tance. This can easily be seen, for as the point moves closer or farther from our eyes, both accommodation and convergence must change to correct for the distance moved. It has been found that a disturbance of the normal associations between convergence and accommodation is a contributing factor to the reduction in stereopsis, and also gave evidence of fatigue effects.[6] People differ in their ability to converge for a specified distance, and still be able to accommodate at distances greater or less than the convergence distance. Tests to determine how "tight" this convergence—accommodation relationship—is for the operators were given. The most significant test of this factor is the prism divergence test, also known as a test of abduction. The normal range of the near abduction break is from 12 to 24. Only 8 per cent of the operators measure less than 12; they were rated low in working efficiency. Of the 12 per cent that measure between 12 to 19, two-thirds were rated high and one-third rated low. Of the 42 per cent that measure between 20 to 24, half were rated high and half were rated low. The top of the normal range is 24, and 38 per cent of the operators measured between 25 to 29, of which half were rated high and half were rated low. The normal range is from 12 to 24, and yet 42 per cent measure from 20 to 24, and 38 per cent measure from 25 to 29.

What we have done, can be done for every job in photogrammetry, in fact for every job. Also this paper very easily could be expanded. Instead, and in conclusion I should like to state what I think should be done. (1) Test about 100 experienced stereoplotting operators on the Bausch and Lomb Ortho-Rater. (2) Instead of the working efficiency rating derived from a paired comparison analysis, develop an objective criterion, such as a work sample test. (3) Correlate the two to obtain the visual standards necessary to predict performance. (4) Periodic retesting on the Ortho-Rater—at least once every two years.

WORLD FOOD PRODUCTION: THE RÔLE OF THE PHOTOGRAMMETRIST*

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MODERN science, in my view, makes possible an efficient agriculture that could produce abundant food for all on a sustained basis. We have the soils and the skills. The realization of these potentialities must be a primary goal of people of good will everywhere, if we are to have the kind of world we want.

I want to talk with you as an operating soil scientist deeply concerned with this problem. If we are to develop the world's soil resources effectively and economically, we must have good aerial photographs and maps. We must know accurately the location of different kinds of soil as a basis for predicting the outcome of land development schemes, for recommending improved systems of farm, forest, and range management, and for guiding investment in irrigation, drainage, and settlement.

First of all, I realize fully that soil scientists will need to increase their skills and understanding. Nor is the job one for soil scientists alone—not by any means. All skills in agriculture and industry are involved—in the natural sciences, in the social sciences, and in engineering. The effectiveness of one man's

[6] Fry, G. A., and Kent, P. R., "The effects of base-in and base-out prisms on stereo-acuity," *Amer. J. Opthom.* Vol. XXI, pp. 492–507, 1944.

* An address before the Sixteenth Annual Meeting of the American Society of Photogrammetry, Washington, D. C., January 13, 1950.

work depends upon another's. We could start anywhere, say with the breeding of superior animals. But the animal geneticist must have the help of the pathologist, of the entomologist, of the agronomist, and of the soil scientist. But then, livestock farming in warm countries requires refrigeration; the soil scientist will want fertilizers; and so on. This thing soon multiplies, no matter where we start, until we see that all skills are involved and that investments in industry must parallel investments in agriculture.

Well, we cannot go into all of these interrelationships. But even if I talk most about soils, it is not because I am unaware of the other essential elements; it is only that one cannot talk about everything at once.

To meet the food needs of the world's population, according to the World Food Survey of FAO, we should be producing 21 per cent more cereals in 1960 than just before World War II. The comparable figure for fruits and vegetables is 163 per cent, 100 per cent for milk, 46 per cent for meat, 80 per cent for pulses and nuts, 34 per cent for fats and oils, 12 per cent for sugar, and 27 per cent for roots and tubers. To realize these increases means an enormous number of tasks. Nor is it by any means a physical and biological problem. Already, now, some countries are worrying about the spectre of agricultural surpluses; while in others, food is in very short supply. Thus, the problem would be great enough, even if we could take the world as a whole. Actually, when we get down to cases, it is far more difficult in some places than in others.

At the same time, we know that soil depletion is going on—unnecessary soil depletion through erosion, through losses of organic matter, through destruction of soil structure, and especially through declining soil fertility. Soil erosion has received far more attention in recent years than the other soil depleting processes, and perhaps even more than the production needs. Some have been so impressed with the symptoms of poor soil management—low yields, erosion, and poverty—that they have failed to evaluate the positive side—the great and growing body of skills and materials for improving soils, for making them more productive than they were naturally.

Under conditions of stable prices and fair tenure, with opportunities for health, education, and employment, and with access to the needed industrial products, farmers *can* plan their soil management systems on a long-time basis. Where farming systems are looked at in terms of 10 to 15 years, not just one or two years, there are very few conflicts between those systems that give maximum production and those that maintain the soil at a high level of productivity.

If we are to meet the food needs of the world, these conditions for farmers must be more nearly met than they are now. Four major goals must be sought simultaneously: (1) production for the farm family, the community, and the country; (2) conservation of resources under use; (3) good living standards for health and education; and (4) full employment of the labor and genius of people. Obviously, these goals mean also the full use of forests, water, minerals, and the other resources besides soil, and the parallel development of agriculture and industry. Efficient farming requires machinery, electric power, fertilizers, insecticides, and a wide variety of other industrial products. Although some of these can be supplied by trade, generally each country, and even each region, must produce a large part of its own needs.

The level of farm production and of soil productivity that we are seeking will not be based upon any kind of "natural balance." Nor will it be based upon history—not on the same set of tools of older generations on the same acres. What we are seeking is that level of sustained production made possible by modern science and technology in a peaceful world. In short, we are seeking a *cultural balance* between people and resources, using all the facilities of physical science, social science, and engineering.

Increased food production can come from increasing yields of crops and livestock products on the land already in use and from the bringing in of new land. These two categories are not neatly separated. We may start with the most intensive kind of farming in orchards and gardens and work gradually through general mixed farming and extensive farming to nearly wild land, with no sharp breaks. In fact, estimates of the land already being farmed vary rather widely around the figure of $2\frac{1}{2}$ billion acres. Thus, much of the new land development will really mean greatly increasing the intensity of use of slightly used acres, say from primitive shifting cultivation to regular systems with rotations and mixed cultures of adapted crops, or from extensive grazing to use mainly for both rotations of crops and livestock.

What are the prospects? If we estimate that around $2\frac{1}{2}$ billion acres of soil are now being farmed, it is reasonable to estimate that another $1\frac{1}{4}$ to $1\frac{1}{2}$ billion more than that could be farmed. We could probably increase the acreage in the United States by nearly 20 per cent, if necessary—say up to a total of something like 450 million acres. Under anything like the extreme conditions existing in some countries, we could go a very great deal further than this.

Not much of this new land—the $1\frac{1}{4}$ to $1\frac{1}{2}$ billion acres—can be settled easily. A large part of it is in the tropics. A good deal of it is far from good harbors or transport. Most of it will need clearing and careful management from the start. And it can scarcely be emphasized enough that its development depends upon parallel development of industry *within the same region*. That is, to use the soil efficiently, farmers shall need transportation, electric power, fertilizers, machinery, medical facilities, and all the other essentials supplied by industry.

But is it necessary to bring in all of this new land in order to meet the food goals? Not at all, if we could and would put our technical knowledge into use. Even here in the United States, where agriculture is already reasonably efficient —say around one-third of it is—production could be very easily raised 20 per cent on some items and 30 per cent on others, if farmers generally followed the practices now regularly used by hundreds of thousands of the best farmers. These estimates of 20 and 30 per cent were made about 7 years ago. Without doubt, they are conservative in view of present facilities. Competent agriculturists in the United Kingdom suggest a figure of nearly 50 per cent for their country. I feel certain that 20 or 30 per cent would not be unreasonable for the Soviet Union, at least for the sample areas I have seen. In India there is good evidence that increases above 20 per cent are entirely possible on the basis of existing knowledge.

Thus, taking the world as a whole, it would probably be physically and biologically possible to meet or nearly meet the food needs on the land now being cultivated, through the use of agricultural systems adapted to the many thousands of kinds of soil—systems that are already being practiced by good farmers on these soils. Putting these increases together with those possible from the new land, we could far exceed the needs for 1960.

And I need to add that in strictly physical and biological terms, these estimates are low. They take no account of entirely new technology; yet efficiency of farm production is increasing at an accelerated rate. The potentialities from new research in the tropics are probably very great. Most of us take for granted enormous increases in efficiency in the United States and Western Europe as a result of science, not only in increasing yields, but even in making possible agriculture where it wouldn't be at all. One needs no better example than the southeastern part of the United States. If it were not for the results of plant breeding, insect and disease control, and fertilizers—to mention just three things—a great deal of what is now the best farm land would not be farmed at all.

But, of course, these estimates of physical potentialities should not be interpreted as goals of easy accomplishment. Staggering social, economic, and political problems stand in the way of their realization. Further, the people of the world don't feed out of a common larder; nor can they. For the most part, each country shall need to improve its own production and go a long way toward balancing its own economy. Many countries will need to have help—capital for both public and private investment, and technical assistance. Enormous educational problems must be faced for the hundreds of millions of farm people who can't read. Millions of tiny farms must be reorganized into larger units so that the farm family has a real chance to apply technical methods. Then, above all, some way must be found to get industry going in places like Eastern Europe, India, China, Indonesia, Africa, and so on, so that farmers may have the tools of modern technology, and so that the unused labor on the land may have useful opportunities for effective employment.

If substantial progress is made toward realizing the potentialities of the soils of the world, an enormous amount of work is before us. One could scarcely overemphasize the great differences among these soils—differences they had in the first place. Thousands and thousands of soil types exist in the world. A few of these are naturally productive for food crops; they give a good harvest when first cultivated. Most soils do not. The farmer literally makes his arable soils from the natural soils. The native trees that covered the lands in eastern United States, Western Europe, or in the humid tropics are quite unlike the plants man has selected and bred for his own use. Their soil needs are quite different. Thus, most good farms in these regions have been made good through the use of lime and chemical fertilizers, introduction of legume-grass meadows, and other practices. Each one of these thousands and thousands of soil types has a unique set of characteristics and requires a unique combination of crops and management practices for optimum sustained production. The distribution of crops that we see in the world today is only partly a reflection of growing conditions; it is also a matter of the accident of colonization and the development of transport.

We have no more urgent need now than that of accurate maps showing the soil potentialities of the world. We need basic soil maps that can be interpreted in terms of adapted crops and alternative systems of farming, along with specific management requirements, predicted yields, and effects on long-time productivity.

At least two levels of detail are required. Regional maps are needed on scales of around 1:1,000,000 or less that can serve as a basis for assessing regional potentialities and relationships. For specific recommendations for operating farmers, however, highly detailed maps are needed, say at scales between 1:5,000 and 1:50,000, depending upon the nature of the local pattern of soil types and the intensity of potential use. Occasionally, maps of intermediate scales are also needed, say at scales between 1:100,000 and 1:250,000.

The American Soil Survey began to use aerial photographs as a base for plotting the results of field investigations during the 1920's. Gradually their use increased during the early 30's until all work was done on aerial photographs. Their use made possible more detail and greater accuracy than could be had from using the former planimetric bases. Further, the soil scientist was relieved of the problem of making his own planimetric map and could thus concentrate on soil study.

But many problems arose. Even though the maps could be made more accurately, many expensive and time-consuming steps were involved in compiling proper manuscript maps from the data on the aerial photographs. As you know better than I, developments during the war years especially have improved these processes. I suppose it might now be said that standard methods are in established use in the United States and in several of the other advanced countries. But it still takes a lot of time and money to go from these aerial photographs to a properly adjusted map. I am wondering if there aren't further opportunities for improvements? Especially for reducing the time and cost?

Just now the need for aerial photography in the undeveloped parts of the world having good potentialities for agricultural production is most urgent. Soil surveys are being initiated in several of these places and will no doubt be initiated in a great many more. They shall need to go forward somewhat differently than has been the history in the United States. New soil survey organizations will have the advantage of the long experience in the United States and elsewhere. On the other hand, they will lack, in many instances, the aid of great State research institutes and other scientific services that helped so much in this country.

The soil survey in new and undeveloped countries must be undertaken in ways that will give the maximum of prediction value immediately, long before the whole area is mapped. Predictions based on soil research and soil maps are needed at two levels: (1) for appraisal of regional potentialities within a country, and (2) for making specific recommendations by small individual fields and farms. The details of a practical scheme will vary somewhat from country to country but, generally, the scheme for a soil survey of a new or undeveloped country should proceed somewhat as follows:

(1) A first approximation of a schematic soil association map of the country or large region is compiled from existing data on soils, relief, geology, vegetation, and climate. Where available, *and where each pattern has been studied on the ground by competent scientists*, aerial photographs are useful in drawing boundaries. Each of the soil associations consists of a defined pattern of contrasting local soil types that can only be separated from one another in detailed surveys.

(2) One or more representative sample areas of each soil association are chosen for investigation and mapped in full detail to meet all the requirements of a detailed soil survey. These sample areas may vary from 2 to 25 square miles, depending upon the complexity of the land and the intensity of use. They need be no larger than what is necessary for representativeness, but by all means they should be chosen for representativeness and not at random or in arbitrary strips. The services of a good laboratory should be available to the scientists making these sample maps, and often some field experiments will be necessary.

(3) A full set of predictions is developed for each local soil type and phase in each sample area, with the aid of such research and analysis as can be marshalled. These predictions include the expected yields of adapted crops under alternative systems of management, and the long-time effects of these systems of management on soil productivity. They need to include the responses of the soils to lime, fertilizer, terraces, drainage, irrigation, green manures, and all the other practices. Besides the set of predictions, a key is made to the soils within each soil association in order that agricultural advisors may be able to recognize the soils *by name* within the association.

(4) With the sample areas completed, a second approximation of the

schematic soil association map of the whole region is made. This involves some alterations in boundaries and some divisions or consolidations of associations. But mainly it involves the development of full and complete descriptions with sets of predictions for all the local soil types within each soil association shown on the map. This map is then reproduced for the public, along with the text. Its scale may be somewhere between 1:100,000 and 1:1,000,000. This map serves as a satisfactory basis for appraising sectional and community potentialities and also for giving advisors the specific detail about soils they need for making recommendations about individual fields and farms. At the same time this map is published, special training schools can be held at each sample area for instructing advisors in the identification of soils within their areas and in the use of prediction tables.

(5) After this preliminary job is done, the detailed soil mapping can proceed progressively in accordance with agricultural potentialities that may be realized, local interest in improvement, and the parallel programs of investment in settlement, irrigation, electric power, and so on.

Some such scheme is necessary to avoid a long wait or to avoid basing recommendations on reconnaissance maps. Development in these countries cannot wait for the completion of the detailed survey of the whole area. On the other hand, useful predictions to individual farm families can only be made on the basis of the local, narrowly defined soil types.

I have explained this problem of the soil scientist in undeveloped countries in this much detail in the hopes that photogrammetrists might see how they could be of maximum help. Ideally, of course, we should have excellent aerial photographs of large scale for all these countries. Ideally, the photographs and planimetric maps made from them should serve all the usual purposes in agricultural research and advisory work, geological exploration, electric power development, and so on. Repeatedly it is suggested that when an area is mapped, all of the things that are necessary for all purposes should be gotten in order to avoid the need for remapping. Now, I have the utmost sympathy with the objectives of such an ideal, but my experience tells me that it is rarely practicable. There never has been, nor never will be, a complete "all purpose" map. Even soil maps alone will need to be revised occasionally as results of new research force us to reconsider the relative importance of different soil characteristics, and as new technology changes the relative advantage of different soils. Thus, we don't want to be such perfectionists in getting a basis for working with these undeveloped countries that we in fact get very little done. Of course, we shall need to remap some places, especially in the best areas as they progress.

For the first approximation of a soil map—to get started—is there some relatively rapid and cheap method for covering the whole area? Then, perhaps after the sample areas are investigated, the places deserving more careful work can be laid out and photographed more carefully. What about tri-metrigon or other multiple-lens photography? What about aerial mosaics, small-scale planimetric or form-line maps, and photographic indexes? Competent people need to explain under what conditions such methods have application.

One big problem in many of the undeveloped countries is the matter of who is going to do the aerial photography. Often foreign exchange will be too short for the work to be done by outside contractors. I suspect that in very many places the first question that will arise will be, can it not be done by the military? Though we might point out the advantages of private contractors, still the only way of getting the pictures may be through the military, partly because of the desire in the country to have some corps of trained flyers for local police and patrol duty. What can be done—what could your Society do—to help such organizations do an acceptable job?

In some countries there is the well-known problem of "security." What can your Society do to force the recognition that these aerial photographs are working tools for many peaceful uses and should not be placed under "security" controls, except possibly for cities and harbors and things like that?

I should also like to add a word about photo interpretation as applied to soil study. Frankly, I've been almost shocked by some of the published material along this line. By all means we must avoid the extremes: (1) that nothing useful can be done or (2) that soil conditions may be approximated from a study of aerial photographs (or by observation from planes) alone.

Where thoroughly competent and experienced soil scientists study samples of the patterns on the ground, a useful schematic soil map can be made by interpretation of aerial photographs along with other available data. But one cannot carry over these relationships very far from one region to another. Without this careful ground work by competent soil scientists, exceedingly inaccurate interpretations are not only possible, they are probable. This has happened, sometimes with absurd results.

Thus, while urging for more research in aerial photo interpretation, especially for research cooperative with experienced soil scientists, I wish to emphasize as emphatically as possible the danger of attempting interpretations about soil conditions and soil potentialities without careful ground study of all patterns. This is especially important in rapid surveys of new or undeveloped countries. Often advisory missions are set up in a hurry. A report is wanted very soon. The temptation to do the "best possible" in too short a time will be very great. But if serious errors are made, investment funds may be wasted and the opportunity for their use on a promising development lost.

Finally, I should like to urge that your Society organize itself to consider this matter of expanded aerial photography in new and undeveloped countries with the view of preparing standards for alternative methods of aerial photography, of map compilation from the photos, and of interpretation. Many groups are and will be seeking advice. Unless you who are expert in the field are prepared to offer it to them, and in terms of their facilities and problems, others less competent will do so.

NEWS NOTE

DEVELOP FILTER FOR PRODUCING PURE COLORS

The Bausch & Lomb Optical Co. announces development by it of a revolutionary filter that may someday play an important role in color television. The Interference Color Filter, provides the simplest means yet devised for producing color of a high degree of purity. When ordinary white light passes through the coated filter, one of its component pure colors—red, blue, green, yellow—emerges. The "secret" lies in three thin films, of silver and magnesium fluoride, applied under high vacuum to one side of the glass. First silver is introduced into an evaporator on a heated metal strip. Under vacuum the silver particles fly off and bombard the glass, forming the first film. A coating of magnesium fluoride is then applied in the same manner, then another layer of silver. A cover glass is then cemented on to protect the triple film coating. The thickness of the magnesium fluoride film determines which color will pass through the filter. If a uniform coating is applied, a uniform color will appear over the entire surface of the filter. If the fluoride coating is applied thinner at the center and thicker toward the edges, different colors will appear as concentric rings.

Although the filters are now used primarily in laboratory work, wide application is predicted in such varied fields as color television, photography, refractometry, vision testing, and astronomy.