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Color and IR Photos for Soils

Color stereo photos surpass both B & W and IR for interpreting drainage classes and for classifying slopes.

ABSTRACT: *A quantitative method measured the accuracy of interpreting soil characteristics from black-and-white, infrared, and color aerial photos of selected sites in Onondaga County, New York. These sites represent a diverse set of soil forming conditions, soil parent materials, and several types of vegetative cover. Color and infrared photos were better than black-and-white photos in interepreting soil drainage and slope.*

INTRODUCTION

SOIL SCIENTISTS HAVE been making soil surveys in the United States since the turn of the century. They have examined the morphology of soils in the field, have classified these soils, and have constructed soil maps which pictorially separate the different soils occurring in the field. U. S. Geological Survey topographic maps or plane table maps[1] were used as a base for the early soil surveys. In 1929 Jennings County, Indiana[2] was soil surveyed using aerial photographs as a base for the soil maps. This new method proved so successful that since the mid 1930's most soil surveying in the United States has been done on aerial photos.

The base maps now commonly used by the National Co-operative Soil Survey are flown with panchromatic film[2] at a scale of 1:20,000. In most soil surveys the maps used in the field are these 1:20,000 photographs enlarged to a scale of 1:15,840 or four inches per mile.

In recent years great progress has been made in the development of new kinds of film for aerial photography. Color and infrared photographs have been used by Colwell and others[3] to detect crop diseases, weed growth in fields, crop identification and yield estimates, estimating crop vigor, and insect infestations. They also have been used to detect various kinds of pollution in streams,[4,5] and to study rock formations in the field of geology[6]. Simakova[7] conducted a study with 1:25,000 aerial photos near the Caspian Sea. His results show that photos made from two-layer spectrozonal color film to be more accurate in interpreting soil types than black and white photos. In an investigation in the Sierra Navada Mountains in California[8], Dominquez concluded that boundaries between soil types could be delineated more accurately and more quickly on color than on black and white aerial photos. Parry[9] found in working with small freshly plowed fields in Quebec, that soil types and soil boundaries could be interpreted more accurately from color aerial photos than from black and white photos.

The present investigation was undertaken to determine if color and infrared aerial photos are superior to black and white for making interpretations of selected soil characteristics. The test was made by measuring the accuracy of interpretations made from aerial photos against an acceptable soil map made in the field with a large amout of on-site checking.

MATERIALS AND METHODS

Four kinds of aerial photographs were used. Three were at a scale of 1:12,000 (5.28 inches per mile) and the fourth was at 1:7,920 (8

* Submitted under the title "Soil Interpretation with Color and Infrared Photographs." The author is also employed by the U. S. Department of Agriculture Soil Conservation Service as a soil scientist. The 1:12,000 aerial photos used in this study were furnished by Eastman Kodak Company, Rochester, New York.

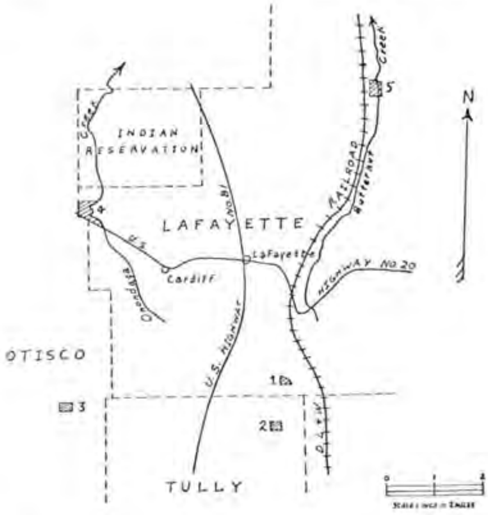


FIG. 1. Map of soil sites, Onondaga County, New York.

inches per mile). The 1:12,000 aerial photographs were: Kodak Ektachrome Infrared Aero film, type 8443, Kodak Ektachrome MS Aerographic film (Ester Base), type SO-151, deveolped to a negative as described in the Kodak Aero-Neg System, and black-and white-prints made from the Kodak SO-151 negatives.

The camera used for taking the 1:12,000 photographs was a Wild RC-8 with a six-inch Universal Aviogon lens. The 8443 film was exposed at 1/250 second at f/6.8 with a Wild 500 nm Pan 2.0×A.V. 1.4 filter. The SO-151 film was exposed at 1/200 second at f/5.6 with a Wild A.V. 2.2 (antivignetting) filter. The black-and-white prints were printed on Kodak Panalure Paper from the SO-151 negatives. The photographs on 8443 film were made between 11:20 and 12:30 A.M. and those on SO-151 film between 1:40 and 2:40 P.M. on September 9, 1966.

United States Department of Agriculture panchromatic photography[2] was the fourth type used in this investigation. The photographs were made on June 22, 1966 at a scale of 1:20,000. They were photographed with a vertical camera equipped with an $8\frac{1}{4}$-inch focal-length lens, which exposed a 9×9-inch image area. Enlarged prints were made from the negatives to bring the scale up to 1:7,920.

Five sites representative of soil materials and landscapes in Central New York State were selected for the study (Figure 1). Von Engeln[10], in writing about the glacial geology of this part of the Finger Lakes district, described the area as having "remarkable scenic and scientific interest." Sites 1, 2, and 3 are on glacial till uplands, and sites 4 and 5 are on a mixture of alluvium, outwash, and lacustrine sediments in glacial through-valleys.[11] The sites ranged in size from 41 to 106 acres. Stereo pairs were available for all sites.

After a site was selected the following investigation procedure was followed. Each site was examined on a single 1:12,000 black-and-white, infrared, and color photograph. All areas of similar tonal or color pattern were delineated on a clear plastic overlay with india ink. The areas were numbered and briefly described as to color and contrast. Each area was interpreted as to soil drainage, substratum or parent material, soil depth, and erosion where applicable. After the photos were examined singly they were examined again using a standard mirror type stereoscope. Areas were delineated as before, but soil slope became an additional factor. Using this method, six sets of interpretations were obtained for each site; black and white single and stereo, infrared single and stereo, and color single and stereo (Figure 2 is a control soils map with stereo interpretations). In order to reduce the bias that might accumulate in studying the photos consecutively, different sequences were used on different sites.

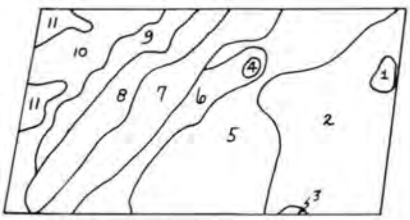
After the office interpretations, the black-and-white, 1:7,920-scale map was taken to the field and used as a base to make a soils map of the site. This was the only time that the site was examined in the field. Soils on the map were delineated and designated by appropriate symbols for soil series, slope, and erosion phases. The resulting soils map at a scale of 1:7,920 was used as a control map against which the accuracy of the interpretations made on the other maps was judged.

Concepts of established soil series set up in Onondaga County by the National Cooperative Soil Survey were used in making the control soil maps. Eight drainage catenas grouped the 24 soil series used in the investigation. Four soil series represented the drainage sequence in each catena (not all the members of each catena were observed in the study). In addition to the soil series, three miscellaneous land types were mapped on the sites.

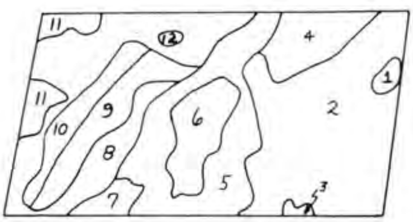
The upland soils are members of four catenas in glacial till. Included are: deep, slightly acid to neutral soils with textural *B*-horizons, formed in sandstone and shale dominated till (Hapludalfs); moderately deep (20 to 40 inches to bedrock) strongly acid soils formed in siltstone dominated till (Dystrochrepts); deep, strongly acid soils with a fragipan in the subsoil formed in siltstone dominated till (Fragiochrepts); deep, slightly acid to neutral soils with textural *B*-horizons formed in glacial till mixed with glacial lake sediments (Hapludalfs).

The valley soils are members of four catenas in glacial outwash, lacustrine sediments,

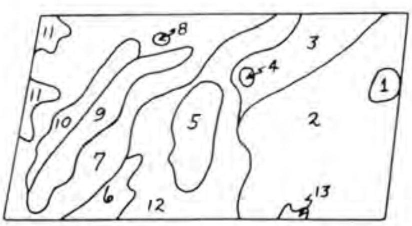
Site 2 -- Control Soils Map



Map 10 -- Black & White Stereo



Map 11 -- Infrared Stereo



Map 12 -- Color Stereo

FIG. 2. Site 2 soils map and stereo interpretation maps.

TABLE 1. SYMBOLS USED IN IDENTIFYING SOIL SLOPE

Mapping Symbol	*Slope Group, percent*
A	0 to 3
B	3 to 8
C	8 to 15
D	15 to 25
E	25 to 35
F	35 to 70

and alluvium. Soils formed in glacial outwash are moderately acid to neutral and have a textural *B*-horizon (Hapludalfs). Soils formed in glacial lacustrine sediments are slightly acid to neutral and have a textural *B*-horizon (Hapludalfs). One catena is predominantly medium textured and the other is fine textured. The alluvial soils are neutral with little soil development (Eutrochrepts).

Slopes were identified as shown in Table 1. On the control map most of the map units were designated by a two-part symbol. The first number indicated the soil series. A dash separated the series name from the slope phase which was a letter as indicated above. Eroded areas had a three-part symbol. They were delineated as above with the addition of another dash and the number three. Hence a non-eroded area might have as a complete mapping symbol *20-C* and an eroded phase of the same soil the symbol *20-C-3*.

The accuracy of the photo interpretations made in the office was measured by the control soils map. The maps on acetate sheets at a scale of 1:12,000 were enlarged with a photo enlarger to a scale of 1:7,920. They were fitted to the exact outline of the control map and corrected for any distortion that had been introduced because they were made as overlays on several different aerial photos of the same site. New clear acetate overlay maps were then drafted at a scale of 1:7,920.

Each overlay map was placed over the control soils map for comparison. A dot counter having a scale of 1 dot equal to 0.156 acre was placed between the control map and the acetate map. The numbered areas on the interpretation map were measured by dots as to the amount of various kinds of soil delineated on the control map. The amount of the area that was interpreted correctly relative to parent material, depth, and erosion was indicated by the number of dots. On the single photos drainage interpretations were measured for accuracy, whereas on the stereo pairs both drainage and slope interpretations were measured and the amount of deviation from the control map was recorded. Slope was mapped in the six slope groups listed previously. Drainage was separated into four classes: well drained to excessively well drained; moderately well drained; somewhat poorly drained; and poor to very poorly drained.

For example, an area might have 10 dots of well drained, 15 of moderately well drained, and 6 dots of somewhat poorly drained soils. This same area might have 20 dots on a *C* slope, 5 on a *D* slope, 4 on a *B* slope, and 2 on an *A* slope. If the area was interpreted on the acetate overlay map as being a moderately well drained soil, then 15 dots were considered as having no deviation from the control, 6 dots were higher (dryer) drainage than on the control map so were given a +6, and 10 were of lower (wetter) drainage than the control map so they were given a −10 on the drainage measurement. If the area was interpreted on the acetate overlay as being on a *C* slope then 20 dots were considered as having no deviation from the control map, 5 dots were of a lower (flatter) slope group than on the control map so were given a −5, and 6 were on a higher (steeper) slope than on the control, so they were given a +6 on the slope measurement. The degree of deviation from the control was also indicated. Slope and drainage interpretations for this example would be recorded as follows:

Drainage							*Slope*						
−3	−2	−1	0	+1	+2	+3	−3	−2	−1	0	+1	+2	+3
		10	15	6					5	20	4	2	

The accuracy of the interpretations are indicated by the areas having zero deviation from the control map. The method of presenting the data indicates the direction of the deviation from zero by plus or minus, by magnitude indicated by numbers of dots, and by distance from zero deviation of one, two, or three slope groups or drainage classes. There were only four drainage classes recognized so maximum drainage deviation was three classes. Although there were six slope groups, no measurements varied more than three in either direction.

Results and Discussion

Each site had a unique grouping of soils, therefore each stereo interpretation map is discussed separately before they are summarized as a group. Results from the single interpretation maps are only summarized as a group. In soil survey it is common to use a stereoscope for studying aerial photos, therefore the value of the single interpretation maps is not as great as the stereo interpretation maps.

The surface textures of the soils on all of the sites range only from heavy silt loam to fine sandy loam. Because of this narrow range, it was not possible to separate different surface soil textures by any of the interpretive techniques that were attempted.

The infrared (Kodak type 8443 film) photographs were sharper and the overall quality of these photos was superior to either the color (Kodak type SO-151 film) or the black-and-white (black-and-white prints from Kodak SO-151 film) photographs. The superior quality of the infrared over the other photographs may have been due, in part, to having been flown earlier in the day. The sky in Central New York commonly clouds over or becomes hazy as the day progresses. A few small clouds were present on some of the color and black-and-white photos, but none were observed on the infrared photos.

Individual Sites

Site 1 is 41 acres in size, the smallest of the five sites that were investigated. Most of the area was idle land except for one small field of hay. Brome (Bromus inermis) and orchard (Dactylis glomerata) grasses were dominant with a few deciduous trees in low areas, along drains, and on one moderately steep spot. Slopes vary from 0 to 20 percent. Drainage ranges from well to poorly drained. The parent material is glacial till. Several small kettles indicate the former presence of stagnant ice in the area[12]. In some places the parent material appeared to be partly sorted or reworked by water (ice-contact stratified drift), but not enough to classify it as outwash.

The photo interpretation sequence and accuracy are shown in Table 2. This is the only site where the accuracy in interpreting drainage was greater on the black-and-white photos than on the color photos. The investigator had over ten years experience in interpreting black-and-white photos and little contact with color or infrared. This greater experience with black-and-white photos probably influenced the accuracy of the drainage interpretation. The color photos were the most accurate in predicting slope. All of the soils were deep (depth to bedrock was more than four feet) so accuracy in predicting depth to bedrock could not be measured. An eroded area of about two acres was delineated on the control soils map. The tall grass on the idle land obscured this feature so that it was not detected on any of the photos during interpretation.

Site 2 covers 53 acres and has the simplest soil pattern of the sites observed (Figure 2). Land use consisted of pasture, hayland and cropland. Deciduous trees and brush were scattered on the steeper slopes and in low areas near drains. Slopes vary from 0 to 60 percent. The soil ranges from well or excessively well drained to poorly drained. The parent material is glacial till. As on Site 1 several small kettles indicate the former presence of stagnant ice in the area. This site differed from the first in that there was no evidence that any of the till had been partly sorted by water. The photo interpretation sequence and accuracy are shown in Table 2.

The color and infrared maps were more accurate than the black-and-white in predicting drainage, the opposite of the results on Site 1. As on Site 1, the color interpretation map had the highest slope accuracy. Both slope and drainage were predicted much more accurately for Site 2 than for Site 1, probably because of the simplicity of the soil patterns on Site 2. Because all of the soils mapped in the area were deep to bedrock, accuracy in predicting depth to bedrock could not be measured. There were no eroded areas, and no erosion measurements were made.

Site 3 covers an area of 69 acres and included pasture, hayland, and cropland. The soils are all formed on glacial till, but differ from Sites 1 and 2 in that several areas have moderately deep soils (20 to 40 inches deep) over siltstone bedrock. Slopes vary from 0 to 12 percent. Drainage ranges from well drained to poorly drained. The photo interpretation sequence and accuracy are also shown in Table 2.

The accuracy of slope interpretations was below average on all three types of photography. This was the first site examined in the spring of the year, the first two having been interpreted and mapped the previous fall. The interpreter might have lost some of his proficiency in interpreting slopes with a stereoscope after not having done it for several months. Color was the most accurate for interpreting slopes, and infrared was the most accurate in determining drainage. There are several eroded areas and several moderately deep soils on this site. Eroded areas and moderately deep soils were confused on all three types of photographs. An apparent lag concentration of thin elongated coarse fragments of siltstone are scattered on the surface of the eroded areas. Similar coarse fragments are also scattered over the surface of the moderately deep areas which are underlain by siltstone bedrock at depths of 20 to 40 inches. Both kinds of areas appeared lighter colored than surrounding areas because of increased light reflection from the flat surfaces of the light gray siltstone fragments, hence the confusion in interpretation.

Table 2. Photo Interpretation Sequence and Accuracy

Interpretation Sequence	Photography	Stereo Maps: Drainage Accuracy	Stereo Maps: Slope Accuracy
Site 1	Black & White	40%	60%
2	Infrared	21%	57%
3	Color	37%	61%
Site 2			
1	Black & White	69%	57%
2	Infrared	74%	68%
3	Color	74%	72%
Site 3			
1	Infrared	59%	41%
2	Black & White	50%	38%
3	Color	53%	41%
Site 4			
1	Color	49%	67%
2	Infrared	44%	42%
3	Black & White	47%	50%
Site 5			
1	Infrared	30%	88%
2	Color	39%	93%
3	Black & White	31%	84%

Site 4 covers an area of 106 acres and included hayland, pasture, an apple orchard, and idle wet land. Trees were scattered along drainageways and brush covered some of the idle wet land. Most of the area was used for pasture or orchard. There are 39 acres of alluvium, 11 acres of glacial outwash, and 56 acres of lacustrine sediments at this site. The lacustrine sediments occur as a mantle from 40 to 60 inches thick over the outwash It was difficult to separate the two materials. Slope varies from 0 to 20 percent and drainage ranges from well drained to poor and very poorly drained (see Table 2).

The color photography was superior to both black-and-white and infrared in determining slope and drainage. There was a larger deviation in determining drainage accuracy on this site than on the first three sites. On all three types of photography about five percent of the areas were interpreted three drainage classes lower than the control map and about three percent were interpreted three drainage classes higher than the control map. The high interpretations reflect the difficulty in determining drainage on the outwash terrace covered with a mantle of lacustrine sediments. In this situation the investigator tended to interpret a higher drainage (better drained) than was actually observed in the field. The difficulty in trying to interpret drainage on alluvial soils resulted in the five percent placement three drainage classes too low. The dark colors of the alluvium influenced the interpreter to indicate lower drainage than actually occurred in the field. Accuracy in detecting parent material could be measured because several kinds of parent material occurred at this site. The results were nearly the same for all three types of photography; 40 percent accuracy on the black-and-white and infrared; and 43 percent on the color photographs. The generally low accuracy was caused by the difficulty in identifying the lacustrine sediments blanketing the outwash terrace.

Site 5 (Table 2) covers 90 acres and has the same parent materials as site 4. It has 21 acres of alluvium, 9 acres of lacustrine sediments, and 60 acres of glacial outwash. The area was in hayland and pasture, with trees and brush in idle areas along the drains and creek. Slopes vary from 0 to 30 percent and drainage ranges from well drained to poorly drained.

As on Site 4, the color stereo photographs were superior to the black-and-white and infrared in determining drainage and slope accuracy. On the black-and-white and infrared photographs a higher percentage was interpreted one drainage class too high than was interpreted correctly. The causes of the error was a 10-acre area of lacustrine sediments that was 20 inches deep over glacial outwash, and a large moderately well drained area of glacial outwash that appeared to the interpreter to be well drained. The interpreter gave a moderately well drained rating to most of the somewhat poorly drained lacustrine sediment over outwash. Slope was interpreted very accurately on this site, because there are 21 acres of level alluvium on Site 5, and most of the outwash and lacustrine sediments are also on level to nearly level slopes. In addition it was possible to measure the accuracy of judging parent material because several kinds were mapped on the site. The results of comparing the interpretation maps with the control map were: black-and-white, 77 percent; color, 68 percent; and infrared, 67 percent accuracy. The area with 20 inches of lacustrine sediments over outwash material was regarded as having outwash parent material for this measurement. The results in identifying parent material was contrary to those of Site 4 where color photos were more accurate than black-and-white photos in predicting parent material.

SUMMARY OF THE FIVE SITES

Average drainage and slope accuracy for the five sites is shown in Table 3.

Single-photo interpretations for drainage were more accurate with infrared and color than with black-and-white aerial photographs. Drainage can be interpreted more accurately from stereo than from single photos. The input of slope on the stereo photos helps to create a favorable bias in determining correct drainage because in this region, where many soil materials are moderately to slowly permeable, soil drainage is closely related to landscape position.

On the average, color stereo photos surpass both black-and-white and infrared for interpreting drainage classes. If one drainage class deviation is included, as might occur if one is making low-intensity soil maps, the following accuracies were obtained: black-and-white, 80.5 percent; infrared, 83.7 percent; and color, 85.1 percent accuracy. The differences between the various types of photography are nearly the same as when no deviation from the correct drainage was considered. The summary of the five sites in Table 4 indicates there is little difference in the amount of deviation for drainage between the three types of photography. No statistically significant difference occurs between the three types of photography in making interpretations for drainage. The greater accuracy of the color over the infrared and black-and-white photography does indicate a trend in favor of color aerial photography for making drainage interpretations. Drainage interpretations

TABLE 3. AVERAGE DRAINAGE AND SLOPE ACCURACY FOR THE FIVE SITES

Photography	*Drainage Accuracy*		*Slope Accuracy*	
	Mean	*Standard Deviation*	*Mean*	*Standard Deviation*
Black & White				
Single	36.4%	9.8		
Stereo	43.2%	13.9	57.9%	16.9
Infrared				
Single	41.0%	8.5		
Stereo	47.1%	21.5	60.4%	19.5
Color				
Single	41.8%	16.2		
Stereo	49.4%	14.8	68.2%	18.8

TABLE 4. SUMMARY DATA OF ALL SITES

Kind of Photography	Percent Accuracy and Percent Deviation													
	Drainage							Slope						
	−3	−2	−1	0	+1	+2	+3	−3	−2	−1	0	+1	+2	+3
B&W		8.7	11.6	36.4	35.2	6.8	1.3							
Infrared	1.4	8.6	13.8	41.0	23.8	10.6	.8							
Color	1.3	7.2	11.8	41.8	24.1	12.3	1.5							
B&W stereo	1.9	6.2	13.8	43.2	23.5	10.6	.8	.2	.5	14.6	57.9	24.9	1.1	.7
Infrared stereo	1.3	4.4	13.3	47.1	23.3	9.6	.9	.2	1.5	11.3	60.4	24.6	1.3	.7
Color stereo	1.8	2.5	13.2	49.4	22.5	9.7	.9	.4	.8	11.6	68.2	16.9	1.3	.8

of color photography versus infrared photography was probably more accurate because the colors are more similar to features observed on the ground than are the reddish hues (false color) of infrared photography.

There was a slightly larger difference in the accuracy percentages for slope than for drainage. Color photography was 10.3 percent more accurate than black-and-white and 7.8 percent more than infrared when making slope interpretations. If a deviation included one slope group, the accuracy was: color, 96.7 percent; infrared, 96.3 percent, and black-and-white, 86.5 percent. As with drainage, little difference existed in the accuracy of the various types of photography if one considers either no deviation or one deviation from the correct slope. The standard deviations indicate no statistically significant difference between the three types of photography when making slope interpretations. The greater accuracy of the color over the infrared and black-and-white photography does indicate a trend in favor of color aerial photography for making slope interpretations.

Commonly the kind of soil material is interpreted by landform in this region; thus it is independent of type of aerial photography. Because only two sites had more than one kind of parent material, no conclusive results concerning the use of the three types of photography were obtained.

Erosion was difficult to determine on all types of photography in areas that were overgrown with tall grass. Eroded areas and areas moderately deep to bedrock were confused in all cases because both had flat elongated siltstone fragments scattered over the surface. These fragments made both areas look so similar that they could not be separated.

The surface texture of the soils in this investigation ranges from heavy silt loam to fine sandy loam. Because of this narrow particle size range, it was not possible to interpret for different soil textures.

The time of the year might have affected the results[13]. Late spring or early summer is commonly considered to be the best time to photograph soil drainage in this region. Slope is difficult to determine where the land is masked with dense vegetation such as tall grass or trees in full leaf. The best time to photograph slope, therefore, may be either in the spring before trees leaf out or after the leaves have fallen in the fall. The photos available for this study were flown in September; consequently they may not represent ideal conditions for either slope or drainage interpretations.

The experience of the investigator, with more than ten years of field work with black-and-white photography, and little with color or infrared photography, might have biased the results somewhat in favor of the black-and-white photography. The superior quality of the infrared photos might have biased the investigator in their favor, but the sequence in making the interpretations was designed to eliminate some of this bias. It was not evident that the sequence of interpretation had much effect on the overall results.

CONCLUSIONS

Twenty-four soil series and five miscellaneous land types were mapped in this investigation. The soil series are members of eight drainage catenas that represent soils of the uplands formed in slowly permeable glacial till, gravelly soils on outwash terraces, soils on terraces formed in glacio-lacustrine sediments, and soils on floodplains formed in alluvium. They varied in reaction from strongly acid to neutral, and in development from soils with weakly expressed horizons to soils with fragipans and textural *B*-horizons. Land use included crops, pasture, forest, hayland, orchards, and idle land in mixed brush, grass, and trees. The sites are typical of the region and the soils are representative of those in Central New York State. It is thought, therefore, that the conclusions apply to soil interpretations made from aerial photographs throughout much of the humid temperate glaciated region.

The investigation was undertaken to determine if color and infrared are superior to black-and-white photographs for making interpretations of selected soil characteristics. The stereo color and infrared interpretations were slightly more accurate than stereo black-and-white interpretations for predicting drainage and slope. This difference was not statistically significant, so these results only show a trend in favor of the color and infrared photography. Eroded and moderately deep soils formed in glacial till uplands could not be consistently distinguished from each other on the three types of photography used in this study. The sample was not large enough to compare adequately the accuracy in predicting parent material.

The method employed in this investigation quantitatively measures the accuracy of soil interpretations made from several types of aerial photographs. New films and photographic techniques are continually being developed. This method may be useful in determining if new films and techniques are more effective than those presently used in making high quality base maps for soil surveys.

In Central New York State, soil interpretations made in the office with the aid of aerial photographs are below the standards of soil maps made in the field. A great amount of soils information can be obtained, however, from the study of aerial photographs. Drainage can be correctly predicted nearly half the time and the correct slope group nearly two-thirds of the time. Increasing the accuracy of soil interpretations whether by substitution of color or infrared photographs for black-and-white, or photographing the area to be mapped at the time of the year that will more clearly reveal soil characteristics, should permit the soil scientist to make higher quality soil maps and do his field work more efficiently.

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