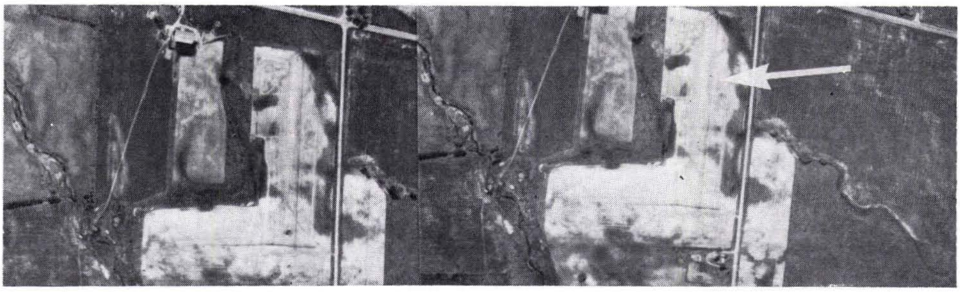

FIG. 1. The exposed soil of those fields that were plowed-under after harvest the preceding autumn displays high tonal reflectance on panchromatic film in mid-May (arrow). The dark *blotches* on the fields indicate those zones that will be difficult, if not impossible to till this early in the season. (*Note:* The detail and sharpness necessary for a rapid analysis is reduced by the half-tone reproductions shown in these illustrations.)

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Time-Lapse Remote Sensing in Agriculture

Agricultural resources, crop identification, cropping practices, and crop yields are applied to worldwide resources analysis programs.

INTRODUCTION

THE TERM *time-lapse* as used in this paper is similar to the techniques used in cinematography where apparent growth or motion can be speeded up by exposing cine film at measured time intervals with a time gap or time lapse between each frame. The blooming of a rose bud, for instance, which may take as much as two or three days to blossom into a fully opened specimen only takes about 30 seconds with time-lapse photography. The lapse of time between each frame, however, must be adjusted to suit the rate of movement and growth of the subject.

In much the same manner the photography for this study had been planned to record the growth, development and management of crops and other vegetation in a portion of Jefferson County, New York (44°00N, 75°45'W; average elevations, 450 ft. at Watertown and 950 ft. on nearby highlands). The area of study was photographed at one-month intervals (with the exception of July) starting at May 15, 1963 and continuing through the growing season until September. An additional flight was made in mid-June of 1964 to record crop rotation and other practices. The following agricultural functions were examined under the stereoscope and recorded: acreages of fields, preplanting preparations, planting and harvesting dates including haying and the number of times a forage crop was cut during the season, spraying practices and manuring practices. All crops were identified and their vigor and seasonal development were recorded. In the initial phase of the project a maximum amount of ground checking was incorporated to confirm all identifications.

Experiments were made with infrared and color photography in sample areas to test for comparative results in data acquisition. Panchromatic film at a scale of 1:6,000 was analyzed to establish a working-scale preference for future surveys.

The scale of photography used for the

entire survey was 1:12,000 (one inch = 1,000 feet) providing ground resolutions of 4 to 5 feet. This is an ideal scale for agricultural data acquisition; however, it was found that scales with larger ground resolutions (1:20,000) can be analyzed equally as well, although perhaps with slightly less accuracy in some micro-imagery evaluations.

Objectives

This is a report of a pilot study in a section of commercial dairy country in northern New York State. Under the direction of Dr. M. J. Wright of the Agronomy Department, Cornell University, its preliminary objective was to determine whether cropping practices could be observed, timed and evaluated by photogrammetric methods to aid agricultural extension and research workers in making valid generalizations regarding current farm practices. The author, who assisted in the project, later expanded on the capabilities of such surveys and formulated methods and identification keys that would broaden the scope and lead toward adoption in world-wide agricultural resources analyses and census data acquisition.

Abstract: *The cinemagraphic technique of time-lapse is applied to remote sensing for the purpose of world agricultural resources analysis. Sequential photography of one-month time lapse is utilized. The techniques presented are designed as a dependable system for immediate application to the need for large-scale resources analysis. Conventional photogrammetric developments are incorporated as they may apply to aircraft or spacecraft operations until such time as multispectral methods are perfected or become practical. This study was conducted in Jefferson County, New York (commercial dairy farming; feed crops) and its methods are expanded to the 17 major agricultural regions of the world. A wide variety of stereo-imagery-recognition keys are evaluated for the dairy regions. Guidelines are established to differentiate such crops as oats, winter wheat, buckwheat, corn, hay, pastures, rowcrops, etc. Crop yield forecasts are acquired by photographic mensuration based on acreage, stand and vigor of the crops. Computer programming is designed to handle the wealth of statistical data. The objective of the study is to provide conclusive data for forecasting world food supply and to help eliminate world food shortages through fore-knowledge of agricultural conditions and potential production.*

Crop Identification and Agricultural Resources Analysis

Commercial Dairy Farming: Feed Crops

Due to the limited space available many of the details and identification keys so necessary to a successful analysis have been omitted. However, some major identifications and activity analysis are herewith included to provide a general understanding of the subject.

Mid-May Analysis

Generally speaking, soils in northern New York are wet during much of May because of snowmelt, rain and low rates of evaporation. This varies, however, from year to year; 1963 was a "late" year. In many fields poorly drained areas virtually prohibit field preparations for early planting. Dark, dendritic, internal drainage patterns are readily discernible on the aerial photographs. Tones are gray and drab and relatively few signs of farming activity can be spotted except on the better-drained soils.

Eugene Louis Schepis

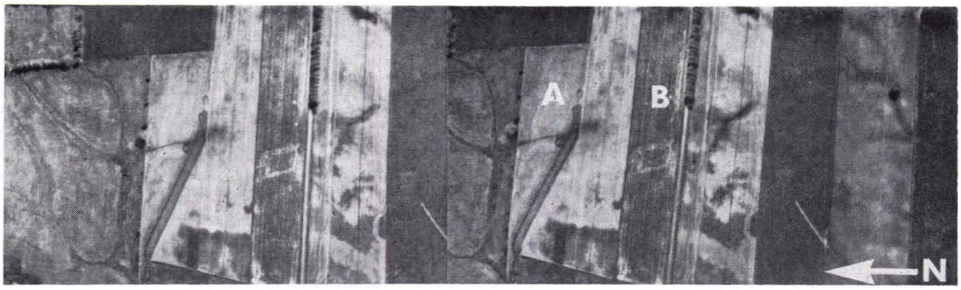

FIG. 2. Field *A* is in the process of being spring-plowed (fitted). In the stereo image the tractor can be seen in the northwest corner of the field immediately after making a test loop in the topographically low area. The freshly turned soil is moist and dark gray in tone while the already plowed portion has dried considerably thus lightening the tone. Field *B* is a forage crop in the first year of development. This is described in the "New Seedings" section on the next page.

MID-MAY FEED CROPS OTHER THAN HAY OR PASTURES

Within the entire study area all fields in this category were yet unplanted and were identified as follows:

Fall-Plowed Fields. Fall plowing is a recommended practice that pre-conditions the soil over the winter months, aerates it, and provides greater moisture-retaining properties. (Figure 1.)

Spring-Plowed Fields. In this short-season area progressive managers are usually eager to get started on their spring planting preparations as soon as the weather and rate of drainage will allow. Whether the field had been fall-plowed or not the previous autumn, preparation of the soil is still necessary prior to planting. (Figure 2.)

Unworked and Manured Croplands. See Figure 3.

Small Grain Identifications in Mid-May. Recognizing small grains in this broad category is sufficient within itself for large-scale surveys. Reliably distinguishing the individual species by photointerpretive methods, however, has long been a problem for agricultural photo analysts. This survey has shown, however, that the system of time-lapse photography can make certain inroads particularly in areas where winter wheat and rye are not competitive and where varieties of grain are not all spring sown:

(1) Winter wheat was distinguished from oats in mid-May by its greater development and higher relief in a three dimensional image. At this date of observation oats have not yet been sown in this region. The mid-May date of photography provides the optimum time for this identification.

(2) It was found that in most farm communities management practices are, for the vast majority of farmers, very similar in the type of crop plantings and rotations. Therefore, mapping of small grain crops in any localized part of the world is generally correlative to mapping only one or a specified few major types of grain. For example, the number of small grain fields in this study were found to be oats 99.6 percent of the time; four fields were planted in rye or wheat out of a total of 578 small grain fields recorded. If all small grains identified in the area had been designated as oats the increment of error would

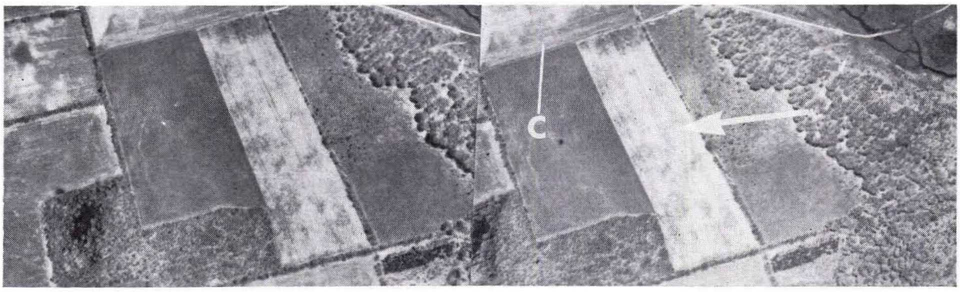

FIG. 3. Unplowed fields in the mid-May photography can be detected as coarse textured and moderate in tone (arrow). The outline of the field, fence lines and *cultivated* appearance signify its usage as a cropland field but to date nothing has been done to prepare it for the coming season. Note the light toned stripes curved at the ends in field *C*. These are trails made by the manure spreader. Barn cleaning is a daily chore for the dairymen but snow and mud may delay spreading until spring, especially on low-lying or remote fields.

be so small as to be insignificant in large scale surveys.

MID-MAY CONTINUOUS COVER CROPS

Hay Fields. The quality of hay for dairy cattle is commonly judged by the percentage of legume contained in the stand. Those fields with stands composed of 95 percent or more alfalfa, or other legumes, have greater food value and greater yield per acre than those fields that contain a majority of grasses. In the photosynthesis process, legumes absorb more radiation energy due to the angle of leafage display than grasses do. For this reason thick stands of forage legumes appear on panchromatic photographs as dark toned and smooth textured. Other fields appear spotty and less vigorous-looking. (Figure 4).

From this uniformity of tone, or lack of it, a classification of forage quality has been established as excellent, good, fair, and poor relating to the legume content (Figure 5.)

New Seedings. A new seeding is a stand sown the previous year as an underseeding to oats. Such a field is discernible in spring as a pattern of contrasting linear tones similar to the drill pattern associated with newly sown oats. This is due to the light-colored grain stubble remaining from the previous year. The stubble disappears as the season advances. (See Figure 2, Field *B*.)

Pastures. See Figure 6.

MID-JUNE ANALYSIS

In mid-June the wet conditions that were so prevalent in mid-May are, for the most part, dry or remain only as small damp areas. Tones are clear and bright and the perennial vegetation cover is thick and lush creating sharp field boundaries and dense shadow tones on the photographs. The major farm activities recorded were haying and oat planting.

MID-JUNE FEED CROPS OTHER THAN HAY OR PASTURES

Mid-June Small Grains (99.6 percent oats). At this stage of development spring-sown grain is identified by drill patterns, spraying patterns, characteristic weeds, etc., as shown in Figures 7 and 8.

Mid-June Corn. Corn fields at this date have recently been planted or are being fitted. From observations of the tonal characteristics of these fields early estimates of corn production can be made.

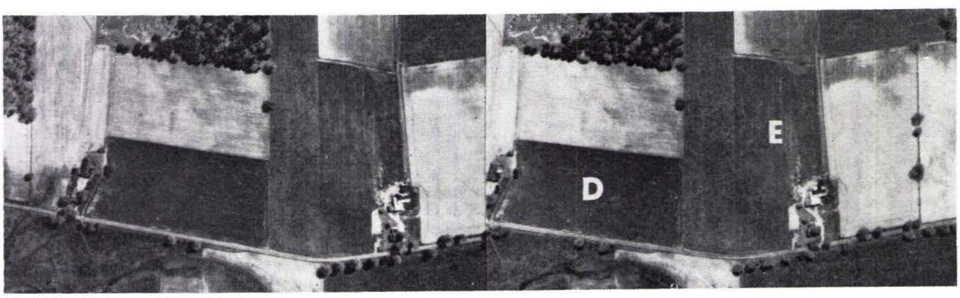

FIG. 4. Field *D* is an excellent stand of forage, mainly alfalfa. A uniform, smooth, dense crop containing as much as 95 percent legume. Field *E* is a good stand. It appears less dense and is fairly uniform with some light tones in sections of the field. This field contains no more than 70 percent legume.

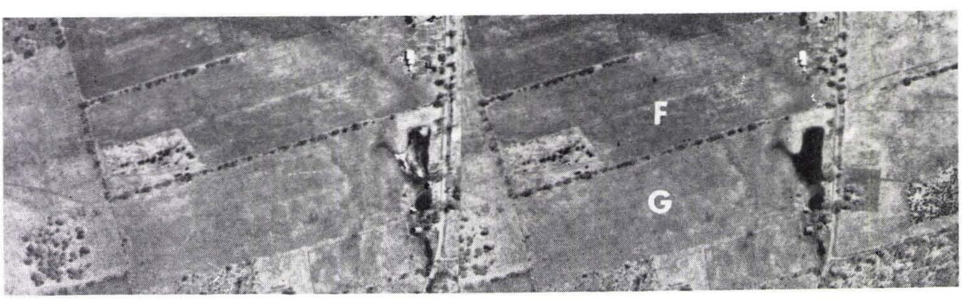

FIG. 5. Field *F* is a fair stand of forage. It displays mottling and zones where only grass grows. This field contains no more than 20 percent legume. Field *G* is a poor stand of forage appearing mellow light-gray in color and medium to coarse in texture. Generally this type of field contains no legumes.

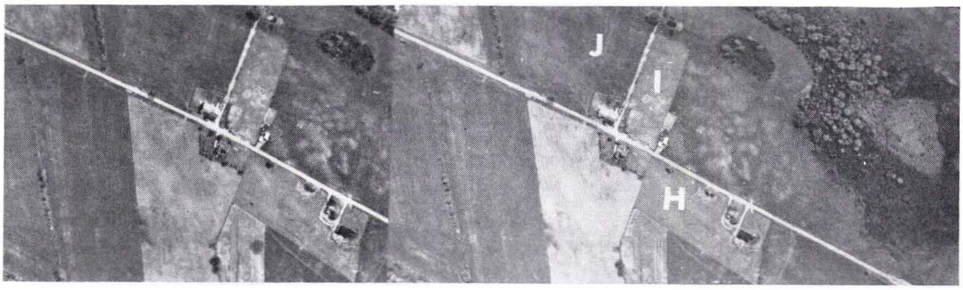

FIG. 6. Fields *H* and *I* have been used for pasture for a prolonged period of years; commonly called permanent pastures. These light-toned fields of short grass have a coarse texture and medium light reflectance from scattered exposures of bare soil. Boulders, bushes and trees are commonly found in permanent pastures and contribute to its unsuitability for cultivation. Field *J* is a forage crop sometimes used for pasture. These fields are particularly evident by darker tones as compared to permanent pastures and the manure spots left by the grazing cows. This self-fertilizing method stimulates growth only around the immediate area of the deposit creating a peppered effect on the photograph.

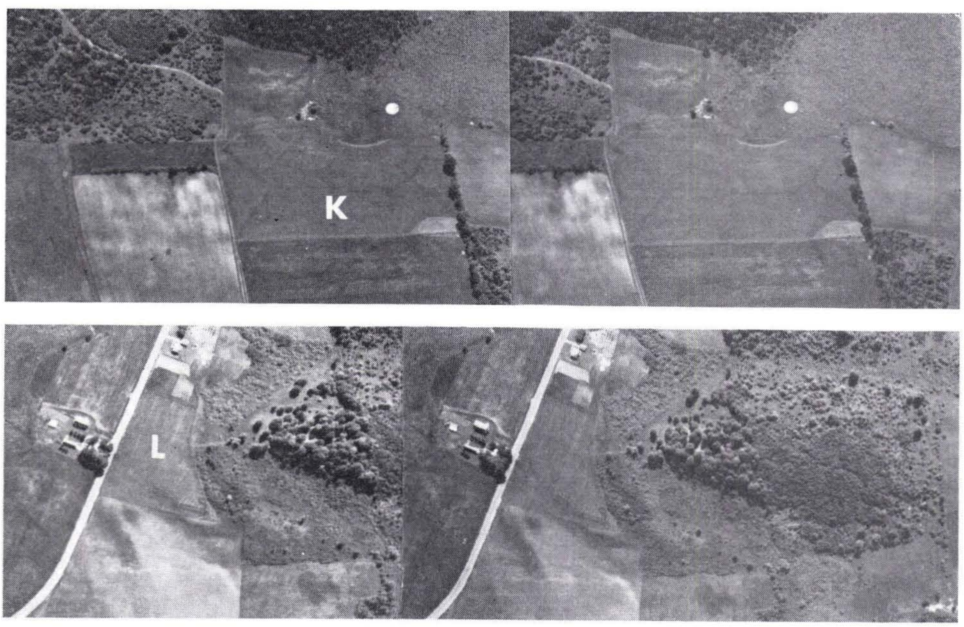

FIG. 7. Oats drilled with a *Y*-pattern; field *K*. The function of drilling, i.e., sowing small grains with a multiple-row machine, by following the outside perimeter of the field and working toward the center creates a pattern on the drill-turn not unlike two opposing *Y*s joined at the tail. The pattern persists on the photographs well into the mature stage of the grain. Field *L* is a field of oats drilled in a straight-line pattern with the drill-turn on the ends of the field. This creates a line of scalloped edges on opposing sides of the field.

MID-JUNE CONTINUOUS COVER CROPS

Hay Fields. On the more progressive farms in this district June is a busy month in the hay fields—weather permitting. In every case, weather that favors aerial photography also favors hay making. Thus, many fields were observed to be in the process of being mowed with machinery visible in the fields (Figure 9). The survey provided an accurate time record of haying, raking, baling and crop removal. This in turn provided a check on how closely the early haying-advice of extension programs was followed.

MID-AUGUST ANALYSIS

By mid-August farming management in New York State is mainly concerned with the harvesting of small grains. Corn is fully developed and stands high in the relief of the stereo image. Many forage crops have regrown sufficiently from the first cutting to be cut a second time.

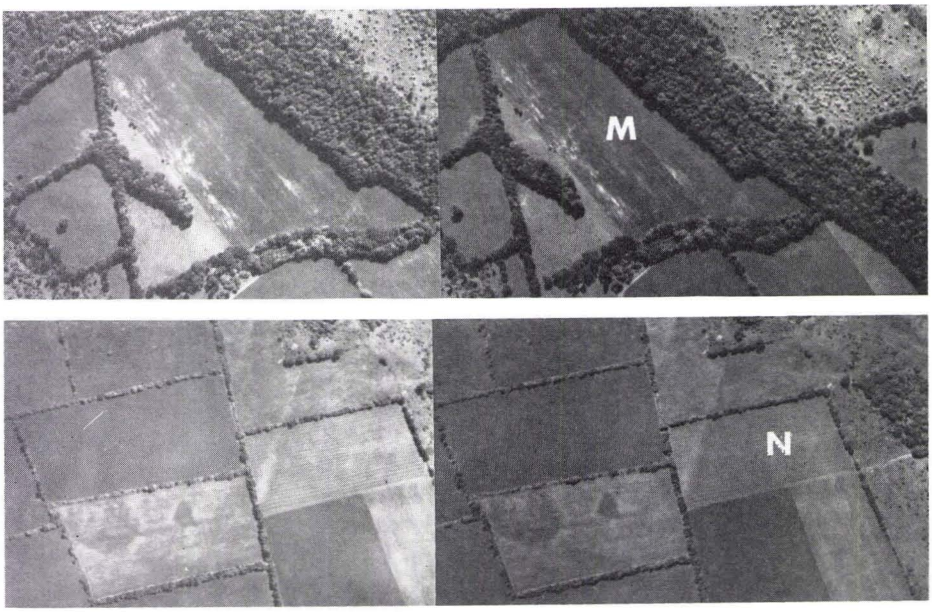

FIG. 8. Field *M* is an oat field infested with the weed *yellow mustard*. In this field, drilled in a straight-line pattern, the mustard infestation is readily seen as light toned streaks at this stage of growth. Field *N* is an oat field that has been sprayed with herbicides to combat weed infestation. The striping was caused by the tire marks made as machinery ran over a 2- to 3-inch growth of oats.

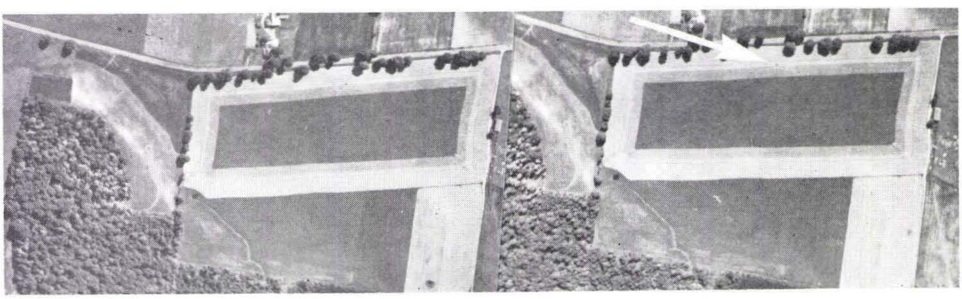

FIG. 9. This hay field (arrow) combines three haying identifications in one view: (1) an excellent legume stand of forage in the center of the field; (2) a strip of cut and curing hay about 40 feet wide; and (3) a strip of raked hay about 60 feet wide being raked at the time of photography. Raked windrows are easily identified as neat, narrow light strips formed parallel to the borders of the field.

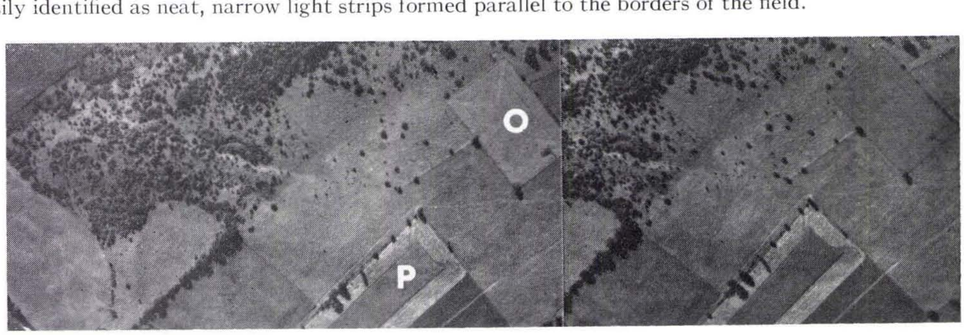

FIG. 10. Ripe oats and oats harvested. The reflectance values of a field of ripe oats (field *O*) can generally be described as medium-high to high. This example illustrates how well the drilling pattern remains as a distinctive part of an oat field even when fully matured. A crop-yield evaluation of this field classifies it as *GOOD* as described on page 1175. In field P the camera has recorded an oat field in the process of being combined. The uncut portion can be seen standing in micro-relief with the combined portion removed. The straw, as a residue from the oats, can be seen laying in narrow rows the way the combine had expelled it.

FIG. 11. In a productive corn field the 6 to 8 feet of relief can readily be distinguished as higher than any other crop save the woodlots (arrow). Sorghum may be seen in this district, though very rarely. Besides the coarse texture and rich tone, a few missed rows in the planting pattern of most fields creates empty furrows as seen from a vertical view. This is commonly caused by planting the field in *lands* (sections). For crop-yield evaluation this example corn field is classified as *GOOD* as described on page 1175.

MID-AUGUST FEED CROPS OTHER THAN HAY OR PASTURES

Mid-August Small Grains (99.6 percent oats). Oats, and other small grains, turn color (Figure 10) as they slowly mature from the heading stage to a completely ripe stage. The change in color is recorded on the panchromatic photograph as a change toward higher reflectance, hence lighter tonal values. With this progressively lighter tone change in a stand of oats, a degree of maturity can be determined by the degree of lighter tonal values. Oats in the boot stage, to partly ripe, to ripe, among other identifications, can be determined by a stereo image.

Mid-August Corn Fields. Corn during the mature stages is prominent in a stereo image from the standpoint of its microrelief, its rich, dark-gray tonal values, and its relatively coarse texture (Figure 11).

The summer of 1963 was drier than normal. As a result, many corn fields did not develop satisfactorily and yields were down 50 percent in some fields while in other nearby fields the drought did not affect them seriously at all. Examples from this survey revealed that one cause of this decrease in productivity was the failure of the manager to fall-plow his fields. (Figure 12.)

MID-SEPTEMBER ANALYSIS

Mid-September in Jefferson County, New York, is a period of intensified harvesting activity. Corn for ensilage is ready at this time of year for cutting and storing, oats which have not been cut to date must be combined, and some second or third cuttings of hay must be made before the cold weather sets in. From an interpretive standpoint, crop identification on the September photographs is not an important factor inasmuch as all crops would normally have been conclusively recognized on the previous photographic runs. This date of photography was found to be mainly beneficial for recording harvesting dates, including late haying, and estimating the success in establishment of new forage seedings in small grain fields.

MID-SEPTEMBER FEED CROPS OTHER THAN HAY OR PASTURE

CORN HIT BY FROST AND CORN HARVESTED. (See Figure 13.)

COMPUTER COMPILATION AND DATA STORAGE

The 75-mile loop of photo coverage for this study incorporated the stereoscopic evaluation of over 3,243 productive fields or the equivalent of 30,466 acres. In numbers, hay fields totaled 2,265 (22,192.7 acres); corn fields totaled 400 (3,401.1 acres); and oat fields totaled 578 (4,862.3 acres). In addition to these, permanent pastures, miscellaneous crops, woodlots and idle fields, etc., were recognized and evaluated but not statistically compiled.

Haying dates, planting dates, and harvesting dates for oats, wheat, corn, etc., were recorded for the fields along with other pertinent data related to the survey.

Twenty 7.5-minute USGS topographic quadrangles were used as a thematic base map upon which all fields were annotated and classified. The data obtained from the photographs were applied to each respective field, according to its individual classification, and stored. From this any statistical datum or combination of data can easily and rapidly be obtained for economic or census evaluations.

CROP YIELD FORECASTS

In 1963, production rates in Jefferson County averaged 11 tons of corn silage per acre, 49 bushels of oats per acre, and 2.4 tons

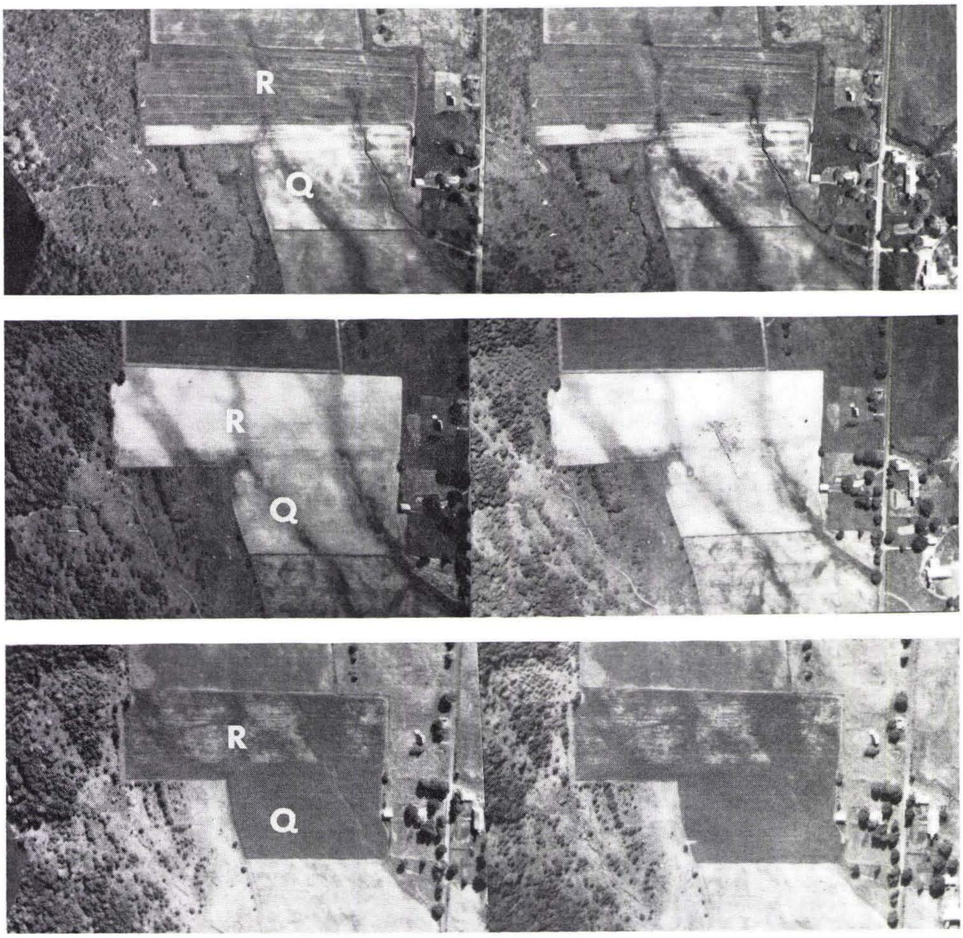

FIG. 12. This series of stereograms displays the results of fall-plowing in two fields adjoining one another. The May photography (top) clearly shows the difference between the high reflectance of field *Q* which had been fall-plowed and field *R* which had not been fall-plowed but was still a rough-textured, grassy meadow at that time. In mid-June (center) it can be seen that both of the fields were plowed and combined into a single corn planting. In the mid-August photography (bottom) it is quite apparent that field *R* was severely affected by the dry summer with stunted growth and only partial development. Field *Q*, however, withstood the drought and developed into a productive crop.

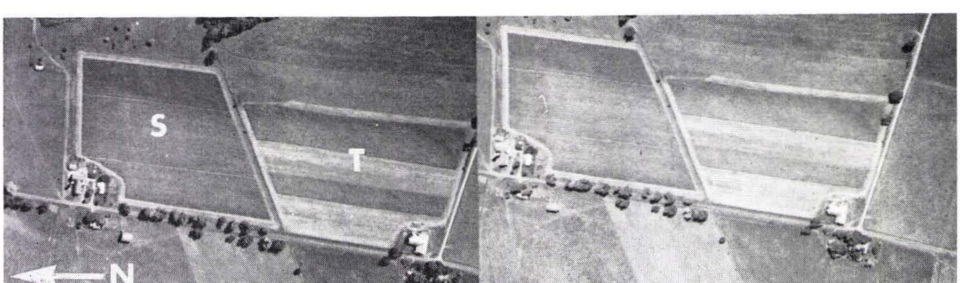

FIG. 13. That portion of field *S* that extends up the western slope of the drumlin is dark in tone and unaffected by frost. The lower portion of the field shows the lighter tone of those plants affected by frost and its direct relationship to the lower elevation. Field *T* had been partially harvested for silage. The harvested portion of the field has a light reflectance tone and coarse texture from the stubble and the exposed soil. The standing corn is contrasted by its darker, rich tones and its stereo relief of 6 to 8 feet.

TABLE 1. CATEGORIES OF CROP YIELDS

	Corn (tons/acre)	*Hay (tons/acre)*	*Oats (bu/acre)*
EXCELLENT	20 and over	greater than 5	81 and over
GOOD	15 to 19.9	3 to 5	61 to 80
FAIR	11 to 14.9	1.5 to 2.9	41 to 60
POOR	10 and less	less than 1.5	40 and less

of hay per acre, according to the Cooperative Extension Association of Jefferson County. These averages were obtained from 28 selected farms throughout the county representing a relatively complete spectrum of farm operations, farm production, economic and soil conditions.

For this study, seven cooperating farm managers assisted the project by providing production figures of their field crops for the year 1963. A direct comparison was made between the micro-imagery characteristics of crops on these farms and their corresponding rates of production. From these data a quantitative recognition system was established whereby vigor, stand, and general appearance of any crop as seen through the stereoscope would disclose the classification of a field and thereby provide a quick and concise method to determine the potential yield range of any crop. Four generalized categories were found to be satisfactory for obtaining reliable potential yield data. These are shown in Table 1.

CORN YIELDS

Owing to the dryness of the growing season of 1963, many fields of corn were low in yield. On an average, the 28 Jefferson County farms sampled produced 11 tons of silage corn per acre in 1963. The average of the 7 cooperating farms in this study produced 14 tons per acre. (See Figures 14, 15 and 16).

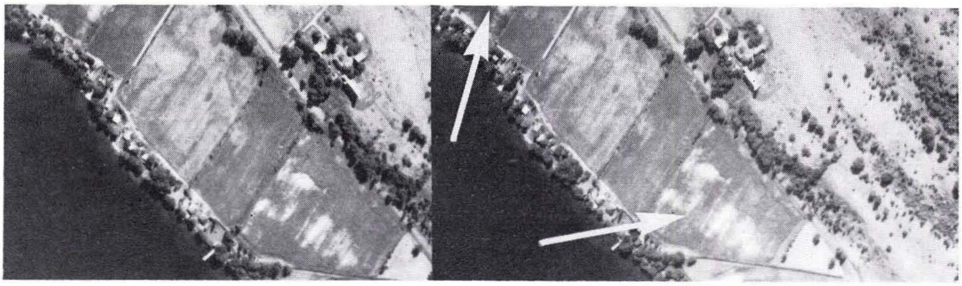

FIG. 14. A field of corn classified as *POOR* is a stand that appears *patchy* in the stereo image (arrows). Stereo relief is irregular with stalks varying in height from 6 feet down to 3 feet and even shorter. Large areas of bare soil show up as zones of high reflectance. In this example the fields had not been fall-plowed and the total yield of the two fields was approximately 112 tons, or 8.0 tons per acre.

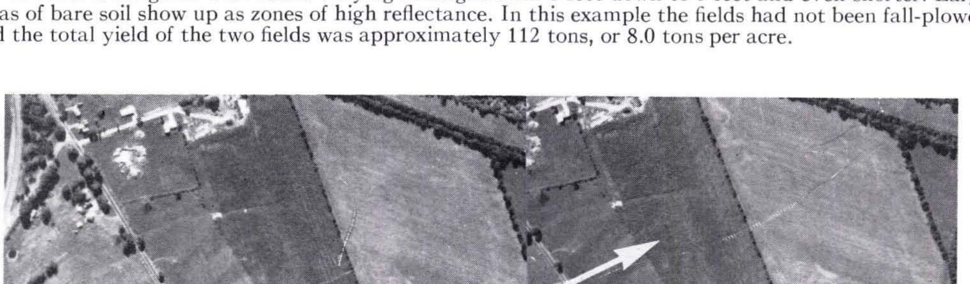

FIG. 15. A field of corn classified as *FAIR* exhibits an irregular or coarse textural stereo pattern on the field (arrow). Relief in the height of the corn is more constant than that of the poor fields, but zones of slightly stunted stalks can still be detected. In many cases a good number of missed-rows leave gaps in the row pattern. In this classification no zones of bare soil are visible because of complete vegetation cover. However, areas of less vigor do exist and are identified by their lower relief. This field measures 20.5 acres and produced 246 tons of silage corn, or 10.8 tons per acre.

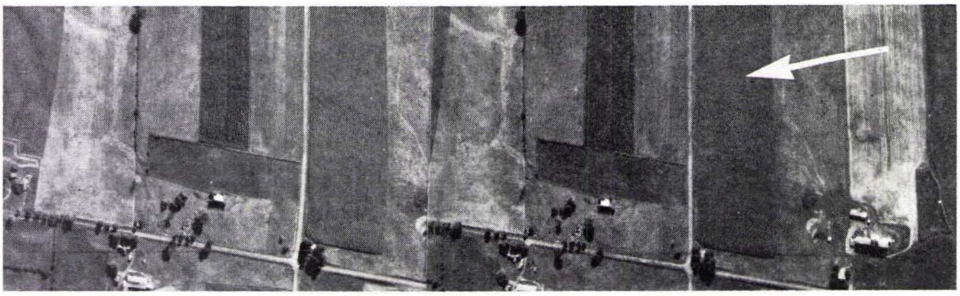

FIG. 16. A field of corn classified as *EXCELLENT* is a very smooth and dense stand as seen in the stereo image and it is constant throughout the field area (arrow). Relief is high and very regular. In many cases a field with this kind of production is planted with 30-inch row-spacing instead of the conventional 36-inch row-spacing. This tends to give the stand a very solid appearance because the rows can hardly be detected under normal stereo magnification. This field measures 17.3 acres and produced 519 tons of silage corn, or 30.0 tons per acre.

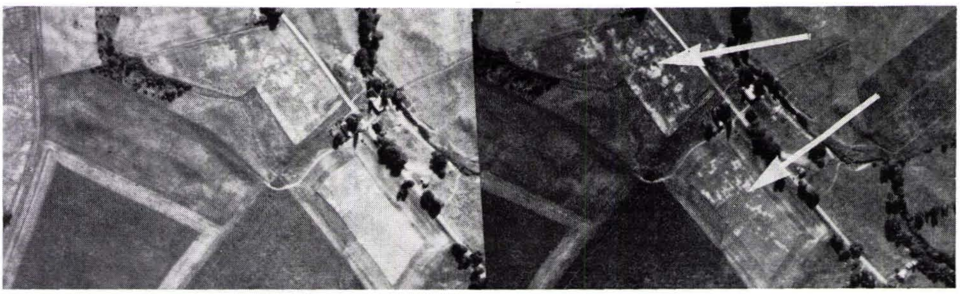

FIG. 17. A field of oats classified as *POOR* produced less than 40 bushels per acre and was commonly found to have been lodged,* seriously affected by disease and/or weeds or managerially neglected (arrows). The most common cause of low oat yield in this study was lodging. In the stereo image a lodged oat field can be detected by the difference in micro-relief between the standing portions and the lodged portions of the field. The random contrasts in relief create an etched appearance peculiar to oats and other small grains. These two partially lodged oat fields together measure 16.7 acres and produced 601 bushels of oats, or 36 bushels per acre.

A field of corn classified as *GOOD* (see Figure 11) appears in the stereo image as a smooth and relatively dense stand of stalks for at least fifty percent of the field area. The field is generally well planted and perhaps only one or two rows were missed forming row-pattern gaps. A near-uniform height of plant is evident and areas of less vigor are rare. Relief is good and relatively constant. This field measures 35.8 acres and produced 637 tons of silage corn, or 17.8 tons per acre.

OAT YIELDS. See Figures 17, 18 and 19.

A field of oats classified as *GOOD* (See Figure 10, Field *O*) represents a field that appears smooth, even, and vigorous in the stereo image. Relief is generally moderate and can be recognized at the edge of the field where it may join another having less relief. Drilling patterns, however, are still obvious in its mature stage indicating a "loose" or careless drilling technique thereby lowering production to the 61-to-80-bushel per acre rate. This field measures 10.9 acres and produced 708 bushels of oats, or 65 bushels per acre.

HAY YIELDS

Accumulative hay yields throughout the growing season have resulted in a variety of statistical data directly related to the number of times a hay field was cut during the year. Hay quality was described above in the mid-May section and classified according to the legumenous content of the field as measured in the stereo image. The relationship of the two, i.e., hay quality and hay yield, is ordinarily proportionate to the amount of legumes in the field and the ability to recover rapidly so as to allow repeated cuttings. The amount of rainfall during the season has a profound effect on second and third cuttings

* *Lodging:* When the standing mutual-support of grain stalks is broken by wind or storm, thus shattering the kernels and rendering the grain unharvestable by modern methods.

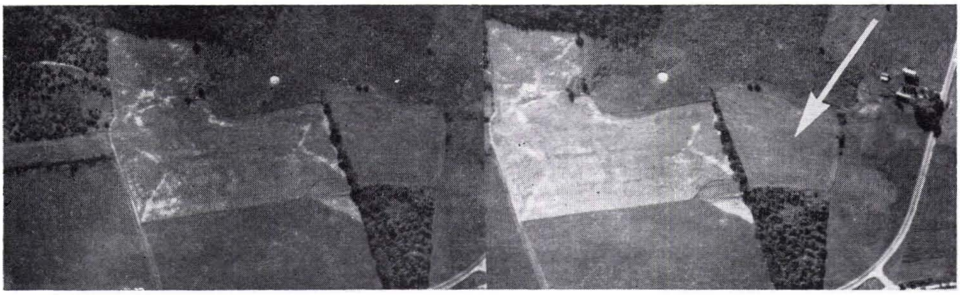

FIG. 18. A field of oats classified as *FAIR* exhibits scattered patches of less vigor in the field (arrow). These are observed in the stereo image as areas of slightly lower relief and higher tonal values. Light tones are generally visible where soil is exposed on the drill-turn patterns. This field measures 5.8 acres and produced 348 bushels of oats, or 60 bushels per acre.

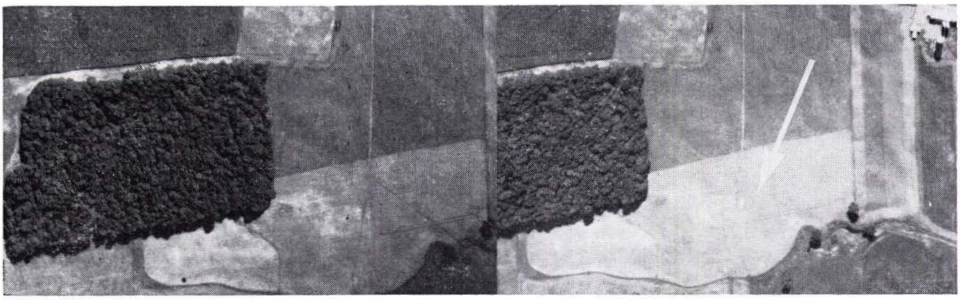

FIG. 19. A field of oats classified as *EXCELLENT* is exhibited in the stereo image as a smooth and compact plant mass displaying only little evidence of a drilling pattern (arrow). The lack of an apparent drilling pattern in a mature stage is due to a *tight* and disciplined drilling technique at the time the field was sown, plus uniform emergence and vigorous development. Relief is high and homogeneous throughout the field. This field measures 21.2 acres and produced 1,759 bushels of oats, or 83 bushels per acre.

of the crop and thereby plays an important role in the rate of regrowth. Other factors including skillful management, acidity and fertility status of soils, etc., are all closely correlated to the annual rate at which hay fields produce.

The total expected yield of a forage crop depends, therefore, on a classification given a field when it is first examined early in the season and the number of times it can be, or is, cut during the growing season. For example, field number 50 on a farm north of Ellisburg was recorded as a new seeding of *EXCELLENT* quality containing a high percentage of legumes in mid-May of 1963. The field was cut three times during the season as recorded on the aerial photographs and was never used as a pasture. The field measures 28.1 acres and the accumulated annual production was 157 tons of hay or 5.6 tons per acre. The field has been given an early season (mid-June) classification of *EXCELLENT* quality and a post season classification of *EXCELLENT* yield because of the number of times successive cuttings had been recorded.

In another example on a cooperating farm, five hayfields were classified as *GOOD* quality in the early season examination. Four of the fields were cut only once and then put to pasture for the remainder of the season. The fifth was not cut at all but simply pastured beginning sometime after the mid-June photography. The first four hayfields combined measure 36.4 acres and produced 80 tons of hay, or 2.2 tons per acre, in one cutting. The post season classification given to these fields was *FAIR* yield even though the fields rated a *GOOD* quality classification in the early season observations. All practices were observed and timed on the aerial photographs.

In experiments conducted in northern New York it was found that a second cutting of hay yields only about 35 percent of the initial cut. The third cutting generally yields about 25 percent of the initial cut.

In summary the following schedule had been established as a preliminary guide for determination of accumulated annual hay yields taken from those haying practices observed on the aerial photographs throughout the season. (See Table 2)

TABLE 2. HAY YIELD CLASSIFICATION

Early Season Classification	*Number of Cuttings*	*Post Season Classification*		*Expected Accumulated Annual Yield*
Excellent Quality	3	Excellent Yield	or	>5 tons/ac.
Excellent Quality	2	Good Yield	or	3–5 tons/ac.
Excellent Quality	1	Good Yield	or	3–5 tons/ac.
Good Quality	3	Good Yield	or	3–5 tons/ac.
Good Quality	2	Good Yield	or	3–5 tons/ac.
Good Quality	1	Fair Yield	or	1.5 to 2.9 tons/ac.
Fair Quality	3	Fair Yield	or	1.5 to 2.9 tons/ac.
Fair Quality	2	Fair Yield	or	1.5 to 2.9 tons/ac.
Fair Quality	1	Poor Yield	or	<1.5 tons/ac.
Poor Quality	3	Poor Yield	or	<1.5 tons/ac.
Poor Quality	2	Poor Yield	or	<1.5 tons/ac.
Poor Quality	1	Poor Yield	or	<1.5 tons/ac.

IMMEDIATE APPLICATION TO WORLD-WIDE RESOURCES ANALYSIS

In spite of tremendous obstacles and variables involved, it is the opinion of many that automatic systems of tone signature recognition and multispectral imagery recognition will eventually enable man to differentiate crops and evaluate farm practices on an automated basis with little or no human involvement. Great strides have been made in this direction and research is continuing to perfect systems which are only now in the ground stage. If this capability can be realized, it will undoubtedly be a valuable survey tool for the photo interpreter. However, most predictions are visionary and the greatest limiting factor of these systems is the time involved for completion and perfection to satisfy the present and near-future needs of resources evaluation analysis.

The time for an aggressive program in agricultural recources analysis is the present. The techniques presented in this paper are designed as a dependable system for *immediate* application to the need for large-scale resources analyses. Conventional photogrammetric developments are incorporated as they may apply to aircraft or spacecraft operations until such time when multispectral applications are perfected and become practical.

Although the pilot study described here is limited to a small section of commercial dairy country it nevertheless has a broad scope in that its application is designed for a world-wide network of agricultural regions. In *Van Royans World Map of Agricultural Regions* (1954) all major types of agriculture are categorized into seventeen regions. (See Figure 20.) The area of this study falls in the region called "Commercial Dairy Farming; Feed Crops," extending from Minnesota, through the Great Lakes region to the east coast and the Cape Race area of Newfoundland. Other dairy regions are found in Europe and Australia-New Zealand. Sixteen other major regions comprise the remainder of the world ranging from zones of "Insignificant or No Agricultural Potential," i.e., the Arctic, Antarctic and deserts, to "Large-scale Tropical Plantation Agriculture."

To facilitate a worldwide system of agricultural analysis such as that described in this study for a commercial dairy area, a small corps of specialists would be trained to be responsible for photointerpretive analysis within their region. For United States agriculture, carefully tutored extension agents could handle the domestic program. Men who know foreign agriculture could specialize in photo analysis of foreign crop production.

The system, of course, is designed with built-in flexibilities to incorporate changes and improvements as more knowledge is gained through working experience. One such consideration may be the adoption of *sampling methods* to keep money and time expenditures to a minimum.

As in most photointerpretive systems, it is important that recognition keys be established for each agricultural division. For the most part, this study provides a wide variety of recognition keys for the commercial dairying region. Auxiliary keys can undoubtedly be supplemented when more of the region is reviewed and additional information is gained from Minnesota to Newfoundland. In like manner, each agricultural region of the

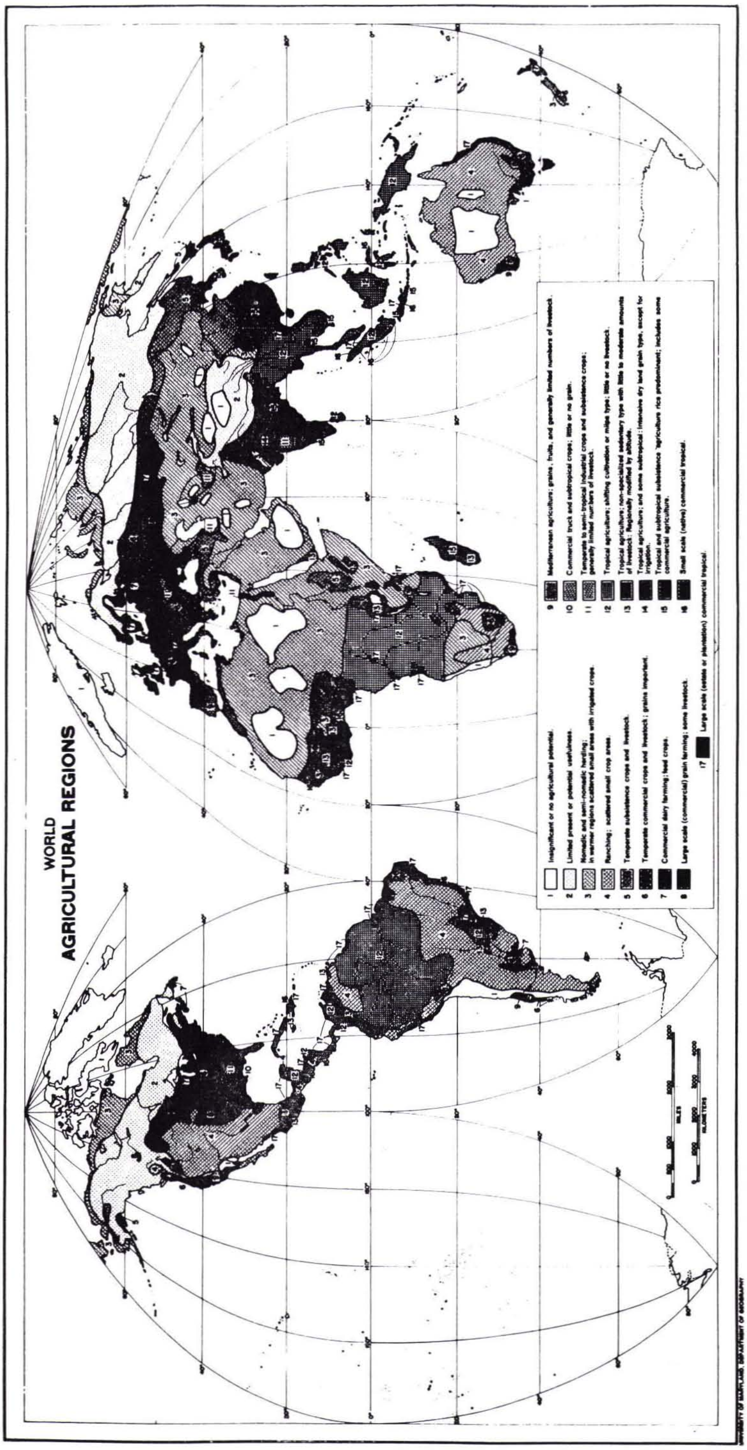

FIG. 20. Van Royans World Map of Agricultural Regions.

world will have its own set of descriptive classification keys, compiled by specialists in each area and ground-checked for accuracy where identification is problematical.

In worldwide resources analysis programs, speed and accuracy of photointerpretation is an important factor. Three major steps are involved once the photography is received: (1) gathering of information by interpretive analysis; (2) plotting of the information on a thematic base map or mosaic; and (3) computerizing the data for storage and quick readback. Of these, number one is the most time-consuming process. Therefore, the proficiency and experience of the analyst are the keys to a successful program. It must be realized that proficiency cannot be gained within the first glance of a stereo image. Training programs must be established to help selected analysts know the importance of projecting themselves into the area viewed; to concentrate their efforts only within their specialized region; and to make fast and accurate decisions. Once the identification keys of each agricultural region are recognized and the imagery is well established in the analyst's mind, identification becomes automatic and almost immediate. Analysis of successive photographic runs in the time-lapse system is an automatic check on previous calculations thereby eliminating the human error factor.

Suitability for Earth-Orbital Missions to Adopt Time-Lapse Systems

Many problems remain to be solved, of course, regarding timing control of continuous flight polar orbital missions. However, the facility of long-duration space flights with repetitious coverage over identical regions of the earth at constant intervals suggests that the requirements for time-lapse systems can be met with no additional technical demands to an orbital space platform program.

Of the 17 agricultural regions of the world mentioned previously, 3 comprise about 75 percent of the total land mass and have insignificant or limited potential agricultural usefulness. These regions include the Arctic, Antarctic, deserts, tundras, and extensive rangelands of the world. The remaining cultivated land masses would require repetitious sensing preferably directed by manned intelligence to avoid unnecessary data acquisition in areas of interference or zones of little interest.

Conclusions

Detailed, but rapid, micro-feature analysis has proven that, with the aid of the computer, a down-to-earth, world-wide system of agricultural resources analysis is feasible now. Manned by a small, well-trained corps of agricultural interpreters, conventional photogrammetric developments can be incorporated as they may apply to aircraft or spacecraft photographic sensing without reliance on costly and complex multisensor or tone-signature instrumentation. Not only is crop identification possible by time-lapse systems, but cropping practices, management procedures, and crop production can also be analyzed equally as fast.

The facility of the planned earth-orbital platform providing long duration coverage over identical regions of the earth at constant intervals suggests that the requirements of time-lapse systems can be met by present space technology with no additional technical demands.

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