Seasonal Changes of the Agricultural Pattern: A Study in Comparative Airphoto Interpretation

DIETER H. BRUNNSCHWEILER*
Graduate School of Geography,
Clark University, Worcester, Mass.

ABSTRACT: *This paper deals with the pictorial variations of the agricultural landscape as recorded on a series of aerial photographs taken at monthly intervals during one year. Tone, texture, and structure (stereoscopic appearance) of land use units are investigated. The effect of these image elements on the photo pattern is analysed. It is shown that no single flight date will bring forth best results for recognition of all elements, but that each of the months represented can be ideal for specific interpretational purposes.*

INTRODUCTION

ONE of the outstanding advantages of aerial photographs over topographic maps is the detail with which the agricultural pattern is illustrated. Some land utilization surveys have made use of airphotos as base maps,[1] but very little has been done with regard to the application of photo-interpretational techniques to land use analysis.

Recent county soil surveys[2] include airphotos of selected areas showing some characteristics of the surface configuration, of the soil and drainage pattern, and of plowing and harvesting methods. In some cases the airphoto-appearance of individual crops is shown. If one were to use these "keys" for crop recognition in other areas, he would be severely handicapped by the fact that the flight date of the photos to be interpreted might not correspond with the flight date of the key set. In order to attain the best results in the interpretation of airphotos representing agricultural land with its particularly strong seasonal changes a regional key is only valid if it accounts for tonal, textural, and stereoscopic variations of image elements as they occur according to the land status at the time the project was flown.

Experience with aerial photographs having wide regional as well as temporal range has led the author to believe that the interpretability of the agricultural scene through airphoto work is primarily dependent upon the availability of photos taken at a time of maximum photogenic contrast within a particular landscape. Investigations in Sweden as to the possibilities of tree-species recognition from aerial photographs have shown that many species offer definite identificatory clues during a short period of the year only. According to Hesselmann most tree species forming pure stands can be identified at one time or another, but only during one week may all of them be identified simultaneously.[3]

To investigate whether or not similar conditions prevail in non-arboreal crop land was one purpose of this study. Its major aim was, through the interpretation of aerial photographs of a test strip taken

[1] A good example for this type of airphoto use is described in: "The Rural Land Classification Program of Puerto Rico," Northwestern University Studies in Geography, No. 1, 1951.

[2] See e.g.: Soil Survey of Franklin County, Indiana. Plates 1–6. U. S. Department of Agriculture, May 1950.

[3] Hesselmann, H.: "A Map of Sweden's Beech Forest Distribution based on Aerial Reconnaissance." *Geografiske Annaler* vol. 21 1939, pp. 77–87.

* 1953–1955 Assistant Professor of Geography, Clark University. Now Professor of Geography, Institute of Geography, University of Zuerich, Switzerland.

at monthly intervals during one year, to evaluate the photo content as to its advantages and limitations with respect to the identification of crops in particular, and to the interpretation of land utilization in general. A crop key is not presented but, rather, it is emphasized how much any crop key might be influenced by the continuous variations of the image elements throughout the year.

The concern, then, is with problems of temporarily comparative airphoto interpretation. With the present availability of photos from flight projects executed practically at any time of the year, a seasonally refined technique of interpretation should be offered in order to enhance the utility degree of airphotos.

Organization and Location of Project

The area chosen for the project is located in the vicinity of the city of Zurich in northeastern Switzerland. Within this area a test strip was photographed from the air seven times during 1952.[4] The flight dates coincided with distinct phases of the annual "landscape development" such as ground snow-covered, spring-plowing, grain maturity and harvest etc. Weather conditions interfered slightly with a perfect schedule insofar as no flight was possible in late July just before the small grain harvest. On flight days detailed fields surveys were made whereby the status of all fields within the test strip was carefully observed and recorded. The following characteristics were included in the inventory as being relevant for the photographic image qualities:

Color (intensity and shade), structure[5] (sowing, cultivating, and harvesting pattern), height above surrounding ground, species and vegetative status of crops, abnormal conditions within fields such as wind-laid patches, weeds, crop failure; surface soil color, amount of soil exposure, stoniness, drainage, and erosional phenomena.

All these criteria were applied to each individual field. The "fields," rarely larger than 3 acres, later also served as the smallest interpretational units. The relatively large scale of 1:13,000 made possible working satisfactorily with such small units. The photos appearing in this paper will of course not reproduce all details which were clearly visible on the originals.

One stereopair was selected to give the reader an idea of the surface configuration of the test area (Figure 1). The stereo area covers approximately one square kilometer. The terrain slopes gently eastward (N at top of picture); the difference in elevation from the highest point in the wooded southwestern part, to the lowest point in the ravine in the northeast corner, is 500 feet. The bedrock is unexposed throughout the area and consists of horizontally lying layers with sandstone, shale, and conglomerate alternating. There is a mantle of till varying in thickness from one to a few feet. The soils are predominantly loamy with considerable stoniness but without boulders. Drainage is adequate and the soils are practically unaffected by erosion.

The area is representative for the proportion of crop land, pasture land. and woodland in northeastern Switzerland. Grain and grass for feed, manured pastures, small vegetable plots, orchards and well-kept mixed woodland surround the hamlet from which all fields are operated. Dairy economy is carried on in these environs. The hamlet is linked with Zuerich, its major market, by a macadam highway.

Seasonal Changes in the Airphoto Appearance of Cropland

On any air photo an experienced interpreter will readily distinguish between the major land use units, such as plowed fields, cropped fields, hay fields, pastures and other types of use. On photos with a scale of 1:20,000 and larger it becomes possible to make much finer differentiations. Familiarity with the type of agriculture and the individual crops of the study area will, of course, help a great deal in obtaining maximum results through photo interpretation.

The timing of the flights made for this study permitted observing crops and their aerial images in many characteristic stages of the growing season. The accompanying photographs speak for themselves insofar as the over-all changes of the

[4] Gratitude is expressed to the Direction of Military Airports, Duebendorf for the execution of the flights and the processing of the film material.

[5] Fields, in their three-dimensionality, can be spoken of as having structure. On the two-dimensional photo, however, this structure will be referred to as texture.

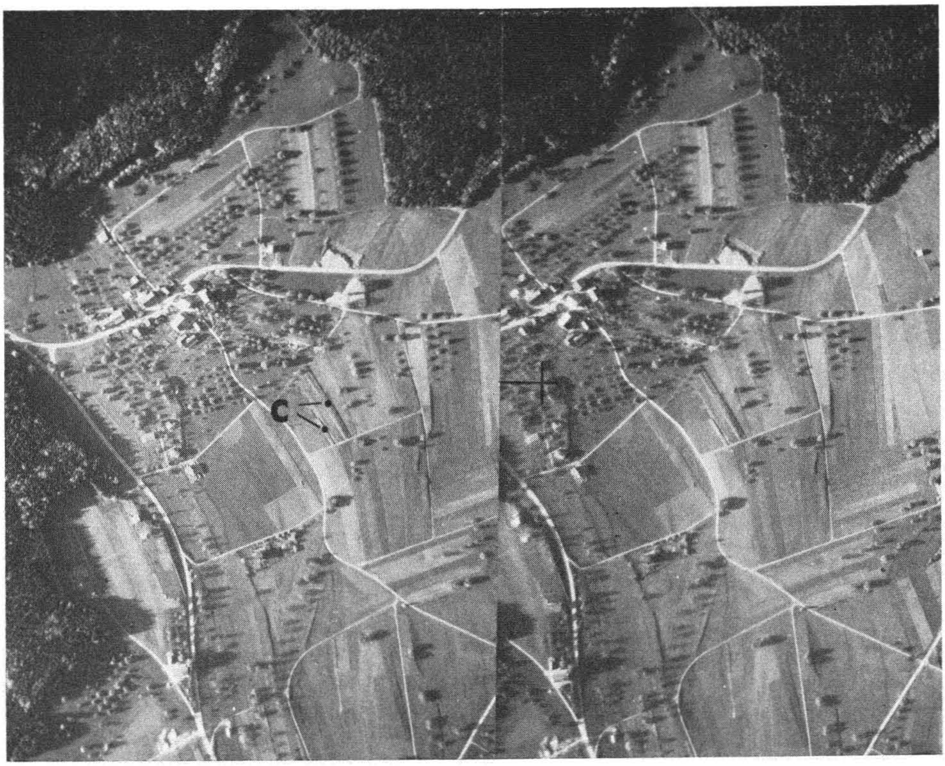

FIG. 1. Stereopair of test area. Date: October 9, 15.27 P.M. Scale: 1:12,500 (same for all subsequent photographs). For explanations see text. North is on top.

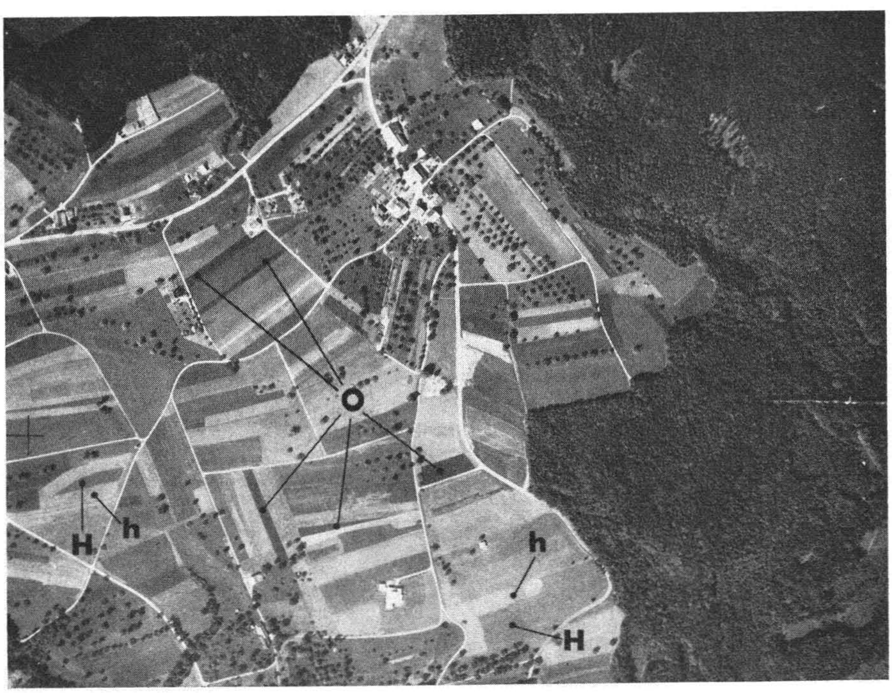

FIG. 2. Date: June 5, 9.25 A.M. Explained in text. North is to the right (as in all subsequent photos).

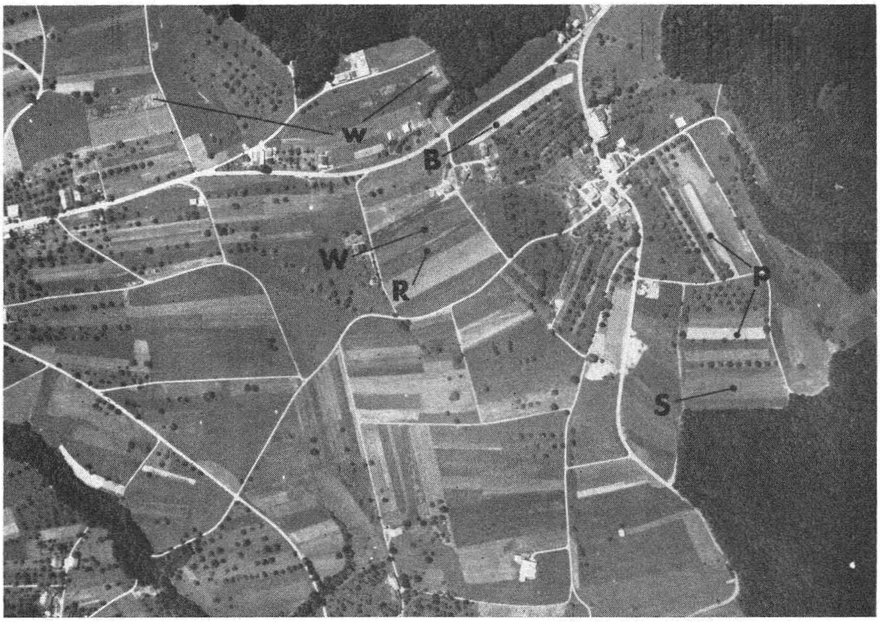

FIG. 3. Date: July 11, 11.55 A.M. For explanations see text.

landscape and airphoto pattern, respectively, are concerned. The reasons for the seasonal changes of the pattern lie in the specific tonal and textural variations occurring in each agricultural unit in the course of the year. These variations are explained for the major land use types in the following paragraphs.

Two crops are particularly suitable to demonstrate the importance of the seasonal factor with respect to crop recognition. The first, oats, exhibits unique identification clues in the early growing season, whereas the second, corn, is readily identified in late growing season exposures.

On Figure 2 five oat fields are indicated (*O* for oats). The outstanding interpretational clue for oats in early June is the dark tone. Relatively speaking, oat fields are darker than all other fields. In an absolute tone scale such as suggested by Dahn[6] with values between white (1) and black (10), oat fields easily give values of ± 7. The actual color of oats on the date of the flight was dark olive, the height of the plants $\frac{1}{2}$–2 feet. Other grain fields looked very similar to oats so that the dark grey photo effect of the latter was quite surprising. All other interpretational criteria (texture, stereo-effect, shadow, associated features) fail as means for a correct identification. Note that in the July photo (Figure 3) oat fields are still somewhat darker than other grain fields.

Any crops reaching a height of 5 feet and more above surrounding ground are easily discovered by stereoscopic inspection. The corn fields in the study area—only two in number—are indicated on Figure 1 (*C* for corn). The "carpet" effect is striking even without stereovision. Identification is facilitated because most other fields are either bare or grass-covered which makes the latter phototexturally homogeneous, whereas the corn plots exhibit a coarse or "woolly" texture.

Differentiation of individual crops is getting more difficult with the advance of the growing season toward grain harvest. The July exposure (Figure 3) is representative for this period.

Tonal range between spring-sown grains is quite narrow with oats still appearing darkest (6). Wheat, rye, and barley have tonal values between 4 and 5. (*W* for wheat, *R* for rye, *S* for spring-sown barley in Figure 3). Fall-sown barley has already reached maturity by this time and shows up in very light tone (*B* in Figure 3). Two other fields have the same tonal values as

[6] Dahn, R. E. "A standardized tone scale as an aid in photo interpretation." PHOTOGRAMMETRIC ENGINEERING, Vol. XV, No. 2, 1949.

winter barley but are, in contrast to barley fields, homogeneous in texture and produce no stereoscopic effect: they are bare and from their smooth and light-colored surface much light is reflected (*p* for plowed in Figure 3). Wind-laid patches are frequent in all grain fields; they are best observed in oat fields where their fleecy texture contrasts strongly with the even dark grey of the undisturbed parts of the fields (*w* for wind-laid in Figure 3).

The photo pattern of early August, with the small grain harvest in full swing, exhibits the strongest black-white contrasts of the agricultural landscape of the whole series. Most grain fields seem to reach their lowest tonal values—practically white—just after harvesting instead of just before. This is undoubtedly due to the combined albescent effect of light reflection from stubble and straw and the reappearance of the parched and light-colored surface soil. The majority of grain fields in the August exposure is already harvested. At this time of the year individual objects rather than tonal or textural criteria, may lead the interpreter to the correct identification of crops. However, harvesting techniques are often not identical even for a single crop. In such cases crop type but not crop species may be identified. Thus oats in shocks (*s* in Figure 4) appear as dark, regularly-spaced dots (shadows!) while oats in sheaves, irregularly distributed on the ground show up as exceedingly light specks (*o* in Figure 4). The tonal and textural unevenness of a mature field of oats (*O* in Figure 4) and of barley (indicated on Figure 3, *S*) are examples of grain fields just before harvest.

At first glance the photo made on May 1 (Figure 5) would look quite similar to the August exposure except for the woods with their light green foliage of deciduous trees and the orchards with their blossoming trees. Both are producing unmistakable seasonal (i.e. phenological) photo effects. Closer inspection of the fields in May reveals the fact that the similarity between identical units in May and August exists only in tonal quality, whereas texturally (and stereoscopically) there are obvious differences. Most fields were sown a few days earlier and lie bare, allowing the camera to record a maximum of soil characteristics. In many fields a fine linear texture (furrows) can be detected, the lines being parallel to the long side of the fields.[7] Discolorations due to differences in soil moisture content cause mottled texture or make visible the dendrites of shallow natural waterways. Two large fields show typical artificial drainage grids (*D* on Figure 5).

The land use types have not yet been considered: grass land, either in natural grass or in mixed hay; and pastures. Recognition of the former is easiest in June (Figure 2) when mowing is in progress. Two fields are indicated and are partly mowed (*H* for uncut hay, *h* for cut hay). The light-toned stubble fields are to be found in other locations in the July photo (Figure 3); they are no longer so conspicuous because they are fewer in number and the tone of the grain fields has now become much lighter, thus diminishing contrast. It is interesting to note that fields of clover and alfalfa appear almost as dark as oats in June; textural differences will then permit the differentiation of grain and grass in most cases.

The largest land use units consist of pasture and natural grass. They experience little tonal variations during the year. Some portions within these units may show irregular patches of lighter tone due to a high proportion of plants with light-colored blossoms (*G* in Figure 5) in spring. In the fall pastures may show an irregularly dotted texture because of clusters of weeds untouched by the cattle. Fences, individual trees, cattle trails, proximity to barns and other associated features lead quickly to the identification of permanent pasture land.

The two last photos were taken before the start of the growing season in the last days of February (Figure 6) and March (Figure 7), respectively. They are less suited for interpreting the agricultural landscape than any of the preceding exposures even though they contain many interesting details. Figure 6 is an outstanding example of the importance of shadows for object recognition. Tree shapes, cast as shadows on the snow, can be seen in an amazing exactness. Determination of tree heights by the shadow method is possible with a high degree of accuracy if due attention is given to the

[7] This fine linearity may not be visible on the photos reproduced in this paper. In originals they can be seen down to a scale of 1:30,000.

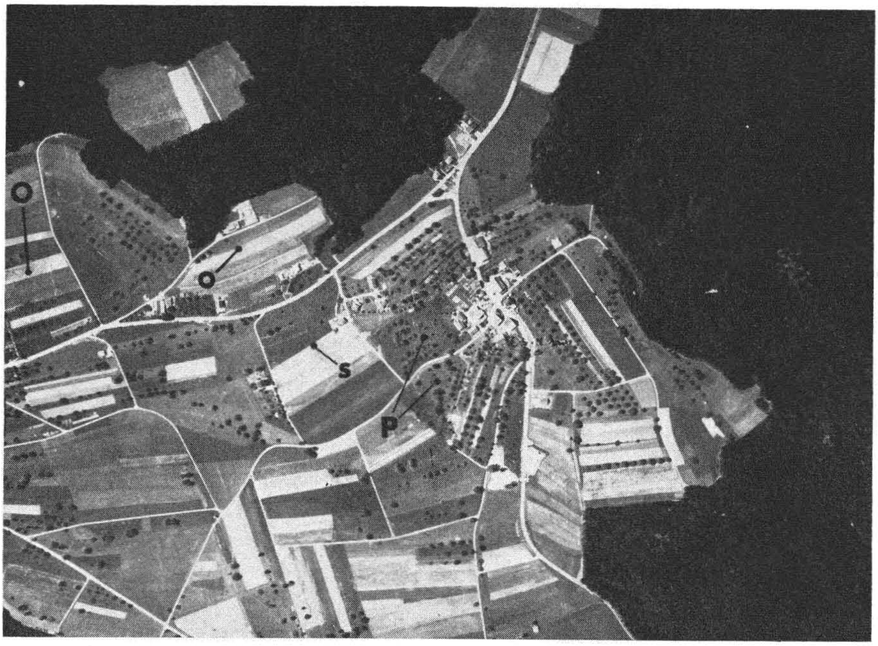

FIG. 4. Date: August 6, 11.00 A.M. Explained in text.

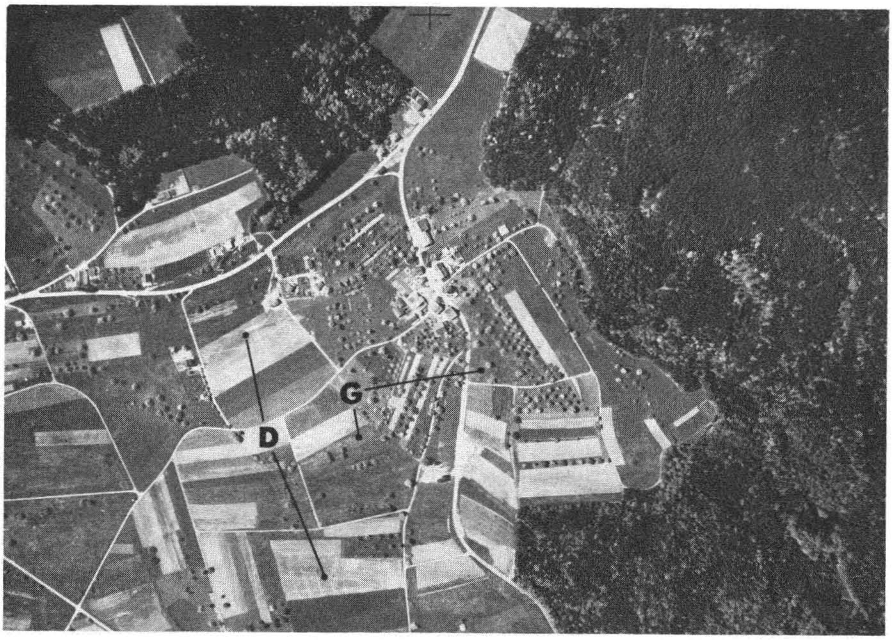

FIG. 5. Date: May 1, 11.10 A.M. For explanations see text.

thickness of the snow cover (6 to 8 inches) and slope angles. The shadow effect also reveals finest surface irregularities such as terrace steps less than 2 feet high. The tonal uniformity—white in open land, black in woodland—makes the viewer immediately focus on individual objects rather than unit areas.

The March exposure shows the terrain in tones of medium grey. Distinction of

FIG. 6. Date: February 28, 3.44 P.M. Described in text.

fallow fields and grass land is difficult because of very limited tonal and textural differences of these two units at this time of the year. The first sign of the beginning of vegetative season is given by a few dozen of tamaracks (Larix europaea); the light-green needles make this species appear as light toned spots against the dark background of the spruces. (*L* in Figure 7).

SUMMARY OF IMAGE CHARACTERISTICS

In the following an attempt is made to demonstrate the significant changes of

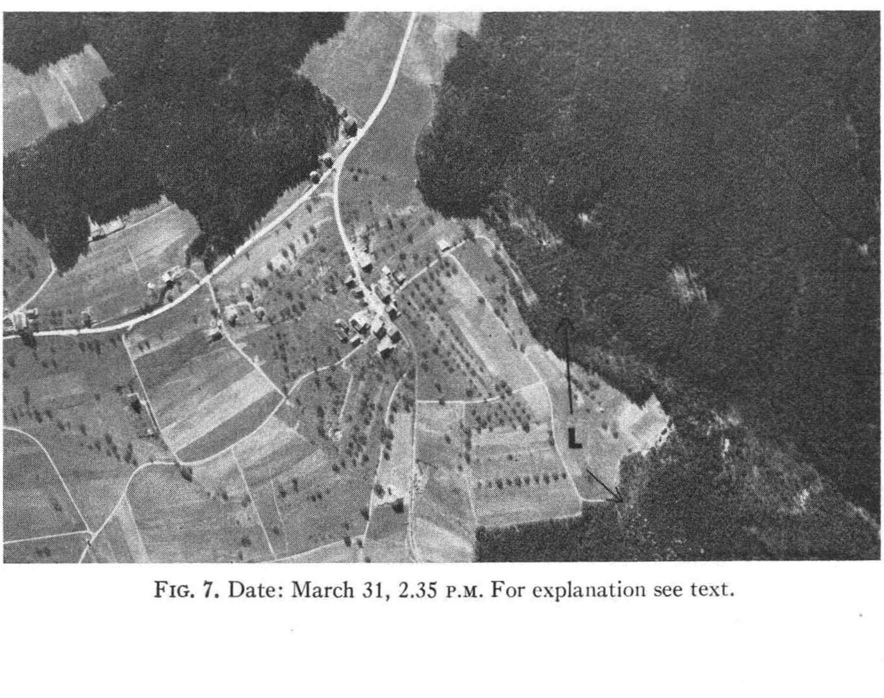

FIG. 7. Date: March 31, 2.35 P.M. For explanation see text.

the image characteristics, i.e. tone, texture, and stereo effect, and to summarize the monthly pattern resulting thereof.

By means of tone graphs the average tonal values of six land use units during the growing season are shown (Figure 8). Average is to be understood as being the mean tonal value of all fields of a particular unit, at the time of the flying. Deviations from the mean of one tone degree or more occurred very rarely. In terrain of more varied exposition and greater slope range deviations may be larger, but they are bound to affect all fields in the same sense.

It is difficult to summarize textural characteristics in the quantitative manner

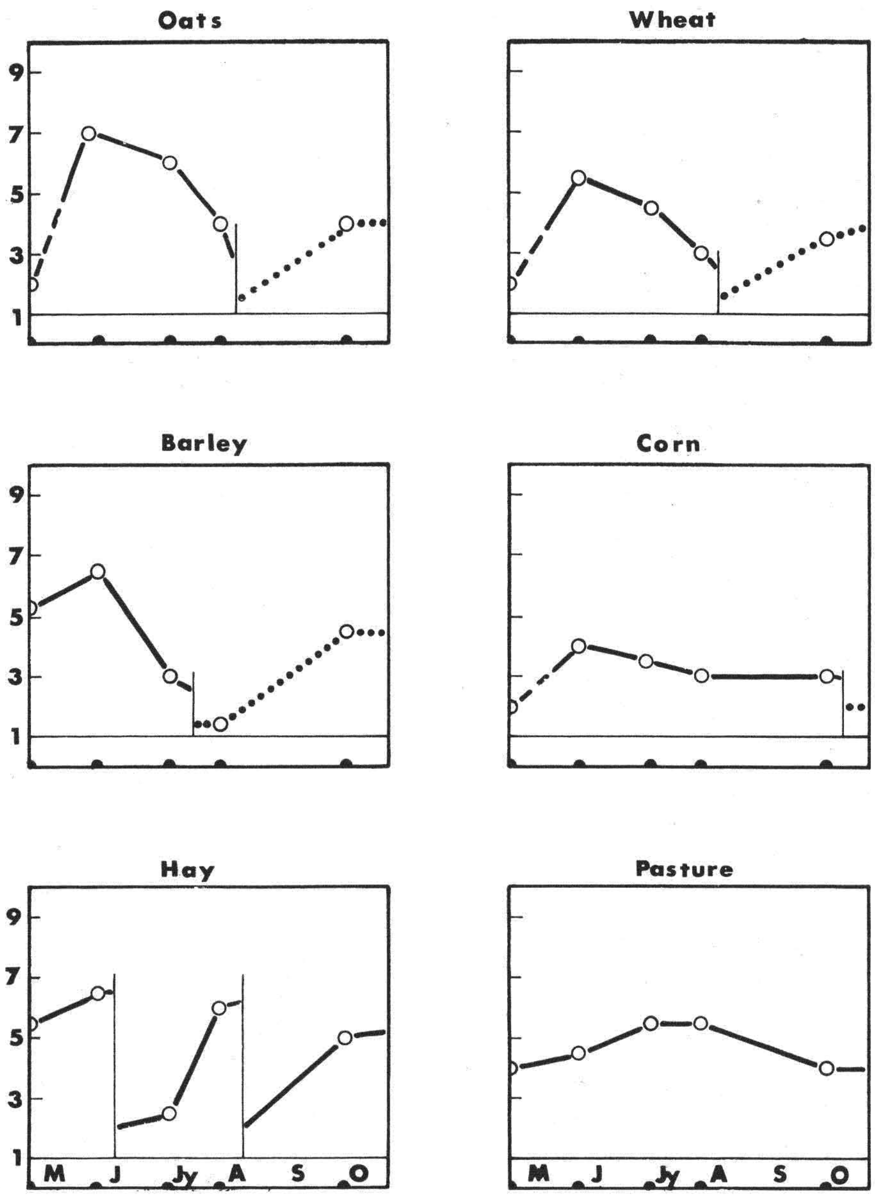

FIG. 8. Tone variations of six land use units during the growing season. Circles: tone values at flight dates (indicated at base of graphs). Vertical lines: grain/hay cutting. Broken line: tone still largely determined by soil color. Dotted line: stubble fields. Tone values: 1 (white) to 10 (black).

used with tone. The small field size and the minuteness of textural details prevent a satisfactory reproduction of a pictorial key. Verbal approximations of image textures were used in the text. This, however, does not mean that texture was given a superficial treatment. On the contrary, it should be emphasized that careful textural analysis is often the only successful technique for differentiating between crops which, in tone and stereo effect, look alike.

As far as stereoscopic work is concerned it is an absolutely necessary third beside tonal and textural analysis. Investigations with the parallax bar have proved that crop "canopies" being as little as three feet above the surrounding ground are measurable and perceivable with a common pocket stereoscope.[8] A "carpet" effect is therefore obtained even from grain fields which is very helpful if poor definition of prints interferes with textural analysis.

The months represented in the preceding photographs can be classified into four groups according to their general tone pattern:

1. March and October (Figure 6 and Figure 1). These exposures have a minimum tone contrast. Medium grey tones prevail and there is little textural variety.
2. June and July (Figure 2 and Figure 3). There are distinct tonal contrasts but still within relatively narrow range. The pattern is a light grey-dark grey mosaic. Considerable textural variety.
3. May and August (Figure 5 and Figure 4). Exposures of these months have maximum tonal contrast caused by plowed fields against grass land in May; by mature grain and stubble fields against grass land in August. A "black-white" mosaic effect is the result in both cases. Different harvesting methods produce a great variety in field texture. Good stereo-effects are obtained from fields in August, none in May.
4. February (Figure 7). Only the extreme values at either end of the tone scale are represented. Shadows accentuate individual objects whereas textural units are non-existent due to the homogeneity of the snow cover.

Depending upon the purpose of an intended interpretation, any of the photos discussed in this series may offer optimum image characteristics. It is quite clear that airphoto analyses dealing with any problems of field structure (e.g. size, shape, or boundaries of fields, amount of plowed land etc.) will produce best results with contrast-rich photos (May or August). If a map of land utilization with differentiation of individual crops is to be accomplished, June or July exposures are definitely the best suited. Soil conditions are best interpreted from May exposures; the same is probably true for tree identification. Early spring and late fall photos are preferable for photogrammetric purposes, due to the homogeneous appearance of the agricultural landscape. Even prints of the snow-covered landscape may contain some striking phenomena unnoticed in previous analysis: shadows above all!

Conclusion

The agricultural landscape and its seasonal variations can be satisfactorily interpreted in a series of panchromatic airphotos, taken at typical stages before, during, and after the growing season. The landscape as a whole exhibits distinct patterns with various degrees of tonal contrast. Most crops and all land use types have specific pictorial characteristics which are a function of time rather than of place, as comparisons with similar studies in other mid-latitude areas have confirmed.[9]

The aim of this study was to show how the interpretability of aerial photographs is affected by the manifold changes occurring in the agricultural scene during the year. Any interpreter who has to deal with problems of rural areas or natural constituents of the landscape, such as crops, soils, vegetation, or landforms, should be well aware of the importance of the time factor.

[8] The reader may check his stereo perception by focusing on the two corn fields in Figure 1. The mean height of the corn stalks is 6 feet.

[9] *Goodman, M. S.*: "The Aerial Photographic Identification of Farm Crops in Northern Illinois." Ph.D. Thesis, Northwestern University, 1954. *Goodfellow, M. J.*: "Seasonality as a Factor in the Use of Aerial Photographs for Geographic Purposes." M.A. Thesis, Clark University, 1955.