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Density Slicing Applied to Forest Type Delineation*

Printing aerial photographs of a forested area on Agfacontour film to achieve density slicing, and subsequently copying the density slices on very high contrast lith film, aided in the discrimination of conifers and broadleafed trees.

Introduction

The appearance of tone in an aerial photograph is one of the most important factors for the photo-interpretation of tree species or forest type delineation. The differences of tone between objects are registered as different densities by the photographic material. And it is these density differences that constitute the key to photo-interpretation.

The tone density differences are quite obvious between conifers and broadleaves in an aerial photograph. Their greatest tonal differentiation, when recorded by a suitable photographic material, is in the infra-red region of the electromagnetic spectrum, although there also exists some difference in the visible range (Figure 1), namely in the green (500-600 nm) and in the deep red (*circa* 700 nm) regions.

Density slices in photographic terminology are the points of a photographic image (i.e., negative or positive image) having the same density[1].

Density slices, also referred to as equidensities (areas of equal density), can be obtained through several methods[2]:

(a) electronically, with an image scanner or TV monitoring
(b) by either solarization or the Sabatier Effect;
(c) by photographic masking; or
(d) by using Agfacontour film.

At present the only available photographic material capable of producing the equidensities conveniently and directly from a photographic image is Agfacontour film. This was the film used in the present experiment for the production of density slices.

The emulsion of the Agfacontour film contains silver chloride (with colloidal silver sulphide) which makes up the negative gradient (green sensitive) of the characteristic curve, and silver bromide which makes up the positive gradient (blue sensitive) of the characteristic curve. The spectral sensitivity curves for the film are shown in Figure 2. When this dual-characteristic emulsion is exposed to light the areas receiving most exposure produce high densities through chemical development, producing the positive part of the characteristic curve. At the same time areas that receive very little light or no light at all also produce high densities through physical development to make the negative part of the characteristic curve. The areas which receive a mid-exposure level produce only a slight density or are not affected at all, thus remaining transparent after development. Thus the mid-exposure areas correspond to the trough formed between the two characteristic curves of the material and so make up the equidensities or areas of equal density (density slices).

This exposure range corresponding to the low density region between the negative and positive parts of the characteristic curve can be adjusted to a required density interval (ΔD) by changing the illumination for printing (altering the light source or color filtering). Thus, by varying the printer light color we can narrow or widen our density slices. Figure 3 shows the effect of different light

* Experiment conducted while following the course of Aerial Photography at ITC, Enschede, Holland

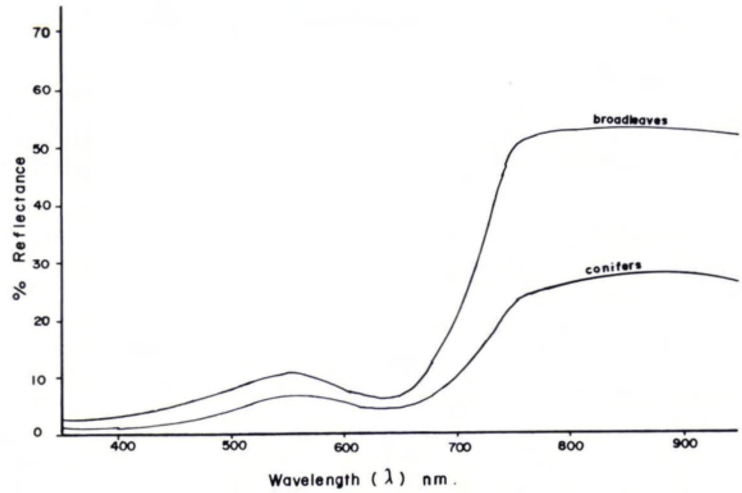


FIG. 1. Reflectance curves for broadleaves and conifers.

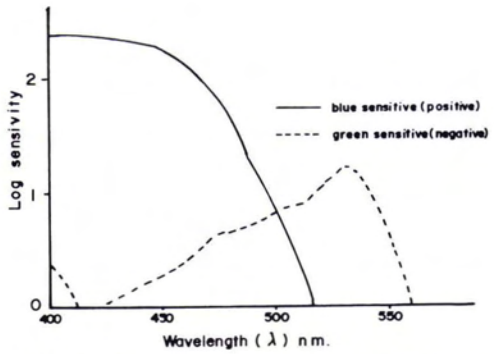


FIG. 2. Spectral sensitivity of Agfacontour film.

sources. In Figure 4 we can see the effect of Magenta *(M)* filtering giving a widening of equidensity and Yellow *(Y)* filtering giving a narrowing of equidensity compared with no filter at all.

Thus, by increasing the *Y* filtering it is possible to narrow the equidensity. Several tests showed that the density slice could be narrowed to about 0.10 (first order equidensity)[2,3]. After reaching this limit, any further *Y* filtering will only serve to move the characteristic curve up the density scale (Figure 5). The relationship between a given density slice and the aerial negative (desired density interval) can be regulated by increasing or decreasing the exposure time. Increasing the exposure time will shift the characteristic curve to the left (corresponding to

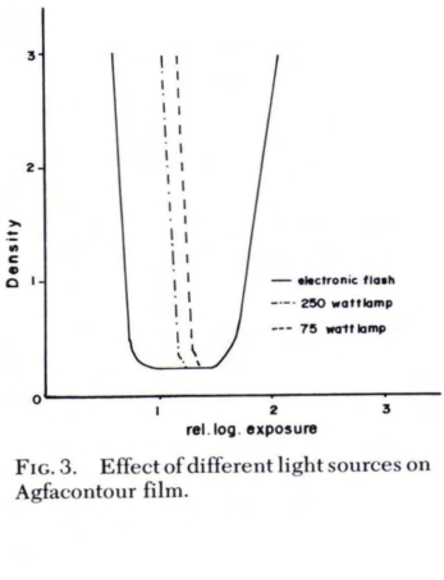


FIG. 3. Effect of different light sources on Agfacontour film.

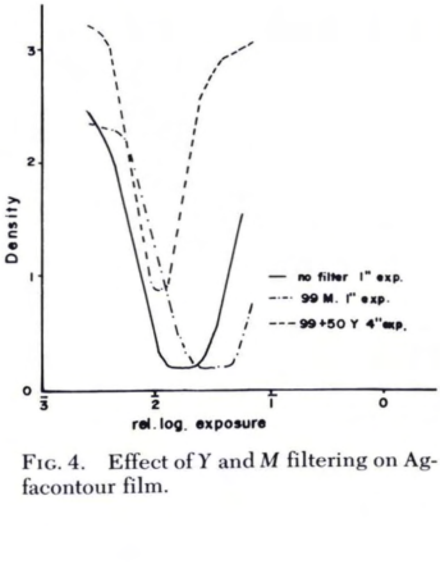


FIG. 4. Effect of *Y* and *M* filtering on Agfacontour film.

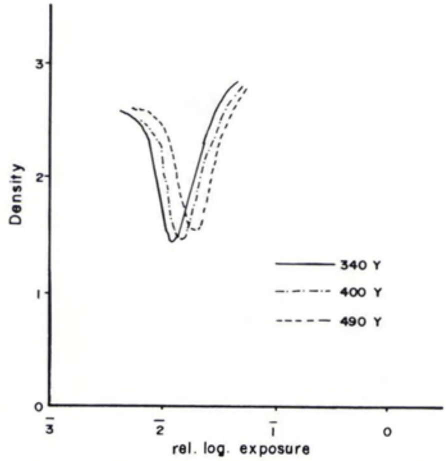


FIG. 5. Effect of excessive Y filtering on Agfacontour film.

higher densities in the aerial negative); decreasing will shift it to the right, given a constant Y filtering. This time-density relationship is expressed quite well by the following expression:

$$T_2 = T_1 \cdot 10^{D_2 - D_1}$$

where T_2 is the exposure needed to obtain a given density D_2 and T_1 is the exposure needed to obtain a given density D_1.

Through this formula it is possible to determine the position of a given density slice by calculating the exposure time required by the particular contact printer-filtering system in use.

For example, with the filtration 220Y (90Y + 80Y + 50Y) and a trial exposure of 4 seconds, the density slice at 0.54 (read on the relative log exposure axis) was obtained; then, to obtain the desired exposure time for the density slice corresponding to the broadleaves,

$$T_2 = (4) \cdot (10^{1.60-0.54})$$
$$= 48 \text{ seconds.}$$

Application Of Agfacontour Film To Forest Type Delineation

The task of applying density slicing to object recognition should be approached carefully. The image of the object that the interpreter sees depends on quite a few variables. The object on the ground will reflect a particular intensity of a certain quality of

FIG. 6. Agfacontour density slice.

light that depends on time of the day, season, physical condition of the object, position of the camera (angle of reflection), haze, filter-film combination, type of material used in the production of the photograph, the type of processing, and the photographic system resolution*[4]. Furthermore, the appearance of the object in the aerial photograph will be affected by the type of processing which not only involves chemicals, temperature, and time but also whether a rewind spool tank or an automated processing machine is in use[5].

Within these limitations the problem of accurate density slicing was approached. It is possible to produce density slices or equidensities corresponding to areas that exhibit tonal differences, as between conifers and broadleaves, using Agfacontour film.

Aerial photography of the Schneegattern Forest District of Austria was available for this particular experiment. The photography was taken in June 1969 with Kodak Infrared Aerographic film 5424, using a Wild RC9 15/23 camera, at an approximate scale of 1:10,000.

A sample area of the forest was selected, and the aerial negative of that sector was obtained. In this negative densities of areas of conifers and broadleaves were measured using a Macbeth TD 404 Transmission Densitometer with a 2mm diameter aperture: 10 measurements for conifers, 9 measurements for broadleaves. From these measurements a mean density was obtained for the conifers and for the broadleaves. The resulting mean densities in the negative were: for conifers, 0.70, and for broadleaves, 1.60.

* The resulting system resolution (R_s) after taking into account the resolution of the film, lens, image movement, and Agfacontour film (density slice). It could be approximately expressed as $1/R_s = 1/R_f + 1/R_l + 1/R_{im} + 1/R_{Ag}$

Production Of Agfacontour Density Slices

Several tests were made to determine the best possible printer-*Y* filtering combination. The printer used was a Zeiss KG 30 Contact Printer equipped with white lamps (2600°K) and an Agfa-Gevaert filter pack. A *Y* combination of 50*Y* + 80*Y* + 90*Y* was selected for giving the narrowest equidensity possible.

The exposure times were calculated according to the formula discussed before, and the Agfacontour density slices produced (Figure 6). The resulting characteristic curves for the conifers (c) and broadleaves (b) equidensities are shown in Figure 7.

Copying Of Agfacontour Density Slices On Lith Film

Although the Agfacontour film has an inherent high contrast (gamma above 7.0 for the negative slope and about 14.0 for the positive slope of the characteristic curve[2]), there are some areas of medium densities which it is desirable to eliminate. This can be done by copying the Agfacontour density slices on very high contrast (hard) paper or a suitable film. The copying has the effect of making the visual recognition a lot easier.

An orthochromatic lith film was used for this purpose. Lith films are very high contrast materials and are developed in a suitable lith developer which encourages a phenomenon

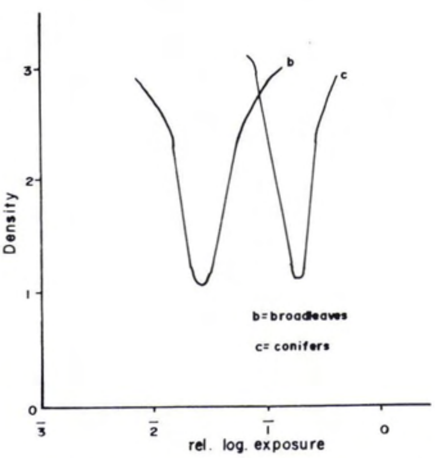


Fig. 7. Resulting density slices for conifers (c) and broadleaves (b).

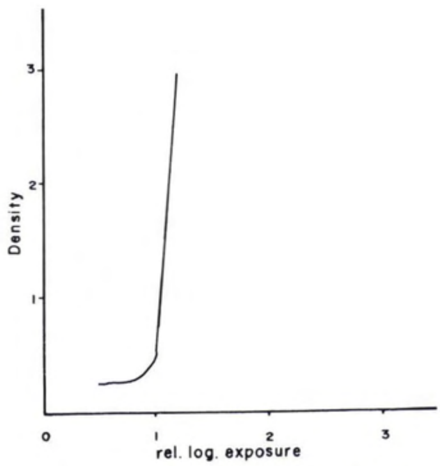
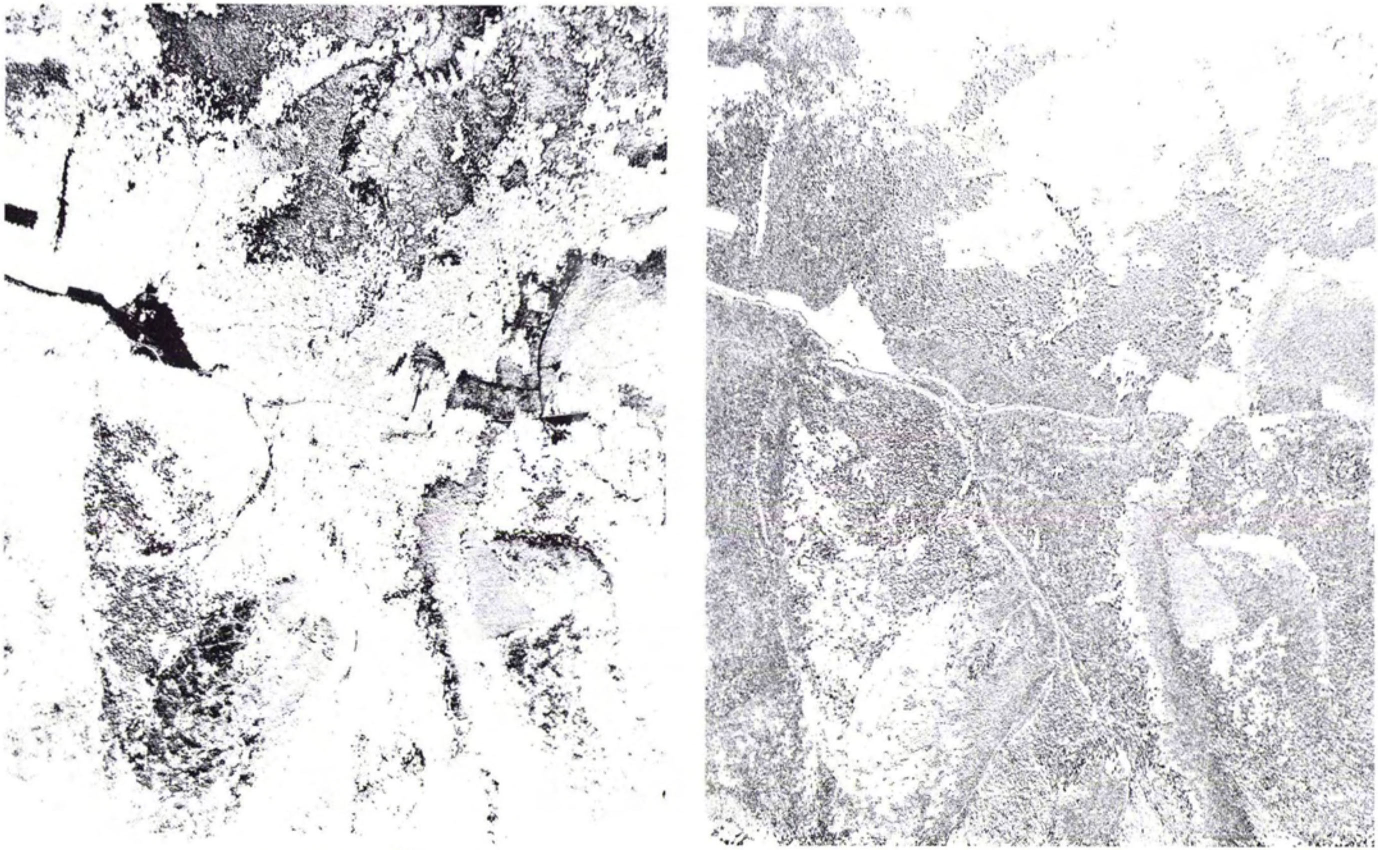
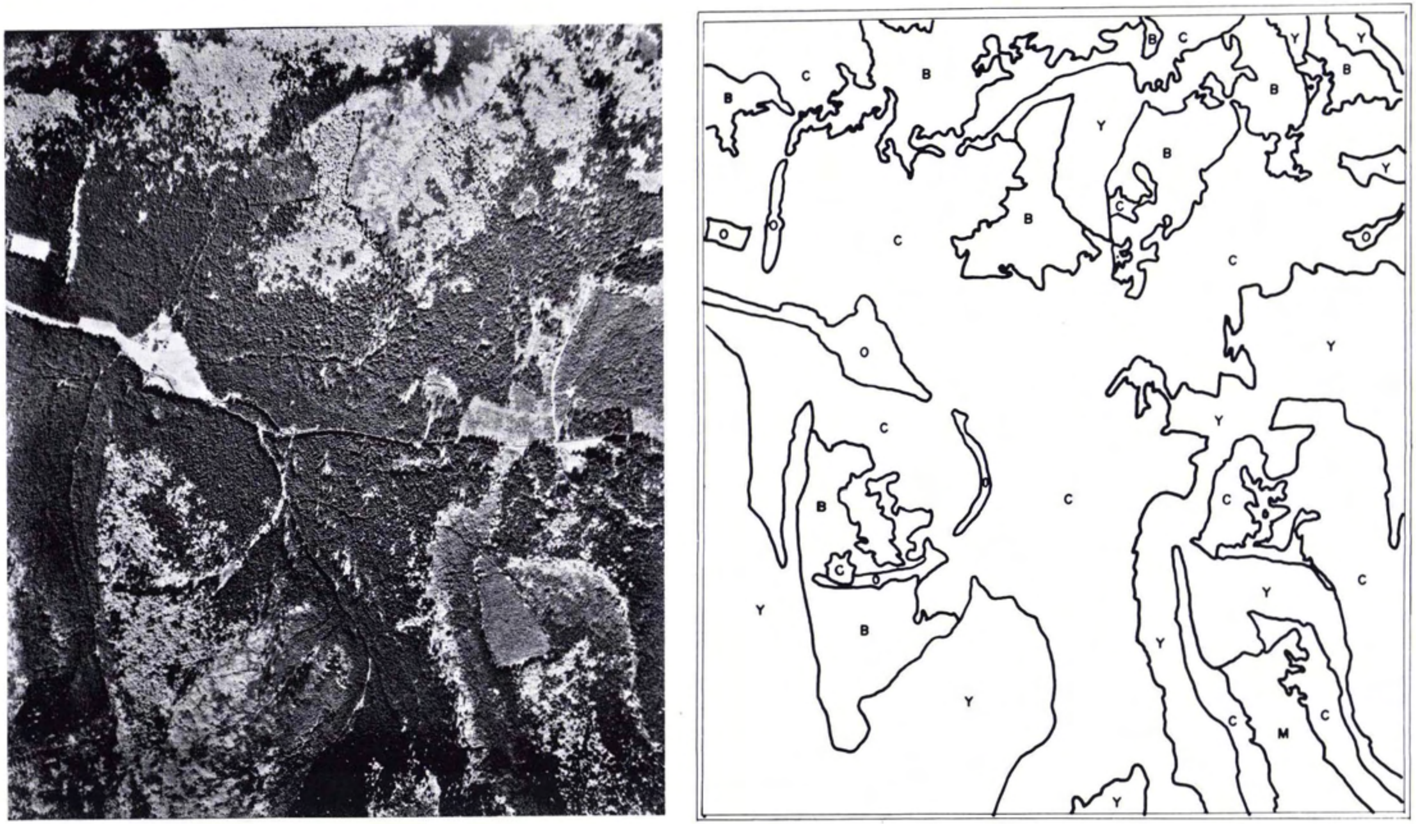


Fig. 8. Characteristic curve of a lith film.



Broadleaves (b) *Conifers (c)*

Fig. 9. Lith film broadleaves (b) and conifers (c) density slices, copies.



(a) (b)

FIG. 10. Aerial photo of the forest (a) and photo-interpretation of the area (b).

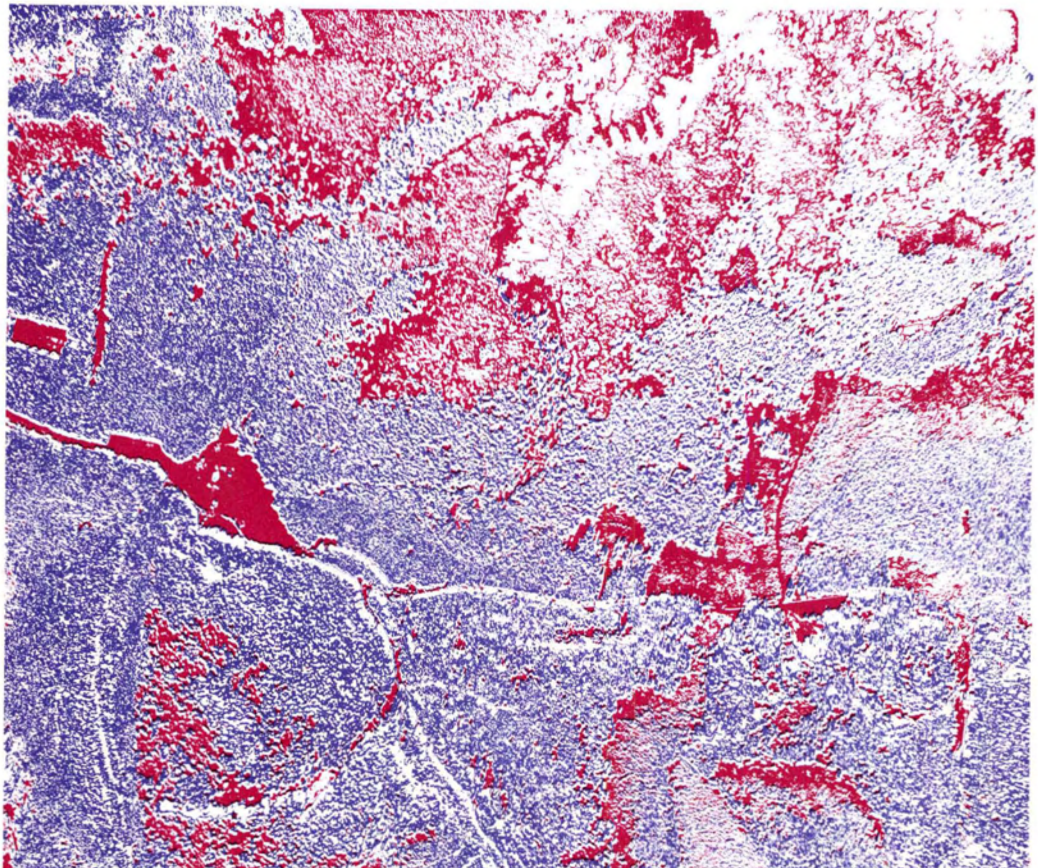


PLATE 1. Diazo color composite of the lith films.

known as infectious development. Except for the first few seconds, very little agitation is employed to provide still-bath development conditions. Because of its extreme contrast, lith film does not reproduce intermediate densities, providing only very high or very low densities. The critical problem when developing is that temperature as well as development time must be watched carefully.

The lith film only shows black-and-white dots or lines, making it well-suited for the reproduction of density slices. Figure 8 shows the characteristic curve of a typical lith film.

The density slices were then reproduced on lith film using a Zeiss KG 30 Contact Printer equipped with argon (violet and blue) light source. The argon light source was necessary since the lith film is an orthochromatic material. Figure 9 shows the resulting density slices on lith film for both conifers (c) and broadleaves (b).

Conclusion And Discussion

The resulting lith film copies of the density slices correspond to the conifer and broadleaf types. Figure 10 shows the forest type delineation and the aerial photograph of the area. Their similarity can be readily seen when compared with the copies on lith film.

The process can be enhanced further by producing a diazo color composite of the lith copies. Plate 1 shows the resulting color composite of the area.

From this experiment it seems feasible to produce a delineation between conifers and broadleaves. However, it should be noted that there was a large ΔD between conifers and broadleaves to begin with, which meant there existed a visible differentiation between them. Nonetheless, the rough delineation obtained could be used for preliminary sampling for inventory purposes. A more detailed delineation (old and young stands subdivisions) does not seem feasible due to the small density differences involved. However, the problem was not explored further. It may be possible to do this delineation using a larger scale photography than the one used in this experiment.

It seems evident from the results obtained that density slicing can be used for this type of delineation. The main advantage is that the system is quick once the densities are obtained and can yield a map (color composite or lith film copies) of the area, ready for observation and assessment. The method is rather simple once some experience has been acquired in handling the material. Also, it should be noted that the color composite renders the added information of the areas of mixed forest, which by itself constitutes a separate type.

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Articles for Next Month

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George Erio, Three-Dimensional Transformations of Independent Models.
Morton Keller, Photogrammetric Circulatory Surveys (PHOCIS)
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