The Quantitative Method in Forest Aerial Photo Interpretation Research—Approaches and Limitations[1]

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ABSTRACT: *This paper has as its basis a research program in progress for a period of six years. Its objective has been to quantify some of the methods and results of forest aerial photo interpretation. The introduction of statistical methods to this type of research is essential but greatly complicates it, as compared to an individual, subjective approach to data gathering and analysis. Problems of communication and implementation are discussed and a number of sample studies are described.*

INTRODUCTION

IN 1955, a paper titled "The Need of Quantitative Evaluation of the Photo Interpretation System" was presented by Dr. Harold Young of the University of Maine (1). At the time of Dr. Young's timely presentation, it would have been difficult to find more than a half dozen published papers in which quantitative evaluation of forest photo interpretation was involved. Such a literature review today, however, would reveal a very considerable bibliography which is progressively increasing both in extent and in its degree of sophistication.

Despite this rather impressive array of literature, it would be most unwise to assume that the photo interpretation process is soon to be reduced to a simple game of numbers. Nevertheless, it has been shown that the system, generally subjective in nature though it may be, is liable to a certain, significant degree of quantification. Albeit the degree of possible quantification is limited, at least in terms of present photo interpretation system components, the ultimate extent to which it can be profitably instituted is felt to be neither fully appreciated nor in any sense achieved at this time.

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A CASE FOR QUANTIFICATION OF FOREST INTERPRETATION

It cannot be denied that many photo interpreters have been, and are, enjoying a high level of success while relying primarily upon subjective judgment for their results. But it appears, at least in forestry, that really outstanding photo interpreters are not overly plentiful. One also finds that these people tend to be individuals with above-normal native capabilities in the art, and that they are also usually possessed of a considerable period of experience in their working area. As an educator, the author is interested in getting the highest possible level of photo interpretation skills into the hands of as

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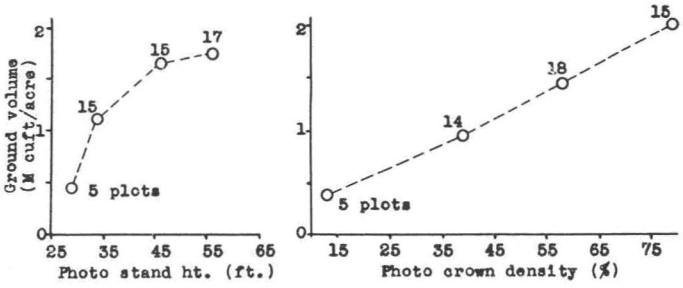

FIG. 1. Relationship to ground volume of mean photo heights and crown densities obtained by 8 interpreters from 52 1/7-acre plots. Fall pan 1/20,000 photography.

many professional foresters as is possible in a short time—certainly many more than just those who have the capabilities of becoming, in time, really outstanding "subjective-skill" interpreters.

The luxury cannot be afforded of either the required experience period or the native ability limitations imposed by the present system. It is contended, therefore, that further quantification of the photo interpretation system provides the best possibility for significantly and comparably raising the level of average proficiency in a shorter period of time.

As a prime example, one has only to look at the characteristics of the forest(ry) situation in northern Minnesota to realize the need and potential possibilities for some further degree of quantification of our photo interpretation system: (a) a vast land area of extremely diverse ownership patterns and types, (b) lack of accessibility, (c) diversity of tree species but a tendency toward stand uniformity in many important commercial types, (d) insufficient personnel, and (e) high costs of data collection by conventional methods.

By current standards, use of aerial photographs by most practicing foresters in northern Minnesota is extremely intensive. Nevertheless, outside of distance and area measurements, conclusions and decisions regarding forest stands are based purely upon subjective judgment insofar as photo usage is concerned. Because of the lack of personnel and the character of the forest, administrative decisions of a surprisingly high level of importance are often necessarily made purely from the photos. To the outsider, this may appear to be extremely risky and, to some extent in some cases, he will be correct. Some unusually skillful interpreters experience a high degree of success and confidence, but results obtained by different interpreters cannot on the average be expected to be constant or comparable. Introduction of a system of actual measurements into the photo interpretation process is felt to be the only way in which the level of accuracy, comparability and statistical reliability of the answers of all interpreters can be substantially improved. Such a system would increase the number and reliability of administrative decisions possible from the aerial photographs. It would tend at the same time to reduce the excessive amount of valuable professional time now being consumed by routine field travel and measurements.

A series of preliminary tests over the past several years in cooperation with the Minnesota and Ontario Paper Company indicate the existence of very strong relationships between photo and ground measurements in their area. A few of these are shown in Figures 1 and 2, the basic studies for which are not yet complete and, hence, statistical analysis has not been accomplished.

Figure 3 illustrates graphically the results of an attempt to classify forest stand volume purely on the basis of aerial photo measurements. The estimates made by the 11 interpreters involved were based upon photo-height measurements, crown-density estimates and the use of a rather crude preliminary aerial stand volume classification table. The table had been previously prepared from data collected in another part of the state (2). Ten of the interpreters obtained aerial volume estimates which did not differ significantly from the ground measurements. Sample correlation coefficients (r) ranged from .466 to .666—all of which were significant at the one % level. None of the interpreters, incidentally, had ever been in or near the test area!

On the basis of these, and similar investigations elsewhere (e.g., 3, 4, 5), much has been learned about the development of aerial tables, plot measurement techniques and

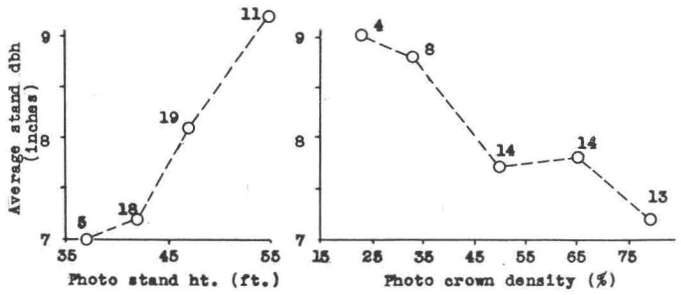

FIG. 2. Relationship to average stand diameter at breast height (dbh) of photo heights and crown densities obtained by 14 interpreters. The 53 1-acre hardwood plots were on 1/15,840 fall pan photographs.

interpreter training. There still remains the problem, however, of organizing these units into a system of application which is sound and simple to apply. This is proving difficult, but it appears probable that one or more basic techniques will emerge in the next couple of years which will be adaptable to many local areas.

THE NEED FOR STATISTICAL METHODS

An attempt has been made thus far to show that quantification of forest photo interpretation is both possible and desirable. The investigator who institutes research of this nature, however, soon finds himself faced with problems peculiar to the subject:

1) Lack of available research background material and suitable instrumentation.
2) Difficulties in enumeration due to the indirect photo approach to the population of interest.
3) The human equation in information read-out.
4) Problems of experimental design, data analysis and data interpretation.

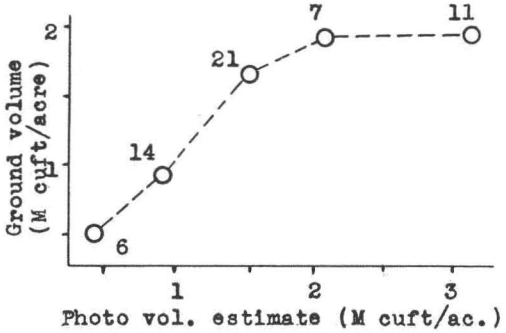

FIG. 3. Relationship to ground volume of photo volume estimates made by 11 interpreters on 59 1-acre plots. Fall pan 1/20,000 scale photography.

Admittedly, the first three items do not constitute "hot" news to experienced interpreters—a fact which does not lessen the degree of their importance. But, despite the magnitude of their role, only the last item has been selected for comment for the following reasons: (a) proper design and statistical analysis is essential to the conduct of meaningful research of a quantitative nature, and (b) it is that part of the research function most photo interpretation investigators know the least about—and the speaker is no exception in this category!

It is becoming amply evident in all areas of scientific investigation that what was acceptable research 10 to 20 years ago is rarely good enough today. A personal opinion rendered strictly on the basis of a mean of several uncontrolled observations was, at one time, as close as we could come to a valid quantitative answer. The advent of statistics as a tool of research and, more recently, the incorporation of the electronic computer have irrevocably changed this. This has not come about, incidentally as a result of a vast, heinous conspiracy on the part of the statisticians; although it must be admitted that they have been busy! Rather, it is the inevitable result of advance and change in our level of scientific knowledge, education and method of research. As a matter of fact, a change in attitude toward the whole conduct and reporting of research is also increasingly evident in the using, professional public. Audiences are becoming more critical and are no longer so easily intimidated by statistical analysis since they are, more and more, becoming trained to appreciate, understand and use it.

Since most investigators in the interpretation field are not highly skilled in the use of statistics, the advice of a statistician must be sought. Most of the problems which, at least initially, often arise in such associations, come

about as a result of difficulties in explanation and understanding. It appears that most statisticians have difficulty at first in understanding the nature of photo-extracted information, the factors which influence it and how it can best be analyzed and used. By the same token, many neophyte investigators have no appreciation of the drastic degree to which the initial design and conduct of their experiment will, in the end, dictate what they can (and cannot) conclude with regard to their findings.

A major value of the introduction of statistical tools into the interpretation process is that it provides the only currently acceptable means for either assessing or implementing the potential degree of practical quantification of the interpretation process. It appears also to afford some hope for the establishment of *standards of comparison* which are generally interpretable and acceptable by a large number of people. Take, for example, the problem of defining that elusive characteristic of forest photo interpretation photography known as "quality." How does one know the attainable or acceptable limits of photo-image quality obtainable?—and if we did, how do we specify it and describe it?

A cooperative, continuing project to study this topic was set up by the Minnesota School of Forestry and Mark Hurd Aerial Surveys, Inc., some six years ago. It had (and has) as its objective, an assessment of what constitutes good forest aerial photo quality and how it might be described and controlled. Admittedly, no neat, numerical descriptive package has yet emerged, or is this likely in the near future; but some of the factors influencing it have now been isolated and identified (e.g., 6, 7, 8).

One series of tests, in particular, pointed out some interesting relationships between photo quality characteristics and their assessment by interpreter judgment as compared to quantitative methods of analysis. In these studies, a number of trained interpreters were given a series of unidentified forest aerial photographs of the same area. All were from the same negative but differed in such characteristics as tone, emulsion, exposure, development and contrast. Even with only cursory examination of the prints, some interpreters were willing to make rankings of what they considered to be the best, next best and worst. But there was rarely any comparable pattern of agreement between interpreters. After that, the interpreters worked intensively with the photography for a considerable period of hours under strictly controlled conditions performing measurements of the forest photo population. At the end of the experiment, the interpreters were again asked to rank the photos on the basis of the best, second best, worst, etc. The results were extremely interesting since an almost identical pattern of results emerged from each test:

1) Instead of a random pattern of interpreter preference, most individuals were unanimous, or nearly so, in their selection of the "best" photography and the "worst" photography. The "in between" prints, however, were not always ranked the same for each interpreter.
2) Analysis of the results of the photo measurements were rather startling since, almost without exception, they revealed the interpreters had, indeed, done significantly better on the "best" and significantly poorer on the "worst" photography. The major difference came on the photos which in both cases were relegated to the "in between." Whereas the interpreters agreed on these photos as a group, they could not agree too well on their ranking within this category. The measurement results, however, were often sensitive enough to show very definite quality rankings within this intermediate group.

These tests serve to indicate that quantitative methods of research can perhaps also be used to determine the range of reliability of subjective judgment and point out ways in which it can be strengthened and improved.

Conclusions

The author in no wise suggests that quantification per se can or should be used to completely replace the subjective aspects of professional photo interpretation. This is neither possible nor is subjective judgment undesirable since it is this act of exercising sound, trained, experienced judgment which gives photo interpretation its tremendous basic value. What is suggested, however, is that through greater quantification of the photo interpretation system we will be able to extend and enhance the bounds of capability and accomplishment of the professionally-based subjective aspect of the interpretation process.

In closing, a word of warning is also felt to be in order with respect to the incorporation of statistical methods into both our research and practical interpretation. One can become too enamored of the magic of numbers and investigators (and readers) should not forget that numbers, as well as words, can tell mis-

truths and be hypocritical. There is always the inherent danger in any revolutionary new approach that too much begins to be ascribed to it or expected from it. Or there is the danger that it becomes an end in itself rather than a tool of research—to the point where subjectivity becomes taboo, and one cannot even render an honest, personal opinion without numerical substantiation verifiable at the 1% level! Let us use it—let it not use us.

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*Significant Measurement in the Lunar Photograph**†*

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Abstract: *In obtaining source data for incorporation into a lunar chart, the principal input at present is from photographs taken with astronomical telescopes. These photographs are considerably different from the material normally used in photogrammetric studies; i.e., wide-angle aerial photographs, and the problems encountered in their interpretation require correspondingly different solutions. Various methods of analysis are presented, with relative effectiveness and limits of application given for each. The concept of smallest significant image areas is introduced, with a consideration of the errors inherent in photographs among the lunar plate collections of several observatories.*

Introduction

During the history of astronomy, the Moon has occupied a somewhat secondary position as a subject for extensive study. The principal area of investigation has been the descriptive analysis of lunar features; and this has been left largely to the domain of the amateur astronomers. They as a group have done much work over the years, but are generally limited by inadequate instrumentation. Groups of lunar photographs have been made at various observatories during the past 70 years; but many of these lacked any systematic program in their acquisition, with the result that the coverage is sparse.

The rapid development in rocket technology over the past few years has made us suddenly aware that lunar exploration missions are not just a part of Jules Verne's writings or

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