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# Image Enhancement for Vegetative Pattern Change Analysis

**Photographic enhancement-overlay processing of aerial imagery gave improved results when compared with traditional change detection techniques.**

ABSTRACT: *Valid management decision making in natural resource planning is dependent upon an accurate data base and the ability to detect changes in resource status. Photographic enhancement-overlay processing of aerial imagery for change detection was developed and tested. Compared with traditional change detection techniques, the new method gave improved results in terms of general accuracy and the specific nature of changes occurring where the objects of interest could be isolated to a specific optical density range. Efficiency of the technique is directly affected by imagery scale and size of area to be monitored.*

## INTRODUCTION

NATURAL RESOURCES have always been of vital importance to man, and recent increasing demands on them have progressively intensified the need for improved management (Carneggie and DeGloria, 1973; Shepard, 1964). Monitoring changes in elements of concern to resource managers consitutes an important phase in the management process. Changes reflect how the environment is reacting to management practices and, thus, provide input for an evaluation of the practices.

Most sequential monitoring techniques contain the major disadvantage that, unless the data are collected while the change is actually occurring, the exact time of the change cannot be documented but only speculated about within the time span of the sequential collection of data (El-Ashry and Wanless, 1967). However, sequential monitoring can provide managers with information on (1) the nature of change, (2) the location of change, (3) the magnitude of change, (4) the direction of change, and (5) variations in the rates of change (Estes *et al.*, 1972). Time spans between sequential data collection dictate the degree of accuracy to which a manager can determine these aspects of change. An effective monitoring system would be one providing relevant, nonredundant information in an efficient and cost effective manner which can be readily used with a sustained management information system (Paul, 1976; Shepard, 1964).

Change detection of resources has been carried out in various subfields of resource management in attempts to obtain broad ideas of resource conditions. Studies have shown aerial photography to be superior to other data collection methods because it allows assessment of a complete area and provides an accurate recording of surface situations (Collins, 1972; Driscoll, n.d.; Shaklee, 1976). Studies reviewed here were based on aerial photographic data collection; however, various analysis and change detection procedures were employed.

## LITERATURE REVIEW

Traditional interpretation and mapping techniques seem to be most frequently used in studies involving change detection. Baseline conditions are interpreted and mapped from imagery which is then compared with information drawn from sequential imagery of the same area. Measures of the total area covered by a resource of concern are taken from both sets of aerial photography. This information is then compared to determine change in total area (Avery, 1965; Bubenik, 1976; Collins, 1972; Estes *et al.*, 1972; Richter, 1969; Wray, 1971). Locations of change have been determined from sequential data by overlaying maps drawn from the imagery at the same scale or by projection of an image onto a baseline map (Milazzo and Lins, 1972; Olson and Meyer, 1976; Shaklee, 1976; Wagner, 1963). These traditional interpretive techniques are time-consuming, wearisome, and subject to omission errors (Shepard, 1964).

Techniques have been developed which consider the problems of traditional interpretation and attempt to reduce amounts of interpretation needed to determine change. Sequential images can be subtracted or averaged with one another by overlaying positive and negative transparencies of an area in register. This results in an image in which areas that have not changed appear medium gray while areas of change appear as light or dark tones (Jones *et al.,* 1975; Reeves, 1975; Simonett, 1974). A "blink" process permits viewing of sequential images alternately at about ten frames per second. Areas on the image which "blink" as the pictures are alternated represent areas which have changed (Masry *et al.,* 1975; Simonett, 1974). These techniques are limited, in that changes of interest to policy makers may be embedded in a "larger amount of extraneous change, or clutter" (Simonett, 1974: 64).

Electronic scanning equipment also has been employed to reduce traditional interpretation needed to detect change. A peripheral processor scanner was utilized as a "quick-look" change detection technique. The scanner records edges of objects on sequential photographs that are subsequently compared by using a computer (Humiston and Tisdale, 1973). Density changes of natural vegetation on sequential imagery have been detected by employing an electronic density scanner. Values computed result in an "index" which increases as differences in vegetation on sequential photography increase (Rouse *et al.,* 1973).

Frequently, resource managers are overwhelmed by the expense and sophistication of some of these change detection techniques and conclude that they cannot be of assistance to a particular management problem. However, demand for rapid collection of information exists, and aerial photography must be considered as a means to provide administrators with the required understanding or with the capacity to efficiently acquire an understanding of resources (Carneggie, 1970; Poulton, 1970).

One of the main limitations of interpretation is the restricted ability of the human eye to readily recognize subtle differences in the diagnostic characteristics of images (Nielsen, 1974). Image enhancement techniques have been developed which reduce this restriction through alteration of the image, accentuating slight differences which could be of interest to the observer. There are primarily two enhancement processes; electronic, which converts image densities to voltage, and photographic, which alters an image by re-exposing it on photographic film.

Electronic processes which can change image densities to voltage display densities, on a cathode-ray tube, allow for various enhancements of an image. Density-slicing or the separation of density ranges is the basis upon which this process works. Density ranges are imaged as separate colors, displayed all at once or separately on a television screen (Sayn-Wittgenstein, 1973; Schlosser, 1974).

Several photographic processes which have been employed to assist the interpreter in identifying subtle image differences include: tone contrast stretching, posterization, edge isolation, Sabattier effect, Agfacontour density-slicing, and litho density-slicing (Clarke, 1967; Kodak, 1973; Nielsen, 1972, 1974; Rodriguez-Berjarano, 1975; Ross, 1976; Simonett, 1974).

Image enhancement provides a technique which can be used to isolate images of selected resources. Isolation of these images can be a means of elimination of the problem of "clutter" effecting interpretation of changes discussed by Simonett (1974). Thus, a combination of an enhancement process to isolate images and an overlay process of positive and negative transparencies of sequential imagery to detect change should provide resource managers with a method which gives information rapidly and can be utilized easily.

Many changes of interest to land managers have a direct effect on vegetation and result in alteration of vegetative patterns. Plant communities integrate separate growth factors which affect the community, and provide a biological expression of these factors through the structure and components of the community (Poulton, 1970). Vegetation has been used in numerous studies to monitor and detect significant resource conditions including urban, wildlife, geologic, and ecologic analyses (Collins, 1972; Dill, 1963; Driscoll, n.d.; Ducker and Horton, 1971; Estes *et al.,* 1972; Hanson and Smith, 1970; Jones *et al.,* 1975; Larson, 1967; Lewis, 1974; Morrison, 1972).

Presently, the gap which exists between capabilities for gathering extensive amounts of aerial imagery and the limited capabilities for handling and analyzing it restricts resource managers in their ability to utilize this source of data in their management decision making process. A monitoring system utilizing a combination of enhancement techniques and change detection processes could provide resource managers with relevant and easily applied information (Carneggie, 1970; Harrell *et al.,* 1966).

The objectives of this study were

(1) To test various image enhancement techniques for their applicability to detection of change on sequential photographs;

(2) To determine the accuracy of a selected enhancement technique for its ability to detect change in sequential photographs;

(3) To test the developed technique using image enhancement and overlay transparencies for the detection of change in vegetative patterns on aerial photography; and

(4) To develop conclusions based on accuracy and expense of the developed technique, concerning its practical application as a change detection procedure for resource management.

## METHODOLOGY

A review of enhancment techniques suggested that density-sliced images would be best suited to change detection. A study of litho-photographic masking, Agfacontour, Sabattier effect, and electronic density-slicing led to a choice of using photographic masking as a study process, because of its applicability to a wide range of users and availability of materials. The application of this process was tested using model situations and sequential aerial photography.

A density step chart was employed to model objects of various tones.* Exposures of the density chart were made onto ortho type film with exposures beginning at 2.5 seconds and at 2.5 second intervals up to a final exposure of 10 seconds. These negatives were then contact printed on ortho film to produce positives. Resultant positives and negatives of different exposures were overlaid in order to mask specific density ranges.

Simulation of aerial photography was achieved through use of near vertical photographs taken of a three-dimensional landscape model. An initial picture was taken of the model to represent a baseline condition. A second photograph was taken after several changes had been made in the simulated trees. Exposures of the initial negatives were made on ortho film beginning at a 5 second exposure and continuing at 5 second intervals terminating with a 60 second exposure. Contact prints were made from these positives to produce negatives. In order to determine which density-slice resulted in the best image of trees, positive and negative images of differing exposures were combined and visually analyzed. To further refine this density-slice, additional exposures were made between the lower and upper limits of the selected density range.

Application of this enhancement process to sequential aerial photographs was achieved by following procedures used for enhancement of photographs taken of the three-dimensional simulation model. Sequential photographs utilized were taken in April of 1951 (CVC-5H-81) and in December of 1962 (CVC-200-269) of an area adjacent to the Double Mountain Fork of the Brazos River in Garza and Kent counties, Texas. Negative transparencies were utilized from Western Laboratory, Aerial Photography Division, ASCS-USDA, Salt Lake City, Utah. Negatives were photographed with 35 mm Plus X Pan film. Exposure settings for these copies were ½ second and *f* stop varied from *f* 5.6 to *f* 16 at ½-stop intervals to insure obtaining images of appropriate exposure for both photographs.

Resultant positives were visually analyzed in order to determine two with similar den-

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* Density in this case refers to optical density which is a function of transmitted light. Density is determined by using the following formula:

Density = $\log_{10}$ [intensity of incident light/ intensity of transmitted light] (Nielson, 1974) sities and contrast. Density-slices were produced employing techniques described for enhancement of the simulated aerial photographs.

A specific study region of 2.25 square miles was selected on the aerial photographs to encompass areas in which coverage of woody vegetation seemed to have changed. A coordinate grid was established within the universe to divide it into 576, 2.5-acre sample sites. Ten sample sites were then randomly selected for detailed study.

Density-slices which resulted from enhancement of sequential photographs were contact printed into ortho film to produce positive and negative images. Positive and negative density-slices of differing sequential photographs were then sandwiched together to produce an image of changes (Figure 1).

Analysis of changes was done through visual comparisons. Negative aerial density-slices were projected onto a 24 by 24 grid at a scale of 1:3960 for the visual comparison. Sample sites were located and percentage tree cover was visually estimated from the 1951 and 1962 enhanced images separately. A positive density-slice of the 1962 photograph was then overlaid with the 1951 negative density-slice to depict subtractive changes (Figure 1). Secondly, the 1951 positive density-slice was overlaid with the 1962 negative density-slice to show additive changes (Figure 1). Net change was computed for each sample site using the formula:

$$C = a - s$$

Where C = percentage of net change in tree cover,

a = percentage additive change in tree cover, and

s = percentage subtractive change in tree cover.

In order to evaluate these estimates of percentage tree cover change, the sum of net change and 1951 tree cover estimates was compared to the estimates of cover from the 1962 density-slice. These two estimates theoretically should have been equal. Estimates which differed by more than ten percent were investigated in order to determine the cause of the difference.

Change in percentage tree cover from 1951 to 1962 on the ten sample sites was also estimated using traditional interpretive techniques as described by Avery (1977). Unenhanced sequential transparencies of the area were individually projected onto a 24 by 24 grid at a scale of 1:3960, on which sample sites were located and percentage tree cover estimated. A difference of these two estimates gave net change.

In order to make a valid quantitative comparison, results obtained and time involved for both methods were considered. Accuracy was tested through a comparison of net percentage change estimated using both techniques. Estimates which were within a 10 percent range of one another were considered acceptable values. Those which were not within this 10 percent range were reexamined to determine why they were not. Time involved in each process tested was compared in order to determine which provided the most economic method of detection of changes in vegetative pattern.

## RESULTS

Simulation of image enhancement illustrated which positive and negative trans-

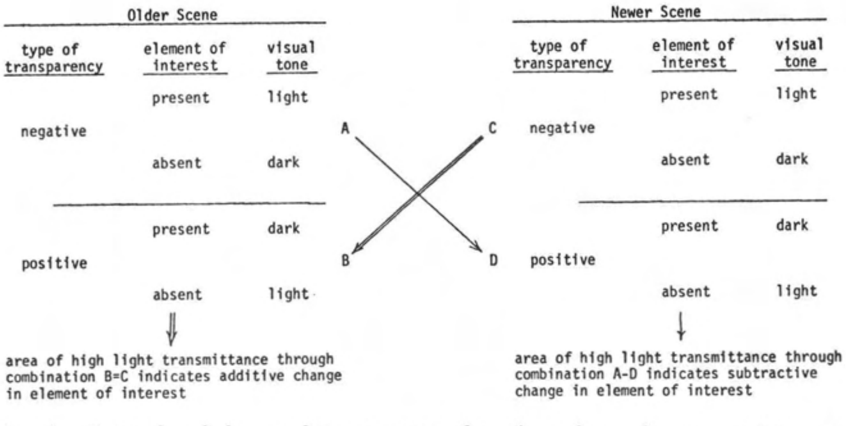

FIG. 1. Example of change detection procedure for enhanced sequential imagery (Jones *et al.*, 1975).

parencies should be combined to image a specific type of change. Additive change such as an increase in numbers or size of individuals was detected by a combination of the new scene negative and the old scene positive (Figure 1). Subtractive change such as a decrease in numbers or size of individuals was imaged by a combination of the old scene negative and the new scene positive (Figure 1).

Positive transparencies, resulting from incremental exposures of the initial landscape model photograph, produced the full density range of that image. An exposure of 5 seconds resulted in an almost transparent image while a 60 second exposure was opaque. An initial image of simulated trees was produced from the density-slice using the 5 and 10 second exposures. Within the density range some objects other than vegetation appeared; therefore, the range was further reduced by combining the 10 second positive with a 6 second negative transparency. Reproduction of this density-slice from the second sequential negative of the landscape model was obtained by systematic adjustment of exposure and scale settings. Table 1 lists enlarger settings, resultant scale comparisons, exposure times, and resultant tone comparisons of these incremental exposures. Settings resulting in desired images were then used to produce 4- by 5-inch positive and negative transparencies.

Changes which were detected by overlaying positive and negative density-slices of these simulated aerial photographs were compared to those known changes which had been imposed on the landscape model. Changes imposed included two additions and three subtractions of simulated trees. These imposed changes were detected. In addition, a slight change resulting from an inadvertent loss of a small portion of a simulated tree was detected.

Enhancement of the sequential aerial photography resulted in images of density ranges in which trees appeared. A 12.5 second negative and a 23 second positive produced the final density-slice of trees in the 1951 imagery. An enhanced image of trees in the 1962 photography resulted from combining a positive of a 16 second exposure and a negative of a 9 second exposure. Negative density-slices which imaged vegetation of interest from both photographs are illustrated in Figure 2. Processing of these density-slices and contacts from them required 3.83 hours.

Estimates of percentage tree cover in sample sites were made from negative density-slices of the 1951 and 1962 photography. Positive density-slices were then overlaid which resulted in images from which percentage cover change was estimated. Figure 3 illustrates these subtractive and additive changes. An estimate of net change resulted from a difference of additive and subtractive changes (Table 2). These estimates from enhanced photographs required 35 minutes.

Estimation of percentage tree cover from the original 9- by 9-inch transparencies for each sample site provided data with which to determine percentage net change. Percentage cover estimates from both dates and net change are listed in Table 3 for each sample site. These interpretations took 55 minutes to complete.

A comparison of net percentage cover change, using both change detection techniques, revealed that estimates were significantly different for a majority of the sample sites (Table 4). Four categories of differences were apparent; those from 75 to 85

TABLE 1
REPRODUCTION OF INITIAL DENSITY-SLICE

| Enlarger Setting (inches) | Scale Comparison | Exposure Time (seconds) | Density Comparison With Previous 10 Second Exposure |
|---|---|---|---|
| 11 19/32 | larger | 10.0 | darker |
| 11 11/32 | smaller | 5.0 | lighter |
| 11 15/32 | smaller | 7.5 | matches |
| 11 17/32 | smaller | 7.5 | matches |
| 11 9/16 | matches | 7.5 | matches |
| | | | Density Comparison With Previous 6 Second Exposure |
| 11 9/16 | matches | 5.0 | darker |
| 11 9/16 | matches | 4.5 | lighter |
| 11 9/16 | matches | 4.7 | lighter |
| 11 9/16 | matches | 4.8 | matches |

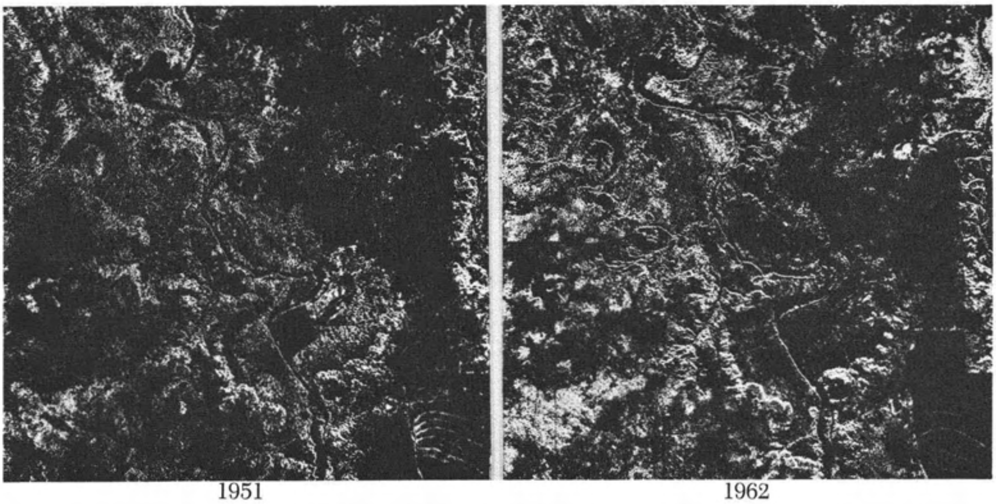
1951 1962

FIG. 2. Density-slices imaging vegetation of interest.

percent, from 30 to 35 percent, from 15 to 17 percent, and from zero to 10 percent. Sample sites which fell into each of these categories were re-examined in order to determine reasons for such a wide range of results.

Sample sites 1, 7, and 10 had the greatest difference between the two techniques. After an examination of the aerial photographs, it was determined that these sample areas all fell within the same general vegetation type. Estimates of cover made in this area were similar for the 1951 images using both techniques because the original image was of high contrast, and trees were easily interpreted. However, 1962 estimates varied considerably because of low contrast in the original image. Evergreens were visible on the projected original transparency; however, deciduous vegetation was indistinguishable from grass because of only a slight density variation. Enhancement of the 1962 photograph imaged deciduous as well as coniferous vegetation, both of which were elements of interest. Thus, a more accurate estimate of net change in woody vegetative cover was made using the enhancement-overlay change detection process on these three sample sites when compared to traditional interpretation techniques.

Differences of net change for sample sites 5 and 6 were from 30 to 35 percent. An examination of the original photographs revealed that these sites were also in areas which were similar in vegetation and topography. Differences between net changes estimated were a result of two factors for these sites. Shadows and low contrast of the original 1962 transparency limited interpretive

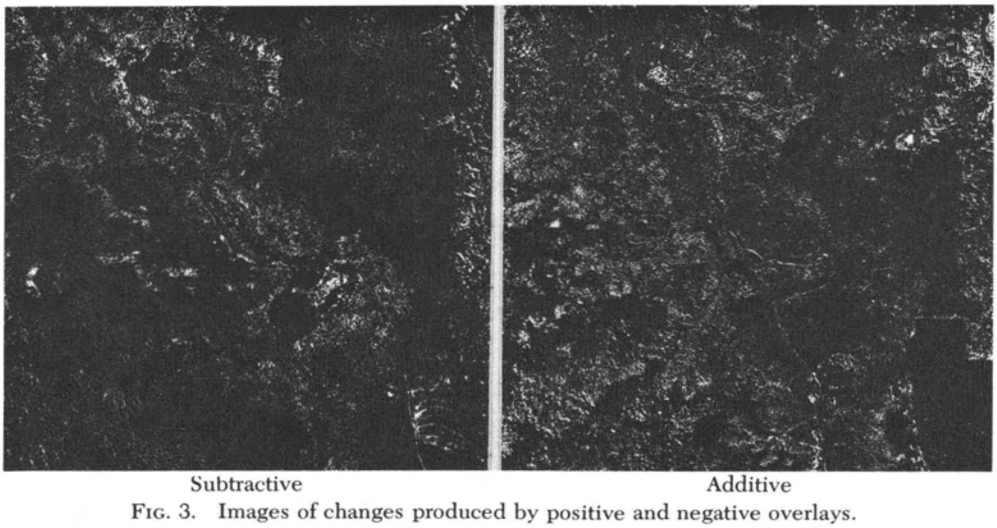
Subtractive Additive

FIG. 3. Images of changes produced by positive and negative overlays.

TABLE 2
TREE COVER ESTIMATES FROM DENSITY-SLICE, ENHANCEMENT-OVERLAYS

| Sample Site | 1951 % Cover | 1951 % Subtractive Changes | 1962 % Cover | 1962 % Additive Changes | % Net Change | % Remaining Constant |
|---|---|---|---|---|---|---|
| 1 | 60 | 25 | 70 | 45 | +20 | 35 |
| 2 | 10 | 0 | 25 | 15 | +15 | 10 |
| 3 | 15 | 10 | 15 | 10 | 0 | 5 |
| 4 | 40 | 25 | 10 | 3 | −22 | 15 |
| 5 | 10 | 5 | 40 | 30 | +25 | 5 |
| 6 | 30 | 25 | 15 | 10 | −15 | 5 |
| 7 | 20 | 5 | 70 | 60 | +55 | 15 |
| 8 | 20 | 10 | 10 | 5 | −5 | 10 |
| 9 | 20 | 5 | 40 | 15 | +10 | 15 |
| 10 | 85 | 20 | 85 | 25 | +5 | 65 |

capability in these areas. Enhancement of the 1962 photograph imaged vegetation of interest and eliminated shadows which impeded traditional interpretation.

Sites in which problems with the enhancement-overlay process were encountered are 2 and 4. Within these sites were features which were not elements of interest but which fell within the same density range as woody vegetation. Differences in net change reflect these added elements which were not interpreted as woody vegetation on the projected original transparencies.

Sample areas which were within a 10 percent range for net changes were considered reasonable for visual estimation of vegetative cover. Sample sites which fell within this limit were 3, 8, and 9. These were in areas of varying topography and vegetation; however, percentage tree cover in these areas was low. Vegetation of interest was imaged well in these three areas, which led to acceptable estimates of cover using both techniques.

Data which resulted from the two change detection techniques (Tables 2 and 3) varied also in total information provided. Through traditional interpretation, estimates of percentage cover from each original transparency led to net change. However, with the enhancement-overlay technique the percentage cover removed, added, and/or remaining constant, could also be estimated.

A comparison of time involved with each technique showed that preprocessing of images restricts efficient use of enhancement-overlay techniques to large areas. Preprocessing involved 89 percent of the time spent in the analysis of the 25 acres sampled. The difference in time spent for the two techniques was 3.5 hours less for traditional interpretation. However, the actual estimation of percentage tree cover took 37 percent less time using the enhanced images.

Time involved for preprocessing of the study region resulted in enhancement of the total 1440 acres. An estimate of tree cover by interpretive techniques for 1440 acres would have taken 53 hours, while it would have taken only 38 hours to do the same evaluation using preprocessing and overlays. This would have represented a 28 percent savings in time involved for analysis of the total area.

## SUMMARY AND CONCLUSIONS

The best possible understanding of the

TABLE 3
TREE COVER ESTIMATES FROM TRADITIONAL INTERPRETATIVE TECHNIQUES

| Sample Site | 1951 Percent Cover | 1962 Percent Cover | Percent Net Change |
|---|---|---|---|
| 1 | 70 | 5 | −65 |
| 2 | 5 | 5 | 0 |
| 3 | 15 | 15 | 0 |
| 4 | 15 | 10 | −5 |
| 5 | 10 | 5 | −5 |
| 6 | 30 | 50 | +20 |
| 7 | 25 | 5 | −20 |
| 8 | 20 | 5 | −15 |
| 9 | 10 | 10 | 0 |
| 10 | 90 | 10 | −80 |

TABLE 4
COMPARISON OF NET CHANGE VALUES

| Sample Site | Net Change Enhancement-Overlay | Net Change Interpretation | Difference |
|---|---|---|---|
| 1 | +20% | −65% | 85 |
| 2 | +15% | 0% | 15 |
| 3 | 0% | 0% | 0 |
| 4 | −22% | −5% | 17 |
| 5 | +25% | −5% | 30 |
| 6 | −15% | +20% | 35 |
| 7 | +55% | −20% | 75 |
| 8 | −5% | −15% | 10 |
| 9 | +10% | 0% | 10 |
| 10 | +5% | −80% | 85 |

natural environment is vital to administrators as a basis for planning and management decision making. Aerial photographic interpretation has been proven to be a valuable technique in collection of basic data; however, monitoring of changes through traditional interpretive techniques is a tedious and time-consuming process. Photographic enhance-overlay processing of imagery for change detection, developed and tested in this research program, appears to offer natural resource managers an effective alternative for detection of changes in resources of concern.

Accuracy of enhancement-overlay change detection was evaluated through a comparative analysis of change data obtained from the enhancement-overlay technique and from traditional photographic interpretive procedures. Results of this comparison indicate 30 percent of the sampled units were equally evaluated using both techniques. Evaluations of 50 percent of the sample units were improved using the enhancement-overlay technique because of typical problems encountered with traditional interpretative processes. Traditional photographic interpretation apparently evaluated 20 percent of the sample units more accurately than the enhancement-overlay technique because of extraneous objects within the density range of interest. This analysis suggests an overall improvement using the enhancement-overlay process for change detection. In addition to improved results, enhancement-overlay processing provides more thorough information on the specific nature of changes which have occurred.

Preprocessing of imagery for employment of this technique represents a limiting factor. Preprocessing time should be considered as an added cost of providing more thorough and accurate data. As enhancement-overlay processing is developed into a continuous monitoring system, the cost of preprocessing will be reduced because baseline data already will be available for subsequent analyses.

Photographic variables which in theory can affect the results of image enhancement-overlay processing are focal length, film, flying altitude, time of day, time of year, and camera systems. Problems which are caused by these variables are perspective differences, scale changes, seasonal vegetative changes, shadows, and optical densities which differ from one camera system to another and from center to the edge of a particular image. The most critical of these is photographic scale correlation, which can be manipulated through image processing.

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# *Forum*

## A Correction on Light Diffusion Underwater.

During the first half of this century the understanding of underwater light attenuation was at such an infant stage that diffusion was not even considered in the attenuation equation.* It was in the 1950s that material published about this area began to account for diffusion as an aspect of oceanography. Even then, and still, the correct diffusion rate in water is not employed. It is presumed that the diffusion rate in water would be the same as encountered through air, i.e., the inverse square of the distance, but in actuality the diffusion rate is approximately 0.75 the inverse square of the distance. When the light photon enters the water medium it experiences a change in speed, a proportional change in direction, and also an equal adjustment to its diffusion rate, described by Albert Einstein's theory of relativity as "time dilation". Therefore, using an illumination source at a stipulated distance underwater will effectively cover only 75 percent of the surface area experienced for that same distance through air. This fluctuates somewhat since the degree of refraction, and the difference in the photon's speed, changes very slightly with differences in the temperature and pressure of the water and also with the individual wavelength being transmitted. Simple tests at close distances confirm this and indicate that its effects should be experienced when observing and photographing underwater.

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* $E = \frac{Le^{-\alpha d}}{d^2}$

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