrush, native grasslands, and seeded grasslands. However, different sites and cultural treatments within native grasslands and ponderosa pine forest could not be so easily discriminated, even though visual differences were apparent in the photos.*

As we become increasingly aware of critical changes in our environment, we need better ways to inventory present environmental conditions and effectively monitor future departures from today's conditions. This need applies to nearly one-half of the contiguous United States classified as wildlands as much as it does agricultural areas and urban-industrial centers.

For decades wildland ecologists, range scientists, and others have obtained information about plant communities and other landscape features primarily by ground research and inference. Their purpose has been to identify plants and soils, classify and map plant communities and their components, and, over time, monitor changing conditions. These ground efforts have often fallen short of desired goals. Thus new, stimulating ideas and advances in technology, including wildland surveillance from aircraft and earth-orbiting spacecraft, are drawing increased attention. We now have a chance to develop successful methods to comprehensively identify, classify, inventory, and monitor changes in our wildland areas.

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Microdensitometry—An Approach to the Problem

Microdensitometry is potentially a useful tool for separating wildland plant communities on color infrared aerial photos. Microdensitometry, as used here, is the relative measurement of light transmission through images on positive film transparencies. The measurement is termed optical density or simply density. Doverspike et al. (1965), who conducted tests to identify tree species and land use classes, described the function of the microdensitometer.

The microdensitometer:

1) looks at a very small portion—as little as 1 micrometer diameter—of a photographic image at spectral levels selected to be compatible with the sensitivity levels and dye component spectral characteristics of the photographic materials
2) reads the optical density of the image by means of a scanning optical system and photo multiplier—log amplifier measuring system
3) scans the sample at a uniform rate, as slowly as 10 micrometers per minute or as rapidly as 250 millimeters per minute
4) presents the data graphically on a strip chart or, when used with analog converter, presents data digitally to a computer for reduction and analysis.

Variation in optical density of microdensitometer scan lines is caused by several factors. Doverspike et al. (1965) determined that aperture size did not improve land use discrimination using 1:1,188 scale photos, although it affected density. Aperture shape (round or rectangular) has less effect than other variables. They also determined that image density differences were greater in the blue region of the spectrum than in the red or green.

Rib and Miles (1969) tested the effects of aperture size and photo scale on imaged density differences among terrain features. They discovered that, as aperture size decreased or photo scale increased, more detail was recorded because of finer tonal patterns of imaged features. Finally, a point was reached where desired information was obscured due to granularity of the film.

Driscoll and Reppert (1968) used image density to discriminate between two forest communities and mountain grasslands in western Colorado on 1:4,600 scale color infrared transparencies. To a lesser degree, spruce-fir and aspen forests could be separated by this automated interpretation procedure.

Methods

Study Location and Required Aerial Photographs

Five study locations were selected in the Colorado mountains to represent various terrain features. These locations have been described in detail (Driscoll and Reppert, 1968) and are summarized in Table 1. All aerial photographs were taken in 1968.

The Blue Mesa Reservoir location was an extensive area including several plant communities. Each photo was taken at a scale (1:139,000) to include as much area as possible. At the time of the photography, September 30, aspen foliage was yellow, and offered a good opportunity to separate aspen forest from the dark green spruce-fir forest.

The Black Mesa location included several sites within a mountain grassland community. Site variation within this plant community was the subject of study. To image and identify small site features, large-scale (1:800) aerial photographs were taken in early August to represent a phenological date when these different sites might best be photographically differentiated.

The test location near McCoy was in an open pinyon-juniper woodland. A photo scale (1:1,100) and date (early August) were selected when individual species are most easily identified by visual photointerpretation (Driscoll and Francis, 1970; Driscoll, 1970).

Two test locations were established at the Manitou Experimental Forest in a ponderosa pine-bunchgrass area. One test location included an extensive area with four major plant communities. Photos were taken at a scale of 1:135,000 when the grassland communities were at maximum phenological difference (October 1) from each other and from the forest communities.

The second location at Manitou was within a native bunchgrass community, parts of which had been altered by fertilizers and herbicidal treatments. The objective of our experiment here was to determine the degree of density separation among the treatments. The scale (1:2,700) was selected to provide single photo coverage of relatively small areas at a time (early August) when there was maximum visual differences on the ground.

Ground Data

Ground data were collected at all areas for all plant communities and components (Francis, 1970). This insured a high probability of correctly assigning density values to the proper terrain features.

Table 1. Terrain features and plant communities in photographed areas.

Location	Features
Blue Mesa Reservoir (communities)	1) water body 2) big sagebrush community (*Artemisia tridentata* Nutt.) 3) aspen forest (*Populus tremuloides* Michx.) 4) Engelmann spruce (*Picea engelmannii* Parry)–subalpine fir forest (*Abies lasiocarpa* (Hook) Nutt.) 5) rock outcrops and bare soil
Black Mesa (range sites)	Two sites within a mountain grassland community (mixed grass and forb species) 1) low productivity 2) high productivity
McCoy (species)	1) pinyon pine (*Pinus edulis* Engelm.) 2) Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) 3) low sagebrush (*Artemisia tridentata arbuscula* (Nutt.) H.C.) 4) big sagebrush 5) bitterbrush (*Purshia tridentata* (Pursh) D.C.) 6) mountainmahogany (*Cercocarpus montanus* Raf.) 7) bare soil
Manitou (communities)	1) native pine-bunchgrass (mixed grass and forb species) 2) seeded pasture (*Poa ampla* Merr.) 3) uncut ponderosa pine forest (*Pinus ponderosa* Laws.) 4) selectively cut ponderosa pine forest
Manitou (cultural treatments)	All within native pine-bunchgrass community (mixed grass and forb species) 1) herbicide 2) fertilizer 3) herbicide plus fertilizer 4) untreated

Camera, Film and Microdensitometer

A Maurer KB-8[1] camera was used to obtain photos with Ektachrome Infrared Aero, type 8443[2], color infrared film with a Wratten 12 filter. This camera has a 70-mm format, cycles rapidly, and has shutter speeds up to 1/4,000 of a second. The lens used for large-scale photos was a 150-mm focal length Schneider Xenotar. For very small-scale photos, a Zeiss Biogon 38-mm lens was used. The camera was mounted in an Aero Commander 500B aircraft.

A General Aniline and Film Corporation Model 650 microdensitometer was used with a Honeywell "Electronik" Strip Chart Recorder attached to generate the scan lines (Fig. 1). Trial scans were made to determine effective aperture, color filter, and film scan speed combinations that would best discriminate between the various terrain features. Measured and visual comparisons indicated that a round aperture used with a green filter (Wratten No. 93) provided the best plant community and community component discrimination based on image density differences.

[1] Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.

[2] Since the research represented herein was completed, the Kodak Ektachrome Infrared Film, Type 8443, has been discontinued. Instead, Kodak Aerochrome Infrared Film, Types 2443 and 3443, are now being produced. The infrared (cyan) sensitive layer of the new film types is slower than the same layer in the old film type. This results in a net effect of reduced red saturation in the photographs. The sensitometric characteristics of the two new film types are essentially the same, the main difference being that the 2443 film is on a 4-mil estar base and the 3443 film is on a 2.5-mil estar base. Both film types are "false color" or color infrared film.

Results

Very small-scale photos were used to make comparisons among the general plant communities. Figure 2 shows the mean and standard deviation in optical density of terrain features in the Blue Mesa Reservoir area. The resulting coefficient of variation provides for a comparison of density among different plant communities and the water and soil-rock features. The mean density of the water body separates it from all plant communities and the rock and soil areas. The communities show some overlap of image density at one standard deviation, although that of aspen forest does separate completely from the spruce-fir forest. There were larger coefficients of variation in the three plant communities compared to the water body, as would be expected since the water had a more homogeneous surface.

Mean densities for the two grassland communities at Manitou were discretely less than for the two forest communities (Fig. 3). The coefficient of variation was much less for the grasslands, especially the seeded area, than for the pine forest communities. The homogeneous big bluegrass area separated from native grassland. The coefficients of variation for the two ponderosa pine forests (Fig. 3) were greater than for the two forest types at Blue Mesa Reservoir (Fig. 2). The pine forest was more open than the spruce-fir or aspen forest. Consequently, there was more shadow and ground surface imaged through the forest canopy, which resulted in a greater range in density.

A test was made with large-scale color infrared photos of Black Mesa to determine if optical densities of two range sites were different (Fig. 4). The mean density of the more productive site was about 8% greater than the less productive site. However, large coefficients of variation produced severe overlap, and, thus, these sites were not easily separated.

Image densities of juniper, bitterbrush, and both sagebrush species at the McCoy area were sufficiently different to allow for absolute discrimination of these three kinds of plants (Fig. 5). In fact, the density ranges at one standard deviation did not overlap for these different plant genera. However, the two species of sagebrush did not separate from one another. Also, the mean densities of pinyon pine and mountainmahogany were so similar that minimum confidence

Fig. 1. *Microdensitometer (*left*) with a strip chart recorder attached (*right*).*

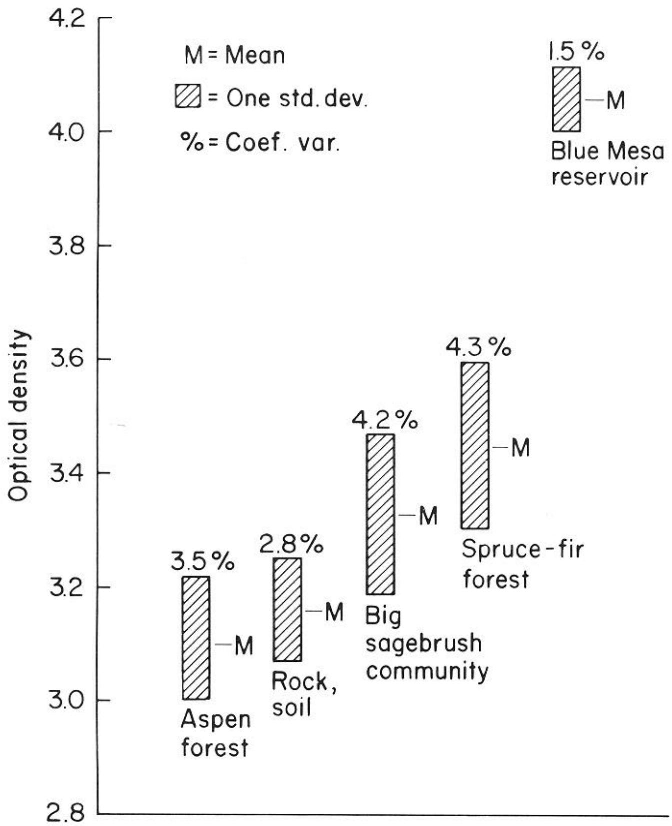

Fig. 2. *Optical film density of three plant communities, rock, soil, and a large water body. Blue Mesa Reservoir, photo scale 1:139,000, color infrared-8443, exposed September 30, 1968.*

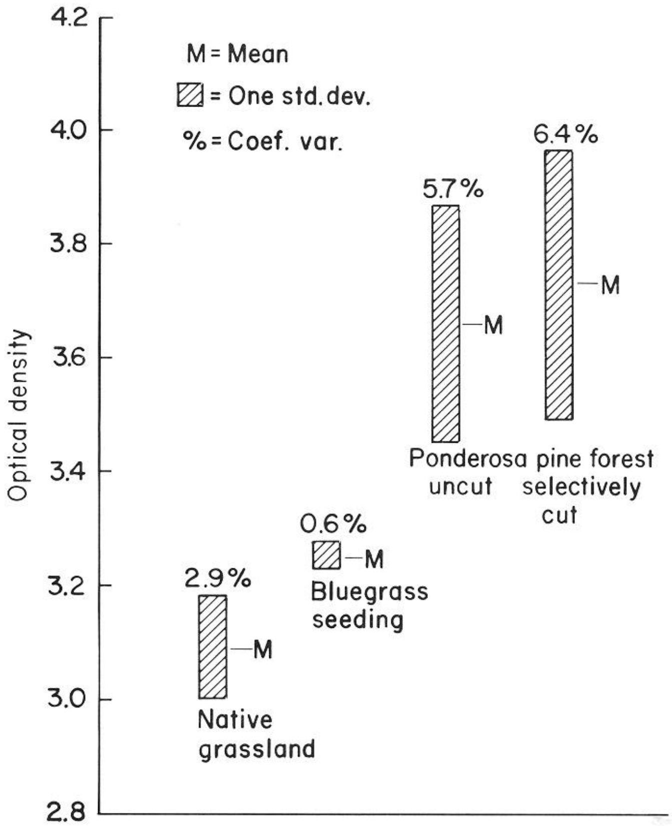

Fig. 3. *Optical film density of two grassland communities and two forest communities. Manitou, photo scale 1:135,000, color infrared-8443, exposed October 1, 1968.*

could be established for discrimination between these species. The reason for this is not known, since visual image characteristics provided for 100% correct identification of these species (Driscoll and Francis, 1970; Driscoll, 1970). The bare soil component of this area could be separated from all the shrub and tree species by image density differences.

The four cultural treatments at Manitou were minimally discrete on the basis of optical image density (Fig. 6). The range in mean density and coefficients of variation were comparatively high. Therefore, treatment effects could not be discriminated even though visual color differences were apparent in the photographs.

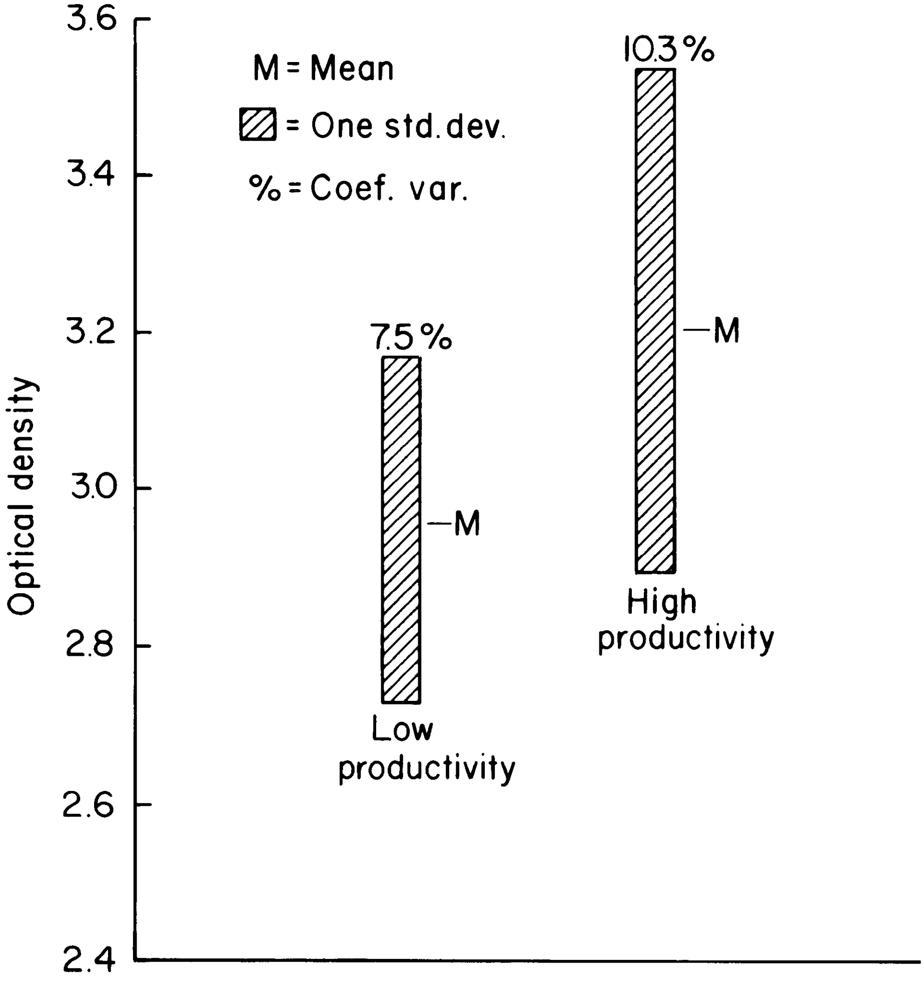

Fig. 4. *Optical film density of two grassland sites. Black Mesa, photo scale 1:800, color infrared-8443, exposed August 7, 1968.*

Discussion

Differences in optical density of film images examined in this study were such that the microdensitometer could separate some, but not all, plant communities and their components. There were seven absolute separations at three locations (Figs. 2, 3, and 5), and 10 partial separations from some of the other plant communities or components. Partial separation means that an absolute separation might be possible with additional research.

The relative homogeneity of a terrain feature is an obvious characteristic that affects image density. Features identified by densities with low coefficients of variation were the water body (Fig. 2), bluegrass seeding (Fig. 3), and soil (Fig. 5), as compared to the more heterogeneous plant communities.

Separation was minimal in three cases, each within a single plant community, even though differences were visible to a photointerpreter. Two cases involved cultural alterations of relatively homogeneous plant communities—a ponderosa pine forest (Fig. 3) and a native grassland (Fig. 6). The third case concerned inherent variation between different sites within a native grassland (Fig. 4).

This study indicates that microdensitometry has potential value in automated interpretation of plant communities and components on both very small- and large-scale photos. Very small-scale photos seem best suited for discriminating among general plant communities such as different forest and grassland systems. These results are similar to those of Aldrich (1971). He used microdensitometry with Apollo 9 color infrared photos obtained in March 1969 at a scale of 1:2,430,000 to identify 11 land units. As photo scale decreases, apparent resolution decreases and the heterogeneity of the terrain feature is integrated into less heterogeneous units.

Large-scale photos are well suited to discriminate some specific components of plant communities. The results show that imaged density of some plant genera are sufficiently discrete to provide for potential automated photo interpretation of those plants. Image density of bare soil was always less than that for the other community components.

Additional research is needed to more positively identify seasonal and photo-scale effects on image density to increase the usefulness of this automated interpretation system. Also, since frequency and amplitude of the scan lines were different for the terrain features, each feature should show a distinctive pattern based on these values as well as mean density difference. Akça (1971) used image density, frequency, and amplitude of scan lines in a discriminant analysis process and reported a high degree of successful

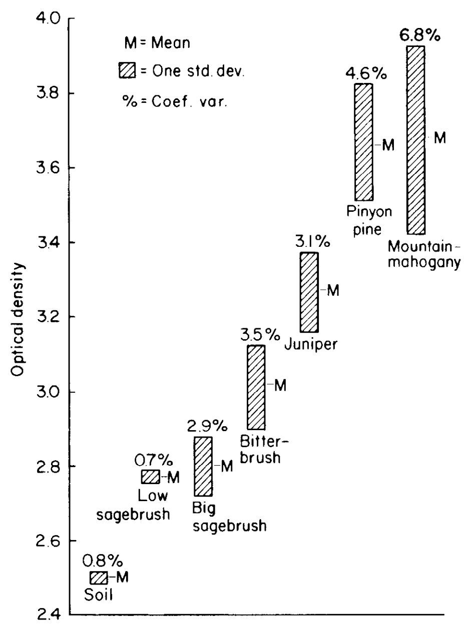

Fig. 5. *Optical density of two trees, four shrub species, and bare soil. McCoy, photo scale 1:1,100, color infrared-8443, exposed August 6, 1968.*

identification of 11 land use classes and forest stand types.

Steiner (1970), working with 11 crop classifications in Switzerland, suggested a 2-dimensional system utilizing time as well as the spectral dimension. He measured density of the 11 crops at 10-day intervals from early April into August and used linear discriminate analysis to analyze the data. The result was 100% correct crop classification.

The time dimension to assist in plant community classification is inferred in Figure 2. At the late September date the aspen leaves were yellow. Although this forest community separated from the spruce-fir forest, it was undifferentiated from the rock and bare soil, and to some extent, the big sagebrush community. Procurement of photographs, when the leaves are developing and when the trees are in full green foliage, would change the apparent optical density of the aspen forest. By combining density from several different phenological times, the aspen forest would likely separate from all other community types and other terrain features.

Steiner (1970) pointed out that sequential photographic coverage would be especially suitable from an orbiting survey satellite. The concept of using temporal change to assist in discrimination should have application for wildland plant communities.

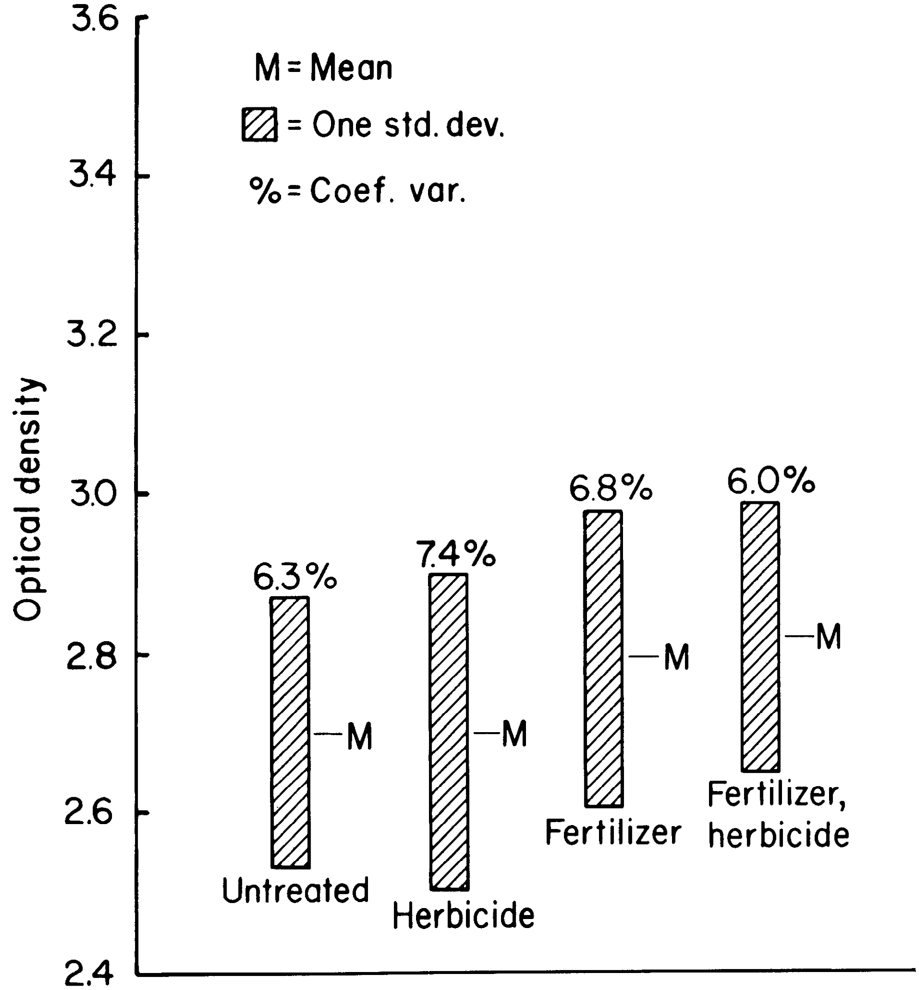

Fig. 6. *Optical film density of four cultural treatments, native grassland community. Manitou, photo scale 1:2,700, color infrared-8443, exposed August 8, 1968.*

Conclusions

Automated photointerpretation by microdensitometry is possible, although more research is needed to identify an operational procedure. The best season and scale, plus various film/filter combinations, need to be determined to optimize discrimination of particular plant communities and components.

To further improve separation, several characteristics from a single photo should be used: optical density, frequency, and amplitude of the scan lines. An effective procedure that uses the information from single-date photos would have widespread application and be relatively inexpensive.

Development of a system which incorporates sequential photographic coverage may further improve separation of wildland terrain features based on optical density and scan line patterns. The chance of misclassification may be reduced or eliminated by taking advantage of phenological changes in plant communities and sun angle effects. A sequential photo system would be especially suitable to inventory and monitor extensive plant communities and land use classes from earth-orbiting satellites.

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