SEQUENTIAL AERIAL PHOTOGRAPHY AND IMAGERY FOR SOIL STUDIES

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Color infrared photographs from 6 dates during a 12-month period and thermal images from 4 times during a 19½-hour period are illustrated. The figures show agricultural fields located at the former shoreline of a small glacial lake. The contrast between the silty lake-bed soils and a small sandy beach ridge can be clearly seen. The contrast between this beach ridge and the surrounding lake-bed soils changes considerably during the year. The optimum time of the year for aerial photography for soil studies in southern Wisconsin is about May 1 to June 15. Based on the preliminary work reported here, it appears that thermal imagery has great potential use for soil-mapping purposes. There should be an optimum time of year and also an optimum time of day for obtaining thermal imagery for soil studies.

•THE INTERPRETIVE use of aerial photographs for soil studies may yield greatly varying results depending on the date on which the photographs were taken. The spectral response of objects and, therefore, the resulting air-photo patterns, vary greatly throughout the year. The tones and color values on photographs result primarily from differences in soil type, moisture content, and vegetative type and vigor. Some effects of date of photography, for which color and color infrared film were used, on air-photo interpretation have been previously illustrated by the author (1). A more detailed example of these effects will be presented here.

An example of significant differences in air-photo patterns in aerial photographs taken on different dates is shown in Figures 1 and 2. These photographs were purchased from the Agricultural Stabilization and Conservation Service of the U.S. Department of Agriculture (USDA-ASCS). The figures show part of a glacial outwash plain in Rock County, Wisconsin, as photographed on panchromatic film on May 18, 1956 (Fig. 1) and on August 15, 1963 (Fig. 2). The striking braided pattern (A, Fig. 1) is a remnant from the time when glacial meltwaters flowed across the ground surface. The meltwaters were not competent to transport all soil and rock particles fed by the melting glacier and, thus, flowed with braided channels. Sand and gravel were deposited, forming this glacial outwash plain. The braided channels are slightly lower in elevation, are somewhat higher in soil moisture content, and have somewhat darker soils than the surrounding materials and thus photograph darker in tone. The braided pattern shown clearly in the May photograph is nearly obscured in the August photograph (A, Fig. 2) because of the vegetative cover (tall green corn). A few traces of the braided pattern can be seen at B in Figure 2, but the pattern is not so sharply defined as in Figure 1.

In an investigation of the effects of date of photography on air-photo patterns, photographs were taken on more than 30 different dates from May 1969 through September 1971 at selected sites in southern Wisconsin. Both color and color infrared 35-mm film were used. The results from 6 dates of photography at 1 site during a 12-month period are presented here. Selected sites were also imaged by a thermal scanner at 8 times during an 11-day period in September 1971. The results of 4 flights within a 19½-hour period at 1 site are also shown.

DESCRIPTION OF TEST SITE

USDA-ASCS aerial photographs of the test site, an area about ½ by ⅔ miles in extent, are shown in Figures 3 and 4. A landform map of the site is shown in Figure 5, and a soil map is shown in Figure 6. Symbols used on the maps are defined as follows:

Item	Symbol
Landform	
Glacial lake bed (silty soil)	A
Younger beach ridge, el 920 ft (sandy soil)	B
Older beach ridge, el 925 ft (sandy soil)	C
Glacial lake bed (sandy soil)	D
Alluvial deposits (silty soil)	E
Made land (highway and industrial fill material)	F
Soil Name According to USDA-SCS	
Palms mucky peat	1
Maumee sandy loam	2
Rodman sandy loam	3
Washtenaw silt loam	4
Ossian silt loam	5
Made land	6

The test site is located a few miles west of Madison, Wisconsin, at the former shoreline of glacial Lake Middleton, an ephemeral glacial lake that is now primarily agricultural fields. This was a small lake, about 3 square miles in extent at its maximum. At its lowest level, the lake was only about 200 acres in size. The beach ridge associated with this lowest lake level is shown at B in Figure 5. The ridge is most distinct at the southeastern edge of the lake (shown here) because the prevailing winds at the time of its formation were from the northwest. It is a small feature, approximately 200 ft wide and only 2 or 3 ft higher than the surrounding lake-bed material. Figure 7 shows a ground photograph of a soil surveyor standing on the ridge while the photographer is standing on the lower lake-bed material. The beach ridge is difficult to notice on the ground and almost impossible to see in Figure 7 because of its small size. This paper will show that it can be clearly seen on aerial photographs taken at the proper time of year and also on thermal imagery.

Figure 6 shows a recent soil map of the area (compiled in about 1968 by USDA-SCS). Table 1 (4) gives typical soil profiles for the soils shown in Figure 6. The features to be emphasized in describing the photographs and thermal images will be the beach ridge shown at B and the surrounding lake-bed soils shown at A in Figure 5. As described by USDA-SCS, and confirmed by field observations, the beach ridge has a fine sandy loam surface soil about 12 to 18 in. thick underlain by deep sandy materials. The lake-bed soils to the left of this ridge are silt loam to a depth of at least 5 ft and are seasonally wet with a groundwater table within 2 ft of the ground surface in the early spring. The lake-bed soils between the ridge at B and the older ridge at C (Fig. 5) consist of silt loam to a 2- or 3-ft depth underlain by alternating layers of silt and fine sand and are also seasonally wet.

As the photographs contained in this report show, the location of the beach ridge is difficult to identify in some aerial photographs and relatively easy in others. For example, the ridge can be clearly seen in Figure 4 (June 4, 1968) but is more difficult to identify in Figure 3 (June 15, 1962). Two different soil scientists, using the 1962 USDA-ASCS photographs (Fig. 3) with selective field sampling, mapped parts of the area shown in Figure 6. The soil scientist mapping the lower two-thirds of the area shown in Figure 6 mapped the ridge as Maumee sandy loam. The soil scientist mapping the upper third of the area shown in Figure 6 was not able to identify the beach ridge and therefore mapped it, along with the rest of the lake-bed soils in the area, as Ossian silt loam. The resulting soil map (Fig. 6) shows the sandy soils on the beach ridge terminating about two-thirds of the way up from the bottom of the map. An analysis of the photographs and thermal images contained in this paper confirms that the ridge actually continues to the top of the map shown in Figure 6, as delineated in the landform map (Fig. 5).

Figure 1. Glacial outwash plain, panchromatic film, May 18, 1956.

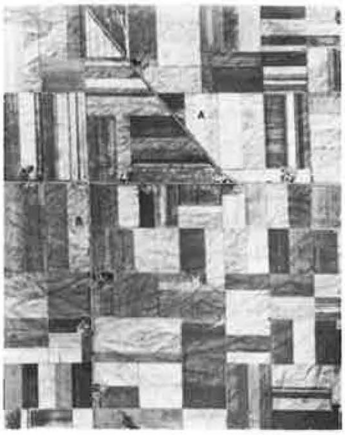

Figure 2. Glacial outwash plain, panchromatic film, August 15, 1963.

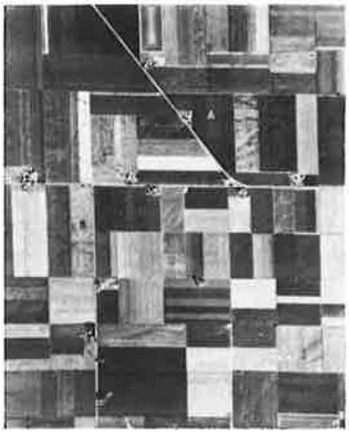

Figure 3. Test site, panchromatic film, June 15, 1962.

Figure 4. Test site, panchromatic film, June 4, 1968.

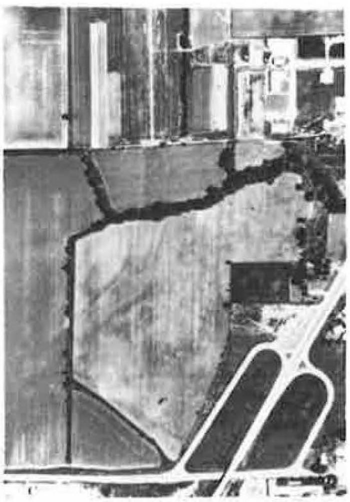

Figure 5. Landform map.

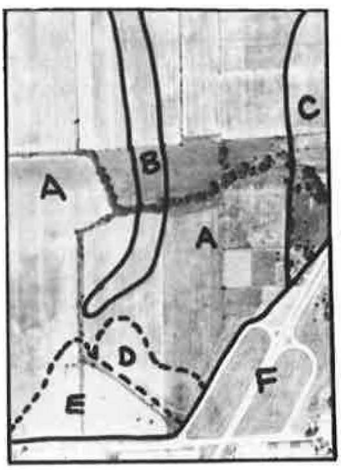

Figure 6. Soil map.

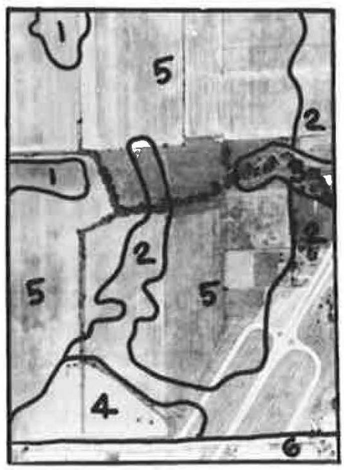

Table 1. Typical soil profiles of USCS soil classes.

Depth (in.)	Soil 1	Soil 2	Soil 3	Soil 4	Soil 5
0 to 12	Pt	SM	SM	ML-CL	ML-CL
12 to 30	Pt	SP	GW	ML-CL	CL
30 to 48	CL	SP	GW	CL	ML
48 to 60	SP	SP	GW	CL	ML

AERIAL PHOTOGRAPHY

Color and color infrared 35-mm photographs of the test site were taken on more than 30 dates during the period of May 1969 through September 1971. This paper contains 8 color infrared photographs taken on 7 dates during this time period. Figures 8 through 14 show oblique photos taken on a Minolta SRT-101 camera using Kodak Ektachrome infrared aero film, type 8443. Typical exposures were 1/1000 sec at f/4.5 or f/5.6 in bright sunlight. Figure 15 shows a vertical photomosaic taken with a motor-driven Nikon F camera using Kodak Aerochrome infrared ESTAR base film, type 2443. It should be noted here that Kodak type 8443 color infrared film, used for many years by various investigators in both aerial format and 35-mm cassettes, is no longer available. It has been replaced by Kodak type 2443 film (available as aerial film and also as 35-mm bulk film upon special order) and Kodak type 2236 film (also known as Ektachrome infrared film, IE 135-20, available in 35-mm cassettes). The new type 2443 film appears to have about the same spectral sensitivity as the type 8443 film. This investigator has had poor results with type 2236 film in 35-mm cassettes and cannot recommend its use as a replacement for type 8443 film. Investigators are advised to purchase type 2443 film in bulk 35-mm format in order to achieve results that can be compared with aerial photographs on type 2443 film or with existing photographs on type 8443 film.

Although the originals to Figures 7 through 15 are in color and color infrared, these illustrations are reproduced here in black and white. (A complete set of 2 by 2 slides of all 20 illustrations contained in this paper, including Figures 7 through 15 in color, is available and can be purchased for $10 from Ralph W. Kiefer, 2210 Engineering Building, University of Wisconsin, Madison, Wisconsin 53706.)

SEQUENTIAL COLOR INFRARED AERIAL PHOTOGRAPHY

Figure 8 shows an oblique color infrared aerial photograph of an area about 1 mile square. This photograph was taken on July 29, 1971, as was Figure 10. Figures 3 through 6, 9 through 14, and 17 through 20 show the area shown in the lower right corner of Figure 8. Although it cannot be seen clearly in Figure 8, the entire former shoreline of the lowest level of glacial Lake Middleton lies within the area shown in this photograph. Most of the former shoreline can be clearly seen in Figure 16, a thermal image that will be described later.

Figures 9 through 14 show color infrared photographs taken on 6 dates within a 12-month period. They were selected from a group of photographs taken by the author on about 30 different dates during a 14-month period, and they illustrate the great changes in air-photo patterns that can occur at different times during the year. The Lake Middleton beach ridge (B, Fig. 5) is clearly visible in the upper left corner of the plowed field in the June 28 photograph (Fig. 9). This ridge is virtually impossible to locate in the July 29 photograph (Fig. 10) because of similar reflectance characteristics of the healthy corn leaves both on and off the ridge. Bare soil cannot be seen in this field because of the dense cover of tall green corn. A careful inspection of the August 11 photograph (Fig. 11) will show that the beach ridge is just barely visible. Without knowing in advance its location, an interpreter might not notice its presence. The location of the ridge is clearly revealed in the September 3 photograph (Fig. 12) because of the difference in green, red, and infrared reflectance of corn leaves on and off the ridge. Because of dry soil moisture conditions on the sandy beach ridge soil, the corn planted on the beach ridge has withered and the leaves have turned brown. The corn on the silty lake-bed soils with a higher moisture content still has healthy green leaves.

Figure 13 shows the ridge the next spring (May 28, 1970). Here, more infrared energy is reflected by the vegetation on the ridge than by the vegetation on the silty lake-bed soils. This is because in the spring the sandy beach ridge soils are warmer than the wetter silty lake-bed soils and, thus, the crop (peas) is growing more vigorously on the beach ridge. Figure 14 (June 29) shows the same area just after it has been plowed and planted in corn. The tones are similar to those shown in Figure 9, taken almost exactly 1 year previously, and are primarily a function of the soil moisture conditions, for the field was recently plowed and there is essentially no vegetation.

Figure 7. Soil survey on beach ridge, color film, June 29, 1970.

Figure 8. Test site, color infrared film, July 29, 1969.

Figure 9. Test site, color infrared film, June 28, 1969.

Figure 10. Test site, color infrared film, July 29, 1969.

Figure 11. Test site, color infrared film, August 11, 1969.

Figure 12. Test site, color infrared film, September 3, 1969.

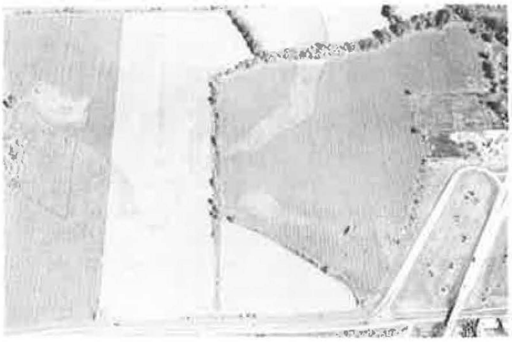

Figure 13. Test site, color infrared film, May 28, 1970.

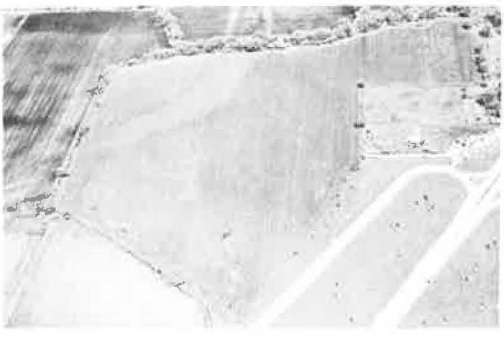

Figure 14. Test site, color infrared film, June 29, 1970.

In the previously mentioned paper by the author (1) is shown the striking tonal contrast related to corn vigor on different soils in the field located at the extreme left edge of the area shown in Figure 8. In that paper are also shown the striking changes in tonal patterns that can occur from one day to the next as bare soils dry out after a rainfall.

Figures 9 through 14 are intended to show the nature of the changes in air-photo patterns that can take place throughout the year. The patterns seen on these photographs are primarily functions of the soil type, soil moisture conditions, and, within any one crop, vigor of vegetation. The principal variable is soil type, for the soil moisture and vegetation vigor vary with the soil type. Therefore, the different patterns shown in Figures 9 through 14, especially the pattern caused by the beach ridge, are primarily the result of different soil types. These figures show that certain dates of photography are better than others for distinguishing among different soil types. For southern Wisconsin, the optimum time of the year for aerial photography for soil studies appears to be May 1 to June 15; the period from September 1 to 30 is excellent under certain conditions.

Persons using available ASCS photographs for interpretive work may find that the most recent date of photography is not necessarily the optimum time of year and should inspect several sets of available photographs to select the optimum set. Those wishing to contract for aerial photographic work for interpretive purposes should consider carefully the time of year acceptable to them for aerial photography.

If photographs on several dates are available, then there should be some advantage in comparing the air-photo patterns at several times during the year. The NASA-ERTS satellite, which has orbited the earth since mid-1972, sends back images of each part of the mainland United States once each 18 days. A temporal analysis of these data should reveal considerably more information than can be obtained from imagery on just one date.

THERMAL IMAGERY

Thermal imagery was obtained for the test site 8 different times during an 11-day period in September 1971. Color and color infrared photographs were also taken during the 4 daytime missions.

The thermal images were obtained with the support of the National Center for Atmospheric Research; a Texas Instruments RS-310 airborne infrared mapping system was used. Texas Instruments (2) describes the scanner as follows:

> The RS-310 is a passive, airborne infrared imaging system that scans the ground along and to both sides of the flight path and produces a continuous image of the scanned terrain. Energy is received by the scanner from the ground, focused on cyrogenic-cooled detectors, converted to light through the use of a light-emitting diode, and by means of a mechanically-coupled recorder exposes the photographic film in the film magazine. The film is moved at a rate proportional to the velocity and height of the aircraft, producing the continuous photographic record of the radiant energy detected.

The basic characteristics of infrared radiation, atmospheric transmission, and infrared detection and recording have been described in several papers in an HRB special report and will not be repeated here.

The specific characteristics of the scanner, detector, and flight parameters, as used for the 4 flights described here, were as follows:

Characteristic	Value
Detector sensitivity, μm wavelength	8 to 14
Spatial resolution, milliradian	5
Flight height, ft above terrain	2,000
Aircraft velocity, mph	150
Scanner field of view, deg	90

Figure 15. Test site, color infrared film, 10:00 a.m., September 18, 1971.

Figure 16. Test site, thermal image, 10:00 a.m., September 18, 1971 (same area as in Fig. 15).

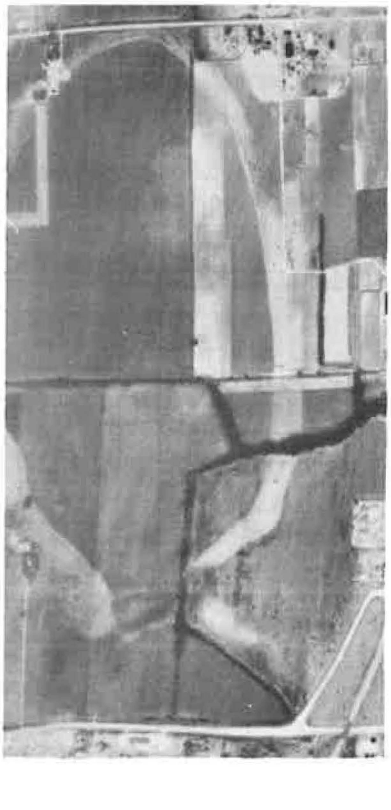

Figure 17. Test site, thermal image, 2:30 p.m., September 17, 1971.

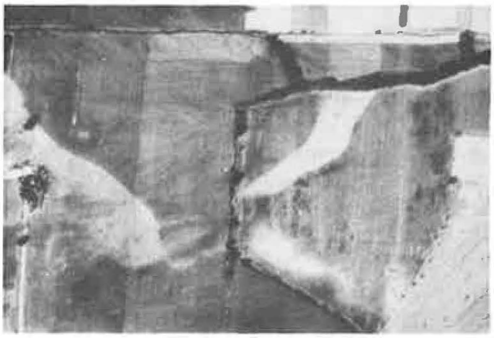

Figure 18. Test site, thermal image, 10:00 p.m., September 17, 1971.

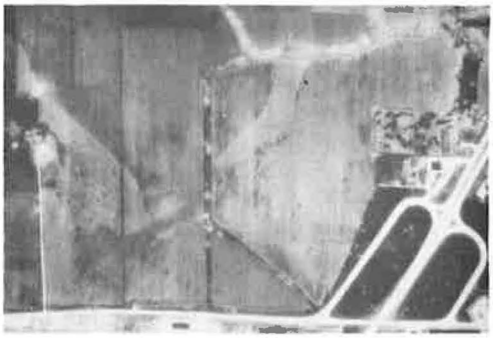

Figure 19. Test site, thermal image, 2:00 a.m., September 18, 1971.

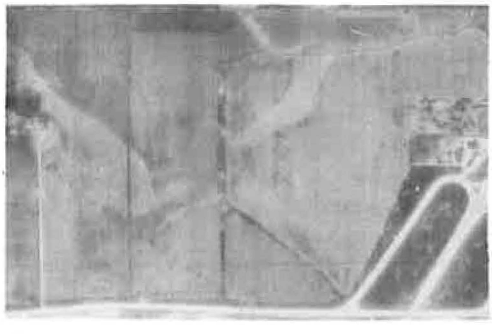

Figure 20. Test site, thermal image, 10.00 a.m., September 18, 1971.

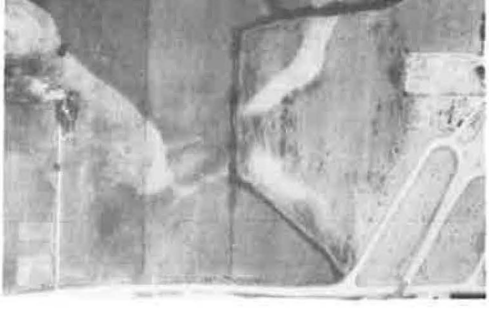

Figure 15 shows a color infrared photomosaic taken at the same time as the thermal image shown in Figure 16. Figures 17 through 20 show the same area at 4 different times during the 19½-hour period from 2:30 p.m. to 10:00 a.m. In all figures shown here, the darker toned areas represent the cooler temperatures, and the lighter toned areas represent the warmer temperatures.

The thermal scanner can resolve small differences in apparent temperature of natural objects. The apparent temperature on the beach ridge shown in Figure 20 is about 61 F, whereas the apparent temperature on the silty lake-bed soils to either side of the ridge is about 56 F.

Based on field radiometric measurements with a PRT-5 radiometer and an analysis of the thermal imagery, it was determined that apparent temperature differences as small as 2 F can be distinguished on the thermal imagery.

It appears that the use of thermal imagery interpretation has great potential for soil studies. Figure 16 shows a very clear image of the former shoreline of the last stand of glacial Lake Middleton. The warmer sandy ridge can be readily distinguished from the cooler silty lake-bed soils because of the difference in gray tone on the image.

Thermal contrast is greatest during the daytime flights (Figs. 17 and 20) because of differential thermal heating by solar radiation. Analysis of these images is still in progress, and further imagery for soil studies can be ascertained. The maximum amount of soils information can probably be obtained by a comparison of thermal images from 2 or more times during a 24-hour period.

SUMMARY

The nature of the changes in air-photo patterns that occur on photographs taken on different dates has been illustrated in this paper. These changes are related to soil type, moisture content, and vigor of vegetation. An analysis of aerial photographs taken at different dates during the year shows that there is an optimum time during the year for procuring aerial photographs for interpretive use for soil studies. In southern Wisconsin, the optimum time of the year appears to be May 1 to June 15; the period of September 1 to 30 is also very good. A comparison of images from several times during the year, such as those from the NASA-ERTS satellite, should yield more information than images from a single date of photography.

Thermal imagery from several different times of day was illustrated in this paper. Aerial thermal imagery appears to have great potential use for the purpose of soil mapping and evaluation.

ACKNOWLEDGMENTS

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