PANEL DISCUSSION

AERIAL PHOTOGRAPHY FOR AGRICULTURAL RESEARCH AND PLANNING*

Chairman: Dr. Charles E. Kellogg, Chief of the Division of Soils, U. S. Department of Agriculture.

Moderator: Mr. Marshall S. Wright, Assistant to the Director, Office of Plant and Operations, Office of the Secretary, U. S. Department of Agriculture.

Panel Discussants: Dr. Roy S. Simonson, Division of Soils, U. S. Department of Agriculture; Mr. Edward Magruder, Soil Conservation Service, U. S. Department of Agriculture; Mr. Karl E. Moessner, Forest Service, U. S. Department of Agriculture; Mr. Ralph H. Moyer, Production and Marketing Administration, U. S. Department of Agriculture.

Chairman Kellogg: I want to follow up a little what I said this morning. I am not a member of this Society or qualified in the field of its major interest, but I do think it important that the expertness in this Society be available. I do not know (probably some of you do) how you act on proposals, but I did make a definite proposal this morning that the Society might be able to organize in such a way as to be available for giving advice to a good many foreign governments that will need advice on various kinds of aerial photography, much of which will have to be done under a good deal less than ideal conditions. I suspect that the program this afternoon is along that same general line—a chance for some customers of the photogrammetrists to say what they have on their chests, both bad and good, about the product. After all, a great deal of photogrammetry is, of course, of interest to itself, but the greatest part of it is done as a service to some other program and the financing is obtained that way; of course agriculture is one of the most important of those.

Our first speaker, Mr. Marshall Wright, is in charge of this sort of activity for the Secretary's office, in the Department of Agriculture.

The Moderator, Mr. Wright: I believe I can assure Dr. Kellogg that we will follow through on his suggestion. This is an undertaking to which the society will be glad to give consideration.

My statement today is largely a repetition of what I said at the Regional Meeting at Denver and printed in the December issue of this Journal.

The Department of Agriculture is probably the greatest user of aerial photographs in the Federal service, with the possible exception of the military agencies. Aside, and entirely separate from the more commonly accepted usage of aerial photography in the preparation of maps, the agencies of the Department, namely, the Soil Survey of the Bureau of Plant Industry; the Soil Conservation Service; the Forest Service; and last, but by far not the least, the Production and Marketing Administration; use aerial photographs—as photographs—to study and to depict and to delineate their many land-use problems. These photographs and/or enlargements therefrom serve as a medium upon which can be graphically outlined all the various factors influencing or affecting the surface of the earth—soil types, kind and extent of soil erosion, timber and vegetative cover, land capabilities, flood and flooded areas and their extent, farm boundaries, indicated crop planting areas, and all other factors affecting or influencing man's use and occupancy of the land. The aerial photograph, in the hands of an experienced agricultural technician, serves as an ideal medium

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upon which he delineates and accentuates his particular problem, and does it in an easily understood and comprehensive form for the layman with whom he most often has to deal.

One must not conclude from the above statements, however, that the agencies of the Department of Agriculture are merely "users of aerial photographs" and have no knowledge of the complex photogrammetric problems involved in their conversion from pictures to maps. All the inherent factors of tilt, tip, relief and relief displacement, and their effect on photo scale and true orthographic projection are daily problems which for the most part, are handled by photogrammetric engineers assigned to the project.

For those of you who may be interested, the Department of Agriculture has executed, either directly or by contract, over 4,000,000 square miles of aerial photography, as of June 30, 1949, at a cost of approximately $11,240,000, or $2.80 per square mile. This photography is, for the most part, on the scale of 1:20,000 and complies with rigid departmental specifications. It should be noted, however, that since the area of the United States is just in excess of 3,000,000 square miles, the excess photographic coverage (1,000,000 square miles) represents photography of the same areas more than once. It may be of further interest that from June 30, 1949 to date, 340,196 additional square miles have been placed under contract, and the photography is now in process of execution.

This morning you had an opportunity to hear Dr. Kellogg present a paper on "World Food Production; the Role of the Photogrammetrist".** At first, one might wonder where the connections lie, but those of us who heard his paper probably realize now, as never before, the far-reaching effect the work of the photogrammetrist has on the welfare of the earth's inhabitants.

Each of the principal participants in this Panel Discussion is requested to outline the kind and extent of the work done in the agency he represents, and the part that aerial photography plays in its solution. After these papers are presented, the meeting will be open to discussions and questions from the floor.

The first speaker is Mr. Moessner, of the Forest Service. He entered the Forest Service in 1933 as a technician in the Civilian Conservation Camps, Lake States region. Subsequently he was assigned to fire-tower and fire-road location; it was there that he first used aerial photographs. In 1942, he entered the armed services as a Reserve Officer. Subsequently assigned to the Army Air Force, he spent one-and-a-half years in England as a Photo Intelligence Officer with Headquarters 3rd Air Division, 8th Army Air Force. At the close of the war, he was assigned as photogrammetrist to the Central States Forest Experiment Station of the U. S. Forest Service.

The name of Mr. Moyer, the second speaker, is synonymous with aerial photography in the Department of Agriculture. He hardly needs an introduction. The Production and Marketing Administration, as you probably know, has offices in practically every county in the United States. Mr. Moyer was born in Fairfield, Iowa, is a graduate of Iowa State College, farmed and fed livestock from the time he finished school until 1933. He has been employed by the Agricultural Adjustment Administration and its successor, the Production and Marketing Administration, from 1933 to the present time. His present duties are as Chief of the Aerial Photographic and Engineering Service of the Production and Marketing Administration.

The third discussant, Dr. Roy Simonson, was born and reared on a wheat farm in North Dakota. He worked as a farm hand for several years before earning his B.S. at the State Agricultural College in 1934. He also worked briefly

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for the Montana Agricultural Experiment Station on soils of irrigation projects, and edited several dozen of the papers in *Soils and Men*, the 1938 Yearbook of Agriculture, while completing his graduate study for a Ph.D. at the University of Wisconsin, in 1938. From 1938 to 1943, he was in charge of the soil survey program of the Iowa Agricultural Experiment Station, and in 1943 joined the staff of the Division of Soil Survey, Bureau of Plant Industry, Soils and Agricultural Engineering. In the following year he was placed in charge of the soil survey program in the Southern States and, except for some thirteen months in 1947–48, he continued with the assignment as Principal Soil Correlator. Later he was transferred to Beltsville, Maryland, where he now is Assistant Chief of the Division. During 1947 and 1948, Dr. Simonson was with the Military Geology Unit of the U. S. Geological Survey initiating a program of soil surveys for the U. S. Army Corps of Engineers, on the islands of the west Pacific Ocean now controlled by this government. His chief interests, professionally, have been in the classification, morphology, genesis, and geography of soils, with secondary interests in land economics and general geography.

The next person on the extreme right, Mr. Magruder, of the Conservation Service was born in Baltimore, Maryland; attended grammar and high school in Baltimore and later took engineering at Maryland Institute and Johns Hopkins University. He received his early training with the B & O Railroad and with Glenn L. Martin aircraft manufacturers and also spent some time with J. F. Dusman, Consulting Engineer in Baltimore. His government service consists of about two years with the U. S. Coast and Geodetic Survey and fifteen years with the Soil Conservation Service. He is now Acting Head of the Map Control Section, Division of Cartography. He is a registered professional engineer in the State of Maryland.

During the reading of each paper, I suggest that you make such notes as you may wish to serve as the basis for questions, later on. When all the papers have been presented we will invite questions.

PRINCIPAL USES OF AIR PHOTOS BY THE FOREST SERVICE

Karl E. Moessner, Photogrammetrist, Central States Forest Experiment Station, Columbus, Ohio

THE Forest Service, U. S. Department of Agriculture, administers 195 National Forests and purchase units and 28 experimental ranges and land utilization areas, totaling some 180 million acres. It cooperates in the field of fire protection with 44 states and territories, and in the field of forest management with private owners in all states. It is involved in nation-wide forest and range research including the Forest Survey. These widespread activities take place largely on wild land that is inadequately mapped and is often inaccessible. It seems probable, therefore, that the normal activities of the Forest Service offer the most varied opportunities for daily use of air photos to be found in any peacetime service.

In the brief 30 years since they were first tried on the Columbia National Forest in Washington, air photos have been used, at least experimentally, in all phases of field work, from the preparation of forest maps to the photogrammetric estimation of board-foot volume in standing timber. Almost without exception their use has resulted in greater accuracy at far less cost than could be secured by any other means.

Throughout most of this discussion we are considering black and white photos taken with a vertical camera on panchromatic film. Modified infra-red film may sometimes be specified for timber surveys, primarily because of its greater tone range in coniferous stands. Photos may vary from small-scale 1:50,000 mapping photos to large-scale 1:5,000 special photos. The standard 1:20,000 Production and Marketing Administration prints have been given by far the widest practical use, largely because of their prevalence rather than their suitability for forestry purposes.

The Forest Service uses air photos in three general ways: (1) in the preparation of many kinds of maps, (2) as map substitutes both in the field and office, and (3) in photo interpretation often supplemented by stereo-photogrammetry.

The maps may be either planimetric or topographic, and may vary from simple base maps showing drainage, land lines, roads, and other improvements to complicated portrayals of timber, vegetative types, and soil and land-use conditions. Base maps are prepared by familiar engineering methods from small scale vertical photography. The resource type of map, however, may be prepared in a somewhat more complicated manner. But regardless of whether it is prepared for timber or range management, or for fire or flood control, the procedure followed is roughly the same.

The initial step in the preparation of a resource map consists of office study of contact prints. Under stereoscope, trained interpreters mark on the photos the boundaries between areas covered by classes of vegetation cover that are recognizable. To avoid scale distortion, work is usually restricted to the net area of the photo. These contact prints, with the outlines of the major vegetation classifications on them, are then forwarded to the field for checking and revision. Here those types largely unrecognizable on photos are added by field men using normal ground-sketching methods. In this step, stereo pairs rather than tracings, single prints, or mosaics are preferred because the many recognizable landmarks greatly increase mapping efficiency. The type lines and other annotations resulting from the combined office and field work are then transferred by well-known methods to previously prepared base sheets, or rarely to mosaics, to form the completed map.

Although base maps are usually compiled from small-scale, winter-flown photos, we prefer medium-scale (1:15,000 or 1:20,000) summer-flown photos for resource maps. Modified infra-red film may be specified for timber surveys in coniferous areas.

The use of air photos as map substitutes is increasing in the Forest Service. As photogrammetrists we recognize these photos are subject to scale errors from a number of sources. But as practical foresters we admit that, except in rugged country, these errors seldom equal the ones we are willing to accept in our commonly-used, ground sketch maps. These map substitutes are desirable on a wide variety of Forest Service projects because of the many identifiable landmarks, and because enlargement does not result in the distortion common to maps. Sample areas or plots selected and marked on air photos are easily located in the field. Evidence of General Land Office corners and property boundaries can often be observed on photos, and can be readily located on the ground. Using dot templets on single contact prints, the forester can easily determine the proportion of a tract that is in timber, grass, or water, and can thus compile reliable area statistics in a fraction of the time needed to prepare and measure a map of the area. Simple plan and progress maps—whether needed for timber sales, land acquisition, fire, or planting—as well as more precise right-of-way plans can quickly be drafted on a photo base. Prepared in this manner, they can be oriented easily in the field and are often more understandable to nontechnical men.

Probably the most intriguing use of air photos is in the field of photo interpretation and stereo examination. True, this technique is actually used in all the above work—for example, it is hardly possible to compile a map from photos, without some photo interpretation. Yet because of its importance, direct stereo use is here considered separately.

For many years the Forest Service has used air photos in the reconnaissance of going fires. Fire fighting closely parallels military action. An estimate of what the fire will do, as well as what the fire suppression crews can do, is a requisite to an intelligent plan of attack. Normal ground-scouting methods seldom produce the necessary information for effective initial attack. Stereo examination of good air photos, even though they were flown before the fire starts, gives a composite picture of terrain (including topography, fuel, water, and means of access) rarely equaled by any practical combination of maps. The many landmarks on these photos allow a rapid plotting of fire boundaries from the piecemeal reports of scouts and line crews. Furthermore, this intelligence is available in time to be of use.

Another stereo use—comparable to highway and airport engineering practices—is the planning and location of forest roads and other improvements. Right-of-ways can be selected, and alignments laid out on photos, to avoid rock, steep slopes, swamps, and heavy timber. All of this can be accomplished with a minimum of expensive field reconnaissance. The use of more precise stereo photogrammetry allows rather precise estimates of cost. Tangents and curves can be drafted in place on photo enlargements, and can be staked in the field from visible landmarks.

A third and growing form of stereo use is the selection of sample plots and research areas so important in forest management, grazing, and other forest research. Here, the stereo pairs afford an excellent opportunity to compare topography, vegetation, soil, and site, and to select and classify samples by their photo characteristics. Frequently, valid statistical comparisons between such sample areas can be based on the photo measurements alone. Even when field measurements are required, previous photo study may well increase field efficiency and reduce total cost.

A fourth and currently very absorbing use for air photos is in estimating board-foot or cubic-foot volume, directly from photo measurements of the timber stand itself. Foresters trained in photo interpretation can roughly segregate timber stands into volume classes, by ocular examination of stereo pairs. But this classification is far more reliable if based on three simple photo measurements.

Chief among these is the average total height of the dominant trees. Using parallax—I personally prefer the simple and inexpensive parallax wedge in forest survey work—it is possible on new 9×9-inch, 1:20,000, photos of good quality to measure tree heights with an average deviation of less than 6 feet when compared with Abney level readings taken in the field. On the usual run of Production and Market Administration photos—many of them 10 years old, nearly half of them flown in winter, and many with a photo base of less than 2.5 inches—our experience indicates that, in two times out of three, photo readings of total height of stands should not vary from field readings by more than ± 10 feet. Aggregate deviation may be as low as 3 feet on less than 20 readings, provided stands have not been logged since the date of photography. Fortunately stand height is closely correlated with stand volume.

A second photo measurement is the average visible crown diameter of the dominant trees. It is usually made by comparing the tree crown image with a dot-type crown scale, and can be consistently read in 5-foot classes. Correlation with tree diameter is good and with stand volume, fair.

The third measurement is crown coverage—the per cent of the area covered by tree crowns—made by comparing the photo image with a crown density scale. Dots, representing 5 to 95 per cent density, allow the interpreter to estimate crown coverage in 10-per cent classes. This measurement can be correlated with per cent of stocking. These three measurements, usually made on 1-acre circular plots, can be correlated with board- or cubic-foot volumes on plots measured in the field. The resulting aerial volume table allows the interpreter to read average gross volume for plots in stands having given average heights, crown diameters, and crown coverage.

Traditionally, timber volume estimates are the product of a mean per-acre volume obtained by measuring many field plots, and the number of acres in the stand. Maps are produced primarily to stratify the area, thereby reducing the sample needed for a given error of estimate, and to aid in measuring the number of acres.

On air photos, we can mechanically select a series of 1-acre sample plots and can stratify these plots by photo characteristics. Multiplying the proportion of plots falling in each class by the area of the entire tract, we can calculate the area of the class. Using aerial volume tables and the photo measurements of height, crown diameter, and crown coverage, we can read a gross volume for each plot, and from the plot volumes within a class we can compute a mean volume for that class. As before, the volume estimate is the mean volume times the acreage. By this straight-line photo procedure, we can logically bypass not only the field work but the entire map compilation, and can obtain a volume estimate at no more than one-quarter of the cost of a timber estimate using the traditional ground methods.

But unfortunately, other statistics are needed in addition to gross stand volume. We want information on cull, growth, tree diameters, and log quality as well as volume by species. At present these must be secured from field measurements. Yet we know that factors from a small field sample can be used to correct and prorate the gross over-all volumes from a much larger aerial sample, and that cull, growth, and other factors can be secured from far fewer plots than are needed for volume in a traditional timber estimate.

Our experience indicates that interpreters can measure plots on photos for 25 cents each, while field plots frequently cost $10.00 or more. It may well be then, that the greatest use of photos in timber estimating will be in stratifying the area, in estimating gross over-all volumes, and in reducing the size of the required field sample. Further research along these lines should perfect the techniques.

The entire trend, since photos were first introduced into the Forest Service work, has been toward their greater and more varied use. With the improvement of photo techniques, new applications to forest problems have been discovered. Each successful application has increased the efficiency of the job of the Forest Service, and has reduced the over-all cost of its work.

The Moderator, Mr. Wright: I now call on Mr. Moyer.

SOME USES OF AERIAL PHOTOGRAPHY IN CONNECTION WITH THE PRODUCTION AND MARKETING PROGRAMS OF THE U. S. DEPARTMENT OF AGRICULTURE

Ralph H. Moyer, Chief of Aerial Photographic and Engineering Service, Production and Marketing Administration, U. S. Department of Agriculture

IN 1933 the American farmer was faced with ruinously low prices for his major crops. This necessitated drastic action to restore a balance between farm production and effective demand for its products. To provide a means for the farmer to correct this situation, the Congress passed the Agricultural Adjustment Act of 1933. This Act provided the means for the diversion of acreages devoted to corn, cotton, wheat and tobacco, to other uses. This reduced the supply of these commodities, and demand raised the prices received by farmers toward parity.

In order to democratically administer this program, community and county committees were elected by the farmers who grew the various crops. To determine the acreages of the various crops grown by individual farmers, it was necessary to determine the number of acres in all the fields on which these crops were grown. This was undoubtedly the largest job of determining acreages that was ever attempted. Furthermore, the areas of these fields had to be determined in a relatively short time. These measurements were made in most instances by the township committeemen, or by neighboring farmers who were hired for that particular job. Practically all methods of measurements were used, many of which were necessarily crude and not too accurate, especially where fields were of irregular shapes. The community and county committeemen were faced with the responsibility of accurately and rapidly determining the acres in thousands of fields, and were anxious to find more accurate and faster methods of determining these areas. Necessity is usually the "Mother of Invention."

In 1934, counties in Oregon, Washington, Minnesota and Ohio let contracts to secure aerial photographs to be used in computing the acreage of fields. In 1935, and 1936, contracts were let for new photography for a large number of counties scattered throughout the country. Photographs were secured from several aerial contractors who had secured aerial photography for various commercial agencies, and photographs were also secured from every other Government agency which had aerial photography.

In 1936, the Congress provided for a national program of agricultural conservation to be administered by the same farmer, community, county, and State committees which had administered the Agricultural Adjustment Administration Programs. In this new Agricultural Conservation Program, practices were determined which would conserve the soil, prevent erosion, and assist the farmer in doing a more effective job of operating his individual farm. In planning the type of conservation practices which were needed for different areas, types of soil, and methods of farming, a new use was found for aerial photographs.

In 1937, the Agricultural Adjustment Administration set up two laboratories, one in Salt Lake City, Utah and one in Washington, D. C., where ratioed and rectified enlargements, as well as other types of reproductions, were made from aerial negatives. The amount of aerial photography secured increased very rapidly, until by the beginning of World War II the Agricultural Adjustment Administration and its successor, the Production and Marketing Administration, had secured photography for well over 90 per cent of the agricultural land of the United States; also ratioed enlargements at a scale of 660′ to the inch were in use in county offices over the entire United States. The primary use of these enlargements of course had been to determine the acreage in different fields and in entire farms. The acreage of individual fields was usually determined by means of a planimeter, although where rectangular fields were to be measured, distances were often scaled on the photograph instead of planimetering the field. In order to secure accuracy in these measurements in hilly areas, photographs were often zoned and correction factors set up for the different zones. In areas where there was a marked difference in scale between the two parts of the photograph, such as where the bottom land along a river occupied part of the photograph and the table land above the remainder, two enlargements were made at different scales to fit the two areas of different elevation.

The securing of accurate acreages of fields was, however, only the beginning of the uses made of the aerial photographs in our county offices. In connection with the Agricultural Conservation Program, the photographs were used in determining the areas which would drain into a pond which was to be established by the farmer or rancher; also the type of cover on the territory to be drained and other factors which would determine the run-off from the area feeding the pond. Ponds and wells were located on the photographs to determine the maximum number of livestock that could be watered with the minimum travel. Areas where pasturing was to be delayed until late in the year were also determined, and laid out on the photographs. The lengths of open ditches and tile drains were determined from the photographs, and frequently also their locations. The location of terraces on fields to be terraced was indicated on the photographs. In fact, the photograph in the county office gave a definite record of the areas of the fields, and of the crops which had been grown on those fields over a period of years, and in addition the practices which had been performed. With this type of record, the county committee, aided by the community committeemen were able to effectually administer agricultural programs, and also to plan what types of programs were actually needed in their individual county, in order to give a more balanced production of various crops, and to better conserve the agricultural resources of the county.

The Production and Marketing Administration believes that the farmer himself can best plan the steps which are necessary to conserve and in many cases to improve the agricultural resources of his individual farm. To do this, he should have the benefit of the experience of other farmers, agricultural experiment stations, and other types of research organizations. The first thing a farmer needs to aid him in working out a plan of agricultural conservation is a good map of his farm. For the purpose of planning farm operations and conservation, the best possible map is a ratioed enlargement from an aerial negative. This aid has been extended to every farmer in hundreds of counties throughout the United States, and is rapidly being given to the farmers in other counties.

An entire aerial photograph was not given to each farmer, but only that portion of the photograph covering his individual farm. The individual farms were outlined on a set of photographs of the county, and the photograph cut up into the individual farms. The photograph of the individual farm was then mounted, usually in a manila folder; permanent fields were marked in, acreage in each field indicated, and a field number assigned to each field. A farm number was also assigned to each farm. The farm numbers and field numbers corresponded to the same farm and field numbers on the set of enlargements in the county office. The individual farmer, with the aid of the photograph, could then plan a crop rotation program, and a conservation program running over a period of years.

Each year, the township committeemen, who are farmers elected by the farmers of the community, confer with each farmer in their community regarding his farm plan, and with him work out a farm plan for the following year, and confer as to how this plan would work over his long-term plan, for operating his farm so as to conform with good agricultural conservation practices. This is farm planning on a large scale; as the county and township committeemen have the benefit of the latest scientific experiments and developments in farm and soil management, they are able to pass this information on to their neighbors, and by working with them, are able to develop a program of agricultural conservation in a democratic and efficient manner.

During the war, the fields which had been taken out of depleting crops such as corn, wheat, cotton and tobacco, and placed in conserving crops such as clover and other legumes, were plowed up; the tremendously increased production on these fields, which had rested over a period of years, provided a tremendous surplus which was exported to help feed our allies. Following the war, other countries have substantially increased their agricultural production. This has lessened our export demand, and we are again faced with the problem of surplus production in a number of crops.

The aerial photographs will again come into play to determine the areas which are taken out of crops for which there is a surplus, and placed in soil conserving crops. This change in the amount of acreage which is necessary to devote to soil-depleting crops increases the opportunity for agricultural conservation and will also make careful planning more necessary than ever before, not only for the country as a whole, but for each individual farm. The aerial photographs will give an indispensable aid in this planning. In order to provide an accurate map from which to plan individual farm operations, as well as broad general planning for programs, we have found it necessary to rephotograph large areas. During the last ten years, there have been more changes in the average American farm than ever before. The conversion to tractor and power machinery operations, coupled with changes brought about by the war, have changed the methods of operation of the average farmer. Some fields have been combined, others have been split, fields have been contoured, or farmed in strips. All of these, plus many other changes, have made the majority of the fields on many farms of a different size and shape than they were not many years ago; accordingly the photographs secured from 1937 to 1941 are obsolete, so far as planning operations of individual farms are concerned, unless the new fields are carefully delineated on the photograph. The cost of doing this is in most cases greater than the cost of securing new up-to-date photography. Consequently, we are now engaged in a program of rephotographing the chief agricultural areas of the United States.

While we are not directly concerned with the use of our photography by others, we are very happy that thousands of individuals and companies have found reproductions of our aerial negatives of value to them, in planning and conducting the operation of their individual enterprises. States, counties, and municipalities are also using them to plan administration of their local units of government. Each year we are furnishing over a million photographs for use outside of our own agency. The use of these photographs in planning both private and public enterprises is something that we believe everyone connected with aerial photography can be proud of.

The Moderator, Mr. Wright: I now ask Dr. Simonson, of Soil Survey, to make his presentation.

USE OF AERIAL PHOTOGRAPHS IN SOIL SURVEYS

Roy W. Simonson, Assistant Chief, Division of Soil Survey, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture

INTEREST in the possible use of aerial photographs in mapping soils first arose in the early 1920's. Limited experimental work was done at two or three locations about the middle of the decade. Photographs were not used for the soil survey of a county, however, until 1929, when they were obtained for Jennings County, Indiana, chiefly through the efforts of T. M. Bushnell of Purdue University and Mark Baldwin of the Division of Soil Survey. These photographs were used in the field operations of preparing soil maps. They were on a scale of 1:31,680, and would probably be considered inferior indeed if we were to try to use them today.[1]

Although the advantages in soil mapping were argued vigorously by Bushnell and others, aerial photographs did not come into general use for some time after they were first tried in 1929 in Jennings County. For one thing, photographs were not generally available for large parts of the United States, as they are now. For another, the cost of $5.00 per square mile in Jennings County, Indiana seemed very high to the men generally responsible for soil surveys. About fifteen years ago, however, aerial photographs were obtained for most of the agricultural portions of the United States, through the activities of the Agricultural Adjustment Administration of the Department of Agriculture. Thus, photographs could be obtained for most areas at relatively lower cost, especially considering the number of uses made of the photography. Since aerial photographs have become available for much of the country, the Soil Survey has made progressively greater use of them. At the present time, we recognize the introduction of aerial photographs as one of the major advances in soil survey during the past twenty-five years.

Aerial photographs are used generally in the field operations and in the preparation of maps for publication. In fact, a soil survey is not started in a county where photographs are not available, unless there are especially compelling and urgent needs for the research.

Though photographs are important both in the field operations and in the map construction, I shall concern myself chiefly with the former in this discussion. This is not to say that the uses of photographs in map construction are any less important. I am sure, however, that you are much better acquainted with that part of our work than with the nature of our field operations. Besides that, I am far more competent to talk about the field operations than about the map construction. Consequently, I should like to sketch for you the nature of our field operations and some of the problems we encounter in using aerial photography in those operations.

FIELD OPERATIONS IN SOIL SURVEY

In this discussion I will consider two types of soil surveys, which can be called detailed and reconnaissance surveys. Modern detailed soil surveys are those in which maps with sufficient detail and of sufficient accuracy are produced to allow us to specify suitable uses and management practices, and to predict probable crop yields from fields within farms. The major effort in the

[1] Baldwin, Mark, Smith, H. M., and Whitlock, H. W. "The use of aerial photographs in soil mapping." PHOTOGRAMMETRIC ENGINEERING, Vol. 13, pages 532–536.

soil survey program in this country is devoted to detailed surveys. Most of the work is under way in the developed and more intensively used agricultural sections. Reconnaissance surveys, on the other hand, are largely restricted to range lands and mountainous regions in the United States. These surveys are conducted where information indicates that need for detailed knowledge of the soils and their patterns of occurrence will not justify the cost of obtaining such knowledge.

The detailed soil surveys now being made in the United States require the field man to cross the land for a study of the soils at least at one-quarter mile intervals. In places where the pattern of soils is complex as, for example, in the limestone valleys of northwest Georgia, the effective traverse interval must be smaller. With few exceptions, the field man travels on foot and examines the soils periodically by means of an auger. As he goes across the country, he sketches the soil boundaries either on an aerial photograph, or on a transparent overlay tacked to the photograph. As a competent soil scientist studies an area, he is able to make more and more correlations between the pattern of soils and the patterns of other features in the natural landscape and on the photographs. With experience, men can pick out from the aerial photographs, the areas of the peat and muck in the Clarion-Webster country of north-central Iowa. They can also pick out the high-lime Harpster soils around the old intermittent ponds, most of the time. They cannot always identify these properly from the photographs, however, because some of the light spots on the pictures will correspond to light spots on the slopes rather than at the pond margins. Hence, the process of mapping soils in the field includes frequent checking of the predictions made, whether from study of the photographs or from observations of the landscape through which the man is passing.

Once a field man is well acquainted with an area, he develops a theory as to distribution of the soils. Subsequently, his actual observations of the soils are made to check the validity of the theory. For example, on Okinawa, we found after some field work that we could pick out most of the areas of reddish-brown Latosols from greenstone, on the aerial photographs or from a distance, without actual borings. Every area we found of any size was being used for crops regardless of the use of the adjacent lands, and it was invariably free of rock outcrops. Beyond that, most of the sloping areas, which included the bulk of the soil, had been terraced. Even after some field experience, however, we continued to miss the smaller areas in our study of the photographs. In order to identify them properly, field traverses and periodic examination of the soils were necessary.

There seems to be no escape from actual field observations in soil surveys as far as we can now tell. Anything which will help to reduce the amount of necessary field work, however, is indeed welcome in the field operations of soil survey. Aerial photographs do help appreciably in this connection, although their first and foremost contribution is to greater accuracy in the placement of the soil boundaries on the maps.

As already indicated, reconnaissance surveys of the United States are largely restricted to range lands and mountainous regions. The field man normally covers a large area in the course of the day, with travel frequently being by car. In reconnaissance surveys of range lands in Montana, Gieseker normally mapped about 36 square miles in the course of a single day. In this type of work it is possible only to map soil associations or areas with similar patterns of soils. These are broad or narrow associations depending upon the purpose of the survey, and the amount of time given to the field work. In general, the field man must be better acquainted with his area to make reliable reconnaissance surveys. There is more need for correlation between the patterns of soils and the readily observable features of the natural landscape. The problems in providing adequate aerial photography for reconnaissance surveys differ from those in detailed surveys.

PHOTOGRAPHIC MATERIALS USED IN SURVEYS

Most detailed surveys are now made on individual aerial photographs with a scale of approximately 1:15,000. Some work is done on photographs with a scale of 1:24,000, and some on photographs with a scale of approximately 1:5,000. The photographs used are generally contact prints or enlargements from the negatives. Usually several hundred prints are required in the soil survey of a single county. Photographs of this type have some disadvantages and also some advantages in soil survey field operations. The chief drawback, due to the large number of photographs, is the need for a multitude of match lines with all the consequent chances of error. There is occasionally some distortion near the margins of the photographs, although this is much less troublesome than it once was. On the other hand, the photographs now generally used do provide stereoscopic coverage, which is very useful in some localities. The study of areas under the stereoscope prior to field work is almost essential in forested and highly dissected landscapes, such as the escarpment along the margin of the Cumberland Plateau in Tennessee. By means of prior study under the stereoscope, the drainage-ways and ravines shown on the aerial photograph become field control where all the forest looks alike, both on the ground and in the photographs. There are areas in which stereoscopic coverage offers few advantages as, for example, in the Flatwoods sections of Florida with very little relief, or in the plains of central North Dakota. A minor advantage of the individual aerial photographs is the size itself, which means that the field sheets to be carried by the soil scientist are small. The field sheets must not be too large or they would be hard to carry and protect in some kinds of terrain. This is especially true in wooded or brushy areas where the going is difficult even for a man on foot.

The difficulties in using individual photographs covering limited areas on the ground are much more important in reconnaissance surveys than in detailed surveys. Smaller scales which permit inclusion of a larger area of land on a single field sheet are necessary for reconnaissance surveys. The scales of the maps on which boundaries are plotted in the field operations in reconnaissance surveys generally range from approximately 1:60,000 to 1:200,000. Very few reconnaissance surveys are made at field scales as large as 1:60,000. In the field work at these smaller map scales, the aerial photography generally available has not been so useful. Most of the reconnaissance surveys made in the United States, even during the past decade, have been made on other types of base maps. Occasionally, photo index sheets have been used with some success, but these are not especially desirable. Furthermore, aerial photography is less commonly available where reconnaissance soil surveys are the only field investigations that are justified. Some type of photography other than the individual photographs generally used in the United States would be desirable for reconnaissance surveys.

NEEDS IN SOIL SURVEYS

I have tried to sketch for you the nature of the field operations in soil surveys, with the hope that this will help you to see our problems more clearly. I think you can readily see that our field operations are a form of photo-interpretation at close range in many places. It is immediately obvious, of course, that the best possible photographs are of the greatest value to the field man, in his soil survey work. The sharper the photograph and the more detail they carry the better they are for detailed soil surveys. Any means of increasing the size of individual sheets somewhat and thus reducing the number of match lines required will also be helpful. Finally, any possible way of reducing costs is always welcome.

I should not take as much as ten minutes of your time without again mentioning the use of aerial photographs in the preparation of soil maps for publication. I know relatively little about the actual steps in the preparation of the published map from aerial photographs, but I do know that the costs are substantial, as are those in field operations of soil survey. I realize that improvements in methods and techniques, especially during the last decade, have lowered costs and permitted more rapid map preparation without loss of accuracy. Are there further opportunities for reducing these costs? To all of us in soil survey, any improvements in aerial photography itself, and in the construction of maps for publication, promise to be helpful, especially so since our research leans so heavily on aerial photography, both in the prosecution of the work and in its subsequent presentation to the public.

The Moderator, Mr. Wright: Mr. Magruder will you now present your paper?

(Mr. Magruder read his paper on "Aerial Photographs and the Soil Conservation Service." This is essentially a condensation or abstract of his paper with the same title which was printed in the December 1949 issue of PHOTOGRAMMETRIC ENGINEERING (Volume XV, number 4). For this reason and in compliance with Mr. Magruder's suggestion, the Publications Committee has approved omitting from this issue, the paper given at the group meeting—*Editor.*)

The Moderator, Mr. Wright: You have heard all the papers. The meeting is now open for general discussion and we welcome any questions that anybody wishes to ask and, with this aggregation of technicians and experts, we hope that we can answer them. I hope all your questions have not been answered. We will be disappointed if that is so, because we did hope there might be some provocative arguments. I urge you to ask questions in connection with agricultural activities.

Mr. Ross French (U. S. Coast and Geodetic Survey): I am interested in the home county and the home farm. Who decides when a soil survey should be made? Is that on a county basis or a state basis? In the case of a county survey, for example, who decides when to make the survey?

Dr. Simonson: The decision lies chiefly with the Agricultural Experiment Station—partly with it and partly with us. The surveys are based partly on interest in the work within the county, partly on the urgency of the agricultural problems in the area, and partly upon the amount of work that we have already available in the general area—how badly do we need another survey to work out our classification and understanding of the soils? All of these things are factors. The decision within a state lies more with the Experiment Station than with anyone else, but it is partly ours.

Dr. C. C. Delavan (College of Forestry, Syracuse University): Dr. Simonson mentioned the difficulty of using individual sheets, but Mr. Magruder made occasional references to mosaics. I wondered if you had tried mosaics in the field.

Dr. Simonson: We have used them in some surveys but not in many cases; in some areas they work out quite well. We have used the individual photographs primarily, I think, because they have been available more readily.

Dr. Delavan: Didn't the Brown Company in New Hampshire use mosaics largely in its type mapping?

Mr. Moessner: In the forestry mapping, I think that is right. By a good many companies, and in a good many places in the Forest Service, mosaics have been used. We prefer to send contact prints to the field to be annotated, because the men have, and need to have, the benefit of stereo. They could use a mosaic with the contact prints but they cannot use it in lieu of the prints, if there is any reason for viewing in stereo, and there usually is in forestry work.

The Moderator, Mr. Wright: You realize there are lots of kinds of mosaics—the controlled mosaic or the uncontrolled—and people often refer to the photo indices as a mosaic, but these are very crude and hardly serve that purpose. Again, the vertical relief of an area is a big factor. The mosaic is relatively accurate in an area of flat terrain but, in an area of steeper terrain, it is not.

Commander Robert N. Colwell (Assistant Professor of Forestry, University of California): I should like to question Mr. Moyer regarding his comment that, because of the large change that has taken place in farm land since 1940, it is necessary to get new photography, since this is cheaper than making revisions on the ground. Do you think it would be feasible to make these revisions from oblique photographs instead of getting new vertical photography, thereby perhaps reducing the cost of photography to maybe one-third of the cost to get complete rephotography at the conventional 1/20,000 vertical scale?

Mr. Moyer: The difficulty would be getting accurate measurements from the oblique photography. Another difficulty is that, extending photography back very far on an oblique photograph, the sharpness is lost and your field lines are not easily delineated. In your primary use in determining field boundaries, we have to perimeter the fields and follow the field boundary lines; accordingly we require a good sharp photograph.

Commander Colwell: One way in which I visualize that obliques might be used, is similar to the use by foresters under favorable conditions. For example, we have instances where we desire to use aerial photos to bring our timber inventory up to date and, since the aerial photos were taken, there have been fires or insect infestations or cutting in a certain area. There, under favorable conditions, it is possible, just from oblique photography, to pick out enough detail, even at a considerable distance from the camera, to transpose these boundary lines, although only vaguely discernible on the oblique photos, to our previously obtained vertical photography, and then use that as a basis for area determination.

The reason I thought this might have promise in agricultural lands is because often they are quite flat and it might be possible to project the oblique onto the vertical by having the two oriented at the proper angle with respect to each other; although you did not see very much detail on the oblique, you could see enough so that, by reference to the vertical, you could end up with the necessary revisions. I do not say this can be done—I am not trying to sell the idea; I am merely trying to get some of the limitations.

Mr. Moyer: This use is something we really have not tried for several years. Before the war, we experimented a little but we didn't succeed in making it click very well, and about that time the war came along and we never got back to do any work on it. There is a very good possibility that there is promise in that field. If we get out from under some of our present rush, I think we will try a little work on that line again and see what we can make out of it, because if we could use something of that nature, it would cheapen the rephotographing a great deal, of course.

The Moderator, Mr. Wright: We are getting into a rather involved and complex field of photogrammetry, as you well realize when you attempt that, and the PMA, for obvious reasons, has to keep its work as simple as possible because it is dealing with land users who are entirely unfamiliar with technical operations; it has to lay before them a picture of their farms, and you can see. what would be involved if you tried to show them, from an oblique photograph the true pattern of their fields. While they would have a complete aerial view of the farm, nevertheless, the field pattern could be outlined only in perspective with sizes diminishing as they recede in distance. I can see a lot of difficulties in attempting the suggested use. When we consider that we pay only half a cent an acre for photographs and that it is such a small proportion of the relative cost of the operations that are conducted, I doubt if it would be worth while to go into it to any great extent.

Commander Colwell: I do not want to monopolize this discussion but could I make one more suggestion? I have noticed several instances in which there might be promise for use of an idea that has occurred to me recently and concerning which I perhaps am a little over-enthusiastic. It is the opportunity for using color photography in solving problems that arise in these various fields of agriculture. I fully realize the difficulty of getting good-quality color photography. I also realize that it is more expensive. I have been encouraged recently, however, by the fact that, under careful control, you can frequently get good color photography. Improvements are constantly being made and the cost of the photography is being decreased.

I think that the way in which color photography might be useful for some of these problems can best be indicated by considering that these various objects that you are trying to identify on photos tend to reflect back differentially the different wave lengths of light in the color spectrum.

Assuming we have to work with scales up to 1/20,000, as these gentlemen have mentioned you pretty much rule out the possibility of using photo detail in making many of these distinctions of agricultural crops or soil types or timber species or "bug" trees in a stand. You do not have enough detail to make those distinctions at that scale. However, if you could point up or exaggerate the difference in *tone contrast* between two elements that you want to distinguish, one from another, then you might be able to do the needed work at that scale of photography. I know that, in certain instances, this can be done at a scale of 1/20,000 or smaller.

All this ties in with color photography in this way; if it is possible to capture the complete reflectance spectrum from all of these different objects on the ground that are being photographed, whether trees, soil types, grass types, or crops of one kind or another, then, by virtue of a spectral analysis of the type that the Bureau of Standards is now making for these various things, you could tell from those reflectance spectrum analyses just where the greatest difference is in reflection of light between two objects that you are trying to distinguish one from another; you could then view these color transparencies stereoscopically, over a light table, with filters placed over your eyes that would screen out all wave lengths of light except those where the contrast is sharpest.

This would necessitate stepping up the light intensity beneath the light table, perhaps, but it would have the advantage of showing, for example, two trees of different species, one of which appears maybe slightly redder on the color photos than another; in this case revealing them as a sharp black-and-white difference, so that they would show up right away. To distinguish a second set of objects on the same color transparencies, you might view them through a second type of filter, and so on.

By way of indicating that this is not just theory, some of us made a test a few nights ago and found that, actually, the method does have promise. We were pleased for example, by the possibility of accentuating the difference in tone between insect infested, coniferous trees, and those which have not been infested, the advantage being that you can detect from photography the forest areas that have been infested.

As for the soil-type problem which was mentioned here, might it not be possible, by this means, to further capitalize on the reddish characteristic of a soil, by capturing all of these different colors that are reflected, and then capitalize on the difference in the red part of the spectrum, perhaps, by viewing the color photography with red filters? In that case, for that particular soil, the light transmitted to the observer would appear much lighter than from any of the rest of the soils.

I have gone into this perhaps further than I should, but I wondered if there were any comments as to the desirability or feasibility of using color photography in these various studies.

The Moderator, Mr. Wright: Dr. Kellogg, would you like to comment?

Chairman Kellogg: I do not know anything about it. I have been plaguing Mr. Whitlock every once in a while about when he and his associates are going to have color pictures for us. To date I have gotten from him quite a few good reasons why he does not think it will be too soon. I know from traveling in planes, that if the sun is coming toward you or over your back, you get a big difference in color. I am afraid that probably would be true of the photograph. And then the light changes quite a bit, irrespective of whether there is any cloud cover between the plane and the ground. All those things must be taken into account.

Color photos would be exceedingly helpful, particularly in the kind of thing I was talking about this morning, in making the first approximation of a new country. For example, if we go into the Amazon country, as I hope we will some day and as we are now going into the whole central African country, with millions and millions of acres of land, we know only that a lot of it is good land and some of it is poor land; that is about all we know. One of the first things we need is a kind of first approximation, a schematic soil-map, to know the area in which we ought to concentrate. For that kind of work, I should think these color photographs would be exceedingly helpful, if they are practical.

When it comes to the actual detail mapping, as in our own country where we are making maps that must show contrasting soils down to areas of maybe one or two acres, I am not so sure. In eastern Tennessee, as an example, we have farms of from 80 to 100 acres. If the man on that farm has one or two acres of soil of a quality to grow Burley tobacco, he has a wholly different farm setup than the adjoining farm that just misses those two acres. They must be shown, and shown accurately. Many things interfere. As Dr. Simonson pointed out, the soil scientist must look at every photo for detail of the soils. He has to look at it with his eye and I do not know whether the color would be very much good there, because he is going to see it anyway, personally.

I think perhaps there might be something to the suggestion for another use of the color photos but I do not know enough about it. For example, if you are going into one of these wild countries and everything is practically the same in the patterns, but one soil is white and one soil is red, it might be just what would make possible making a pretty good guess as to what the soil is, particularly in the tropics.

The Moderator, Mr. Wright: I think this does hold out great promise. Probably within the next ten years we will look back at the pioneer thought that we gave to this matter and wonder why the method wasn't used earlier. It is certainly something that we must keep in mind and develop as time goes on.

The Forest Service, as you probably know, has done some experimental color photography in California. Mr. Massie, who is in charge of aerial photographic work for the Forest Service, is here. Mr. Massie, will you make a few comments on the experimental color work that was done by two commercial operations.

Mr. E. S. Massie, Jr. (Forest Service, U. S. Department of Agriculture): I should like to go beyond the Forest Service work. One or two of us had an opportunity to see some color negatives exposed and processed by one of the aerial concerns. They covered an area in the Southwest. Exposures and colors appeared perfect, with gradation of color between soils. We, with the cooperation of Eastman and Agfa, obtained color film and had it exposed in California. We also obtained color film and had it exposed in Montana. Our results were very similar to some that the Soil Conservation Service, I believe, had: we were not getting ample exposure control and this resulted in unsatisfactory photography. Again, we were working with negatives instead of positives which, for the varied uses in the Forest Service, introduces another problem.

On the other hand, in Montana we took some oblique color photography above bug infested timber. These covered out to a distance of some twenty to thirty miles, and we could pick out individual bug-infested trees to a distance of about 15 miles.

Personally, I think there is a big future in color photography, if it can be developed so that we can differentiate between species, on positive prints—not negatives, But up to the present time, I am very discouraged about it.

The Moderator, Mr. Wright: Are there any more comments or questions? If not, we will stand adjourned. Thank you for your attention.

USE OF PHOTOS BY THE FOREST SURVEY IN CALIFORNIA*

K. E. Bradshaw, California Forest and Range Experiment Station, Berkeley, Calif.

THE preceding speakers have described the use of aerial photographs in both small and large private forestry operations, and in region-wide Federal Management operations. I should like to tell you something of their use by the Forest Survey in California, where they are applied to all sizes of private holdings, and to Federal National Forests as well.

As probably most of you already know, the Forest Survey is a nation-wide project which was initiated in order to gain information on the location, extent, and condition of the forest resources of the United States. Responsibility for conducting the Survey was assigned to the eleven Forest Service Experiment Stations scattered throughout the States. Washington, D. C. set up certain requirements for data which were to be obtained and published by each Station in the form of statistical and analytical reports, but each Station was allowed flexibility in the actual conduct of its survey.

In the California Region, the Forest Survey is based primarily on the fullest use of aerial photographs. In addition to providing the data required by Wash-

* Paper read at Annual Meeting of Columbia River Section of the Society, Portland, Oregon, December 7, 1949.