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Tone Distortion for Automated Interpretation

Automatic quantitative discrimination of terrain cover on aerial photographs presents problems relative to densitometric measurements.†

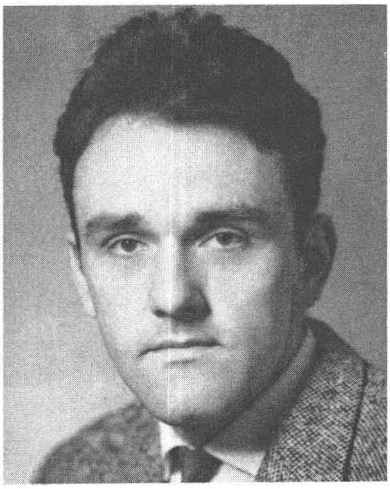
(*Abstract is on page 271*)

INTRODUCTION

A PREREQUISITE for the automated photo interpretation of terrain cover types based on densitometric measurements is a rigid standardization of either the photographic process or the densitometric output. This is because the comparison of digitized densitometer output with a key must rely on a previous statistical analysis of parameters. Such parameters will be measured from photographs taken over sample areas for such diagnostic features as tone and texture. For every cover type these parameters will have a certain range of variation. A key will then provide intervals for each of the cover types within which the parameters will lie with a certain probability. In order to be most effective such keys should reflect standard conditions, i.e., the influence of sources of variation should be minimized. To achieve this minimization a thorough analysis of sources of variation is needed.

TONE DISTORTION IN THE PHOTOGRAPHIC PLANE

One source of variation for macroscopic average gray tones is the non-homogeneous illuminance in the focal-plane of photographic cameras which creates corresponding point-to-point differences in tone or density. This fact necessarily increases the variability of tones for individual terrain cover types if these tones are measured indiscriminately anywhere on the photograph. Amazingly enough, this problem has been given no attention so far. True, manufacturers of lenses have been concerned with the off-axis loss of illumination in their products and are tending to reduce or eliminate it. There are, however, additional factors which produce unequal illuminances. The most important of these is the reflectivity of the terrain, which is dependent on the angle of remission. The density variations caused by these factors take place over the focal-plane and, consequently, the resulting tone distributions can be expressed



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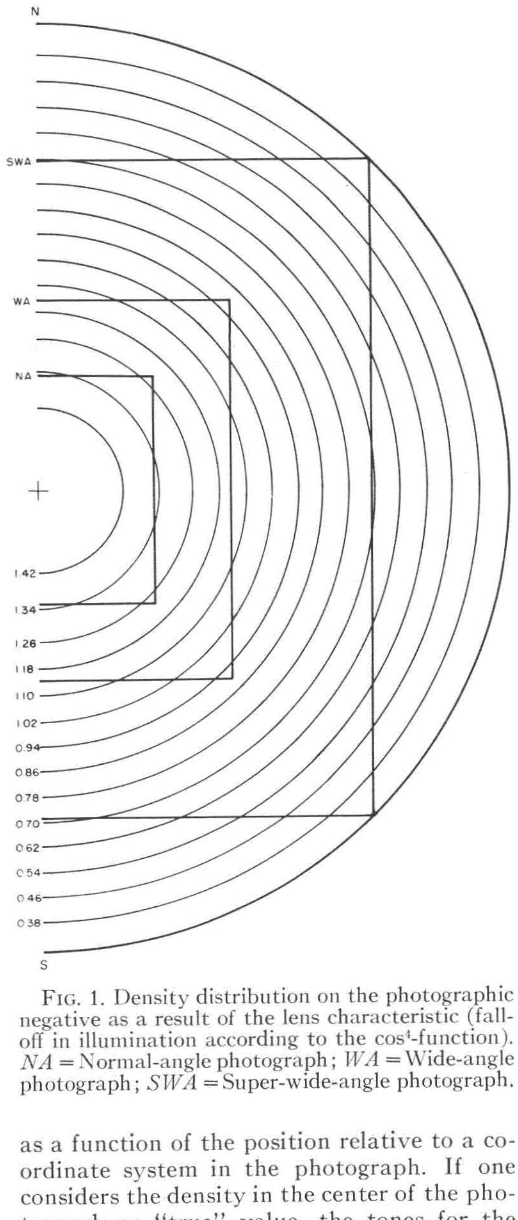


FIG. 1. Density distribution on the photographic negative as a result of the lens characteristic (fall-off in illumination according to the $\cos^4$-function). NA = Normal-angle photograph; WA = Wide-angle photograph; SWA = Super-wide-angle photograph.

as a function of the position relative to a coordinate system in the photograph. If one considers the density in the center of the photograph as "true" value, the tones for the same cover type will assume different values for all other positions on the photograph. In analogy to the geometrical radial distortion, therefore, we call this phenomenon "tone distortion."

FACTORS CAUSING TONE DISTORTION

For simplicity it will be assumed that it is possible to standardize the photographic process in such a way that original contrasts between different cover types are either preserved on the photographs or can be reconstructed. The only technical source of tone variation which is then left is the non-homogeneous density distribution created in the focal-plane by various factors. These factors are:

1. The reflectance of the terrain, which shows a change in intensity as a function of the angle of remission;
2. different intensities of atmospheric light scattering in different directions;
3. a constant alteration of exposure time over the focal-plane in cameras equipped with focal-plane shutters;
4. the off-axis decrease in illumination which is an unavoidable property of every optical lens system;
5. irregularities during the developing process;
6. the application of dodging principles for the printing.

Here we concentrate on factors 1 and 4, namely on the reflectance of the terrain, and on the illumination decrease caused by the lens, respectively.

OFF-AXIS LOSS OF ILLUMINATION CAUSED BY THE LENS SYSTEM

Every lens or lens system causes a decrease in intensity of illumination off the optical axis. Consequently, a photograph taken over a surface with equal brightness in all directions will show maximum negative densities at and around the center, and a steady decrease in density along radial lines. The resulting density distribution can be displayed with a graph showing isolines of density (Figure 1). These isolines are concentric circles around the photographic center.

Formerly, it was believed that this fall-off could always be represented by the equation

$$D_r = D_0 + \log \cos^4 a$$
$$= D_0 + \log \cos^4 \left(\arctan \frac{r}{f}\right),$$

where D_r is the density at a distance r from the center of the photograph, D_0 the density at the center, i.e., at distance $r=0$, a the angle included by the optical axis and an incident light beam, and f the focal-length of the lens. It could be proved, however, that optical systems can be constructed which have an illumination loss much smaller than given by the $\cos^4$-function (see, e.g., Kasper 1953). Modern cameras are even equipped with compensating filters which eliminate the remaining inequalities in illuminance completely. Later it will be demonstrated that this is not a solution which guarantees a maximum homogeneity in exposure and, accordingly, a minimum variability of tones. The reason is that another factor applies having a relatively strong influence on tone distribution: *the reflectance of the terrain.*

Reflectance Characteristics of the Terrain

The intensity of the light reflected from the earth's surface depends on the angle of remission. The value for vertical upward reflection is usually taken as representative for sun in front, and (2) there may be in general a conspicuous alteration in light intensity with increasing departure of the angle from the vertical. Furthermore, even apparently "smooth" surfaces, such as concrete or sand, show either a light-and-shadow effect or give rise to a certain amount of specular reflection.

Data on the relationship between the intensity of reflectance and the angle of remission are very scarce since only a very few studies have dealt with this question. Some experiments have been undertaken in fields of research other than air photography and,

Abstract: *In an automated photo interpretation of terrain cover types, the analysis of macroscopic gray tones (average tones of unit areas) can be a useful first discriminatory step. To get a maximum separation, however, the variability of tones for individual cover types has to be a minimum. Three main sources of tone variation are: (1) an inherent or specific variation, which cannot be eliminated; (2) the reflectance of the terrain, which depends on the angle of remission; and (3) the off-axis loss in illumination caused by the photographic lens system. Variations (2) and (3) cause the density of the photographic negative to be a function of the position within the negative. For this phenomenon the term "tone distortion" is proposed. This distortion tends to reduce the ability to distinguish cover types considerably if tone measurements are taken indiscriminately within a larger portion of the photographs. The problem can be overcome either by restricting the tone analysis to small portions of the photographs or by introducing corrections based on distortion functions.*

the case of air photography. This is true as long as one is concerned only with the central portion of photographs. It will be seen, however, that this vertical value may be far from being a useful approximation to a mean value of tones within a larger portion of photographs.

Most of the cover types on the earth's surface represent a "rough" surface with respect to illumination and reflection. Consequently, there is a distinct contrast between an illuminated and a shady side, unless the sun has a zenithal position. This effect is, of course, most conspicuous for agglomerations of tall objects, such as trees in a forest or buildings in a city. Short vegetation types with thin individual plants, such as meadows and agricultural crops, are usually thought of as reflecting light in a diffuse manner which would imply their having a constant brightness when seen from different angles. This assumption does not match reality. It can be demonstrated with reflection measurements that (1) there is again a contrast between a view with the sun behind and a view with the

therefore, are of limited value for the photo interpretation case.[1] Krinov (1947), in his book on the "Spectral Reflectance of Natural Formations," presents the results of a couple of measurements on different cover types. The experiments, however, were not undertaken in a very systematic manner.

Some years ago, the authors of this paper had the opportunity of carrying out a series of measurements on different crop types in Switzerland. This study was a rather casual side line, within the framework of a larger research project, in photo interpretation and could not be pursued any further and in greater detail.[2] The findings were nevertheless rather interesting.

Although this present paper is thus based on a very limited amount of data the authors

[1] These include studies by Kulebakin (1929 and 1930) and Hagemann (1938) which were conducted in connection with problems of highway illumination.

[2] This photo interpretation research project was sponsored by the European Research Office of the US Army in Frankfurt, Germany.

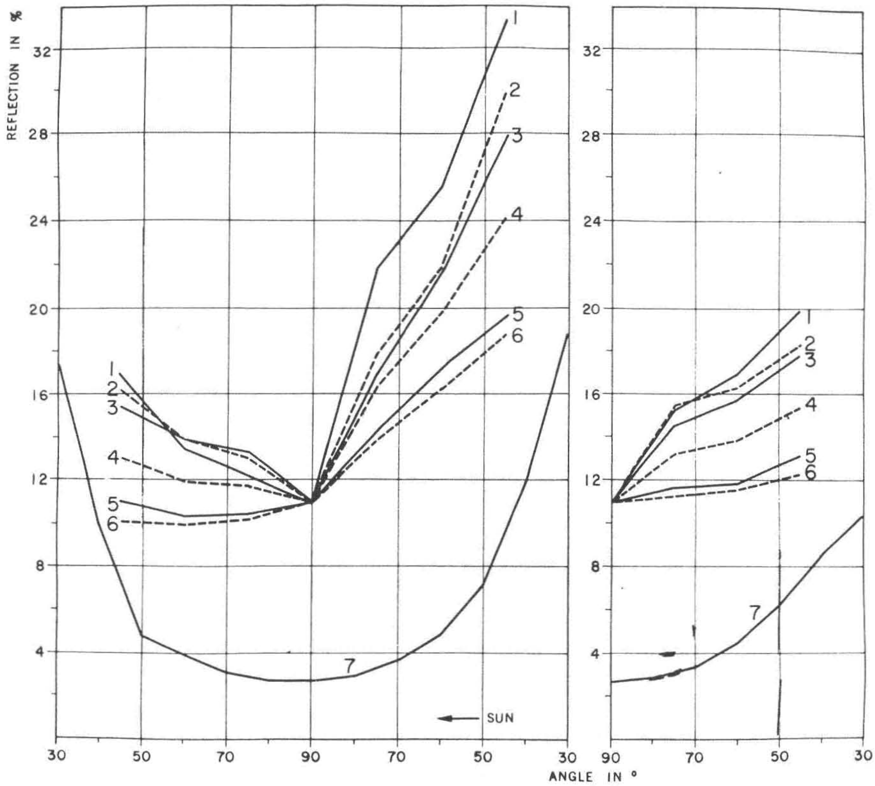


FIG. 2 FIG. 3

FIG. 2. FIG. 3. Reflectance of wheat as a function of the angle of return.

1–6: Ripe, measured at different sun's altitudes (based on the authors' measurements): 1 Solar altitude=33°; 2=38°; 3=43°; 4=48°; 5=53°; 6=58°.

7: Green, at 40° solar altitude (based on Krinov's data). Fig. 2 (left) shows the change in reflectance along the longitudinal axis, Fig. 3 (right) and one along the transverse axis. For the latter only one half of the curve is shown, since it is assumed that the reflection pattern is symmetrical on both sides of the vertical.

believe that its presentation is justified.[3] They were motivated by the surprising fact that at a time when one thinks seriously of automation in air photo interpretation, the problem of differential terrain reflectance causing an increased tone variation on photographs seems to be disregarded entirely.

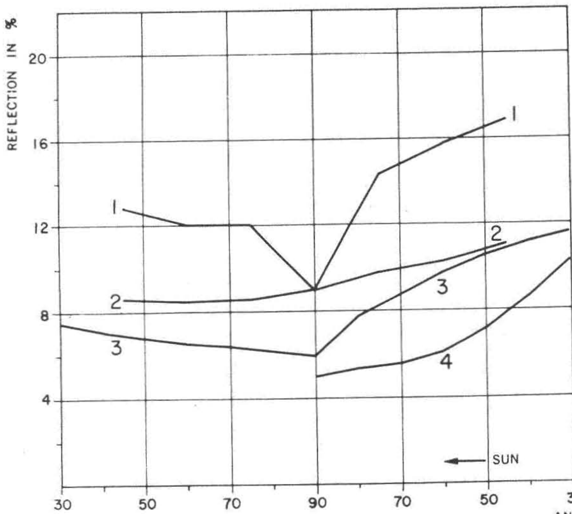
In the following will be presented the most important findings of the reflection measurements, including Krinov's data (compare with Figures 2–7).

(1) All cover types investigated show a general increase in reflectivity with increasing departure of the remission angle from the vertical. This is true for any azimuthal direction. Measurements were undertaken only for the four "cardinal" directions, namely, on a (a) "meridional" axis against and away from the sun, and (b) transverse axis in both directions. The assumption seems to be safe, however, that there will be no basic change in this relationship for any intermediate azimuths. For convenience, let us assume that we are dealing with conditions in the middle latitudes of the northern hemisphere only, and call the four "cardinal" directions "west" and "east" (reflection in transverse directions), and "south" (reflection towards the sun) and "north" (reflection away from the sun).

(2) As a result of (1), the reflection vertically upward is always a minimum.[4]

[3] A brief and very limited account of some of the findings has been given previously in the final report of the above mentioned research project (Boesch and Steiner 1959).

[4] In some cases, especially at high solar altitudes, there is a deviation from this rule and the minimum reflection can be observed at an angle to the "north" of the vertical.



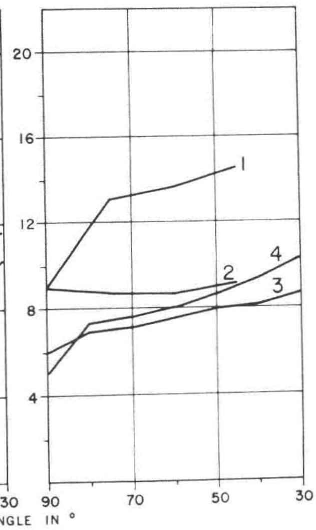
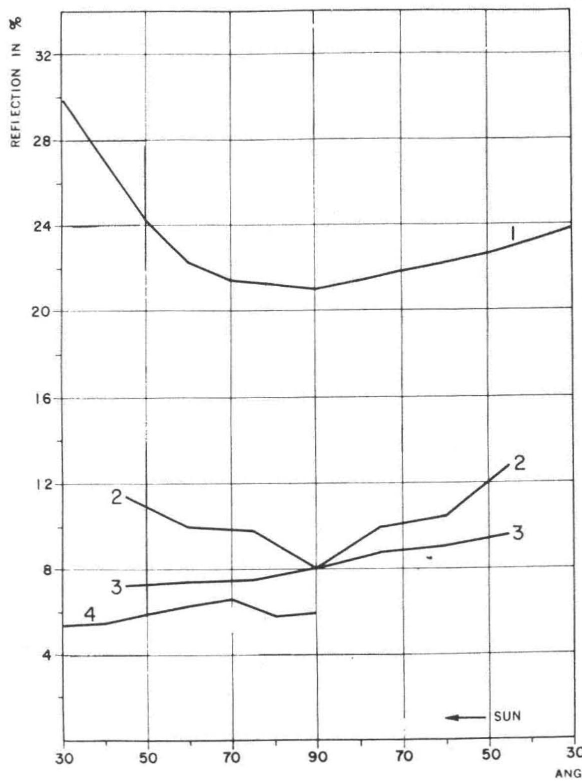


FIG. 4

FIG. 5

FIG. 4. FIG. 5. Reflectance of grass as a function of the angle of return. 1 and 2 based on the authors' measurements: 1 solar altitude = 33°; 2 = 58°.

3 and 4 based on Krinov's data: 3 solar altitude 45°; 4 = 25°. Reflectance along the longitudinal axis is shown in Fig. 4 (left) and along the transverse axis in Fig. 5 (right).



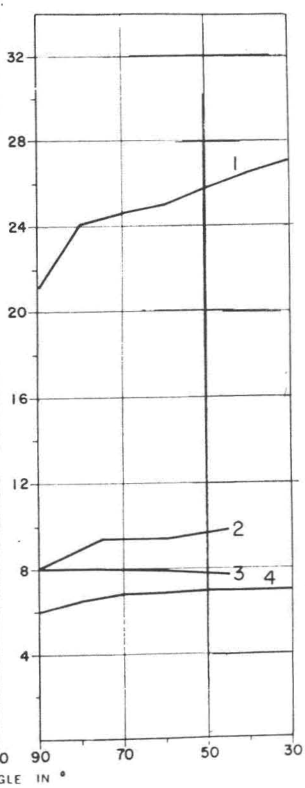


FIG. 6

FIG. 7

FIG. 6. FIG. 7. Reflectance of sand, podsol soil and beets as a function of the angle of return.

1: Barchan sand at 50° solar altitude (after Krinov).

2 and 3: Beets at 33° and 58° of solar altitude, respectively (based on the authors' measurements).

4: Moist podsol soil at a solar altitude of 40° (after Krinov). Reflectance along the longitudinal axis is shown in Fig. 6 (left) and along the transverse axis in Fig. 7 (right).

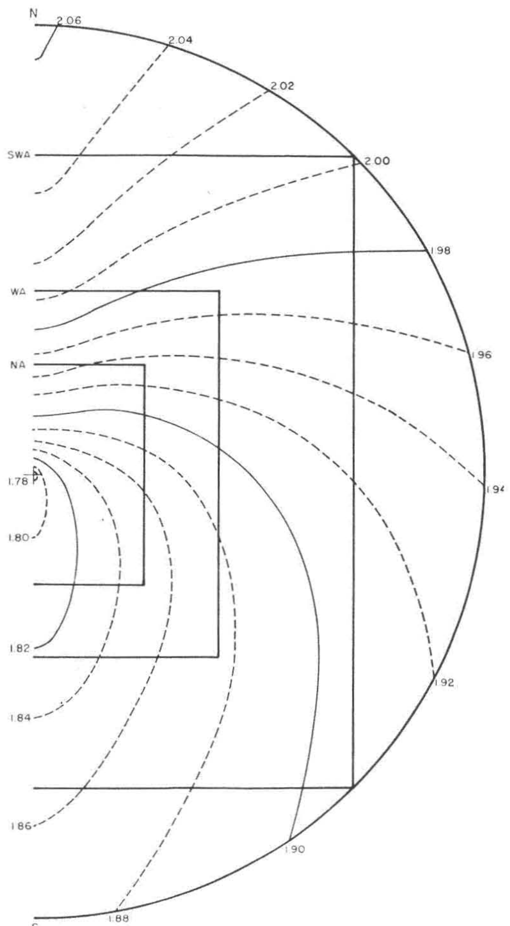


FIG. 8. Density distribution on the photographic negative as a result of the reflectance characteristics of grass at a solar altitude of 45° (based on Krinov's data). *N* ("north") and *S* ("south") refer in this case to the orientation of the photograph, not to the direction of reflection. *NA* = normal-angle photograph; *WA* = wide-angle photographs; *SWA* = super-wide-angle photograph.

In other words, the terrain always looks brighter when observed from an oblique angle than when seen from directly above.

(3) The increase in reflectivity, as stated under (1), is different for the four "cardinal" directions. It is highest at angles in "southern" direction for all cover types studied. The lowest increase can be observed at transverse angles for root-crops and at angles in "northern" direction for hayland and small grains. Note that there is a discrepancy between Krinov's and our own results as far as small grain is concerned. Krinov's measurements taken on wheat show roughly about an identical increase in reflection at angles in both "southern" and "northern" direction, whereas the returns at transverse angles remain lower. Sand seems to behave differently. Here the intensities are the highest for angles in "northern" direction, which, obviously, indicates a certain specularity in reflection.

(4) The reflection characteristics depend on the altitude of the sun. If it decreases, the intensity of the light remitted at oblique angles gets greater relative to the brightness in the vertical direction. Also, the contrast between the "southern" and the "northern" side increases. Krinov's and our own

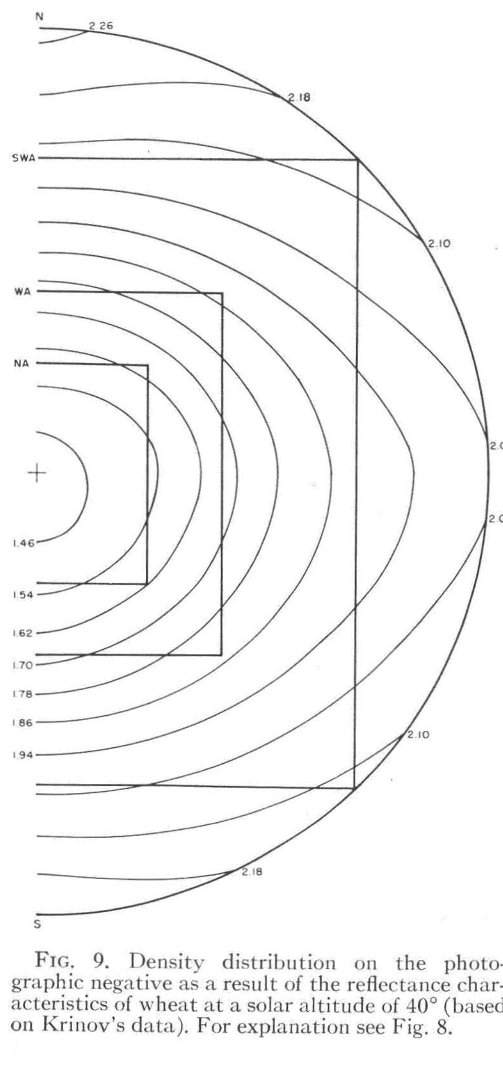


FIG. 9. Density distribution on the photographic negative as a result of the reflectance characteristics of wheat at a solar altitude of 40° (based on Krinov's data). For explanation see Fig. 8.

measurements were confined to a range in the sun's altitude of 20 to 60°. The question remains whether there would still be a further enhancement of the off-vertical increase in reflectance with the sun below 20° of altitude.

(5) Although the basic pattern of reflection is the same for all cover types, there are differences between the types with respect to the rate of brightness increase at oblique angles. According to the author's experience the variation in reflection intensities is the smallest for crops such as beets and potatoes, the largest for small grains, and intermediate for meadows. Whereas vegetation always shows a certain light-shadow effect along the "meridional" axis, such a cover type as sand gives rise to a reverse contrast.

THE TONE DISTRIBUTION ON THE PHOTOGRAPH AS A RESULT OF THE TERRAIN REFLECTANCE

Our next analytical step is the study of the theoretical tone distribution on the photo-

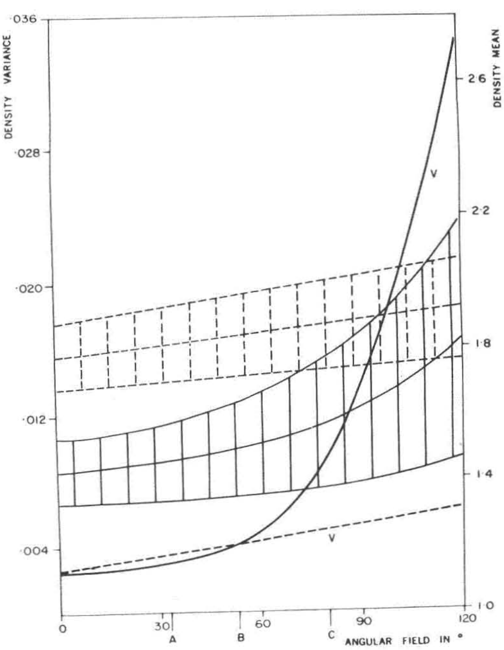


FIG. 10. Density means with variation belts and density variances for wheat and grass as a function of the utilized angular field (based on the density distributions in Figs. 8 and 9).[8] Solid curves stand for wheat, dashed curves for grass. V = variance. The variation belts are given by the density means ±1.96 standard deviations. For further explanation see text.

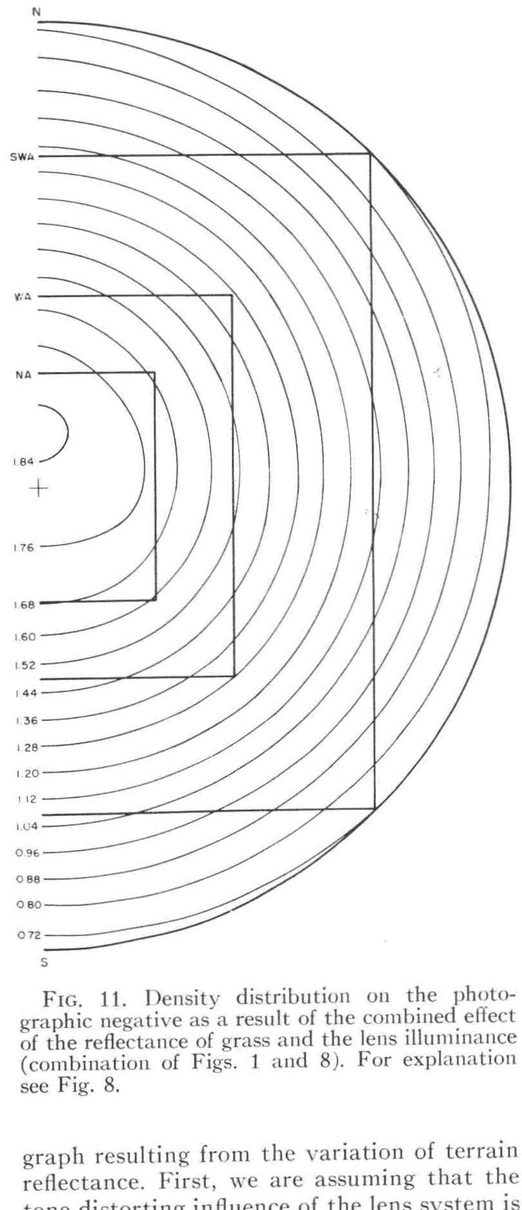


FIG. 11. Density distribution on the photographic negative as a result of the combined effect of the reflectance of grass and the lens illuminance (combination of Figs. 1 and 8). For explanation see Fig. 8.

graph resulting from the variation of terrain reflectance. First, we are assuming that the tone distorting influence of the lens system is completely eliminated. In the next section will be demonstrated the situation for the other extreme, i.e., combination of the two sources of tone variation, terrain reflectance and lens illuminance.

The question of tone distribution as a result of angular differences in terrain brightness has not been given any systematic attention so far. To our knowledge the only paper, previous to the U. S. Army contract final report by Boesch and Steiner (1959) and the latter's Ph.D. dissertation (Steiner 1961) (in

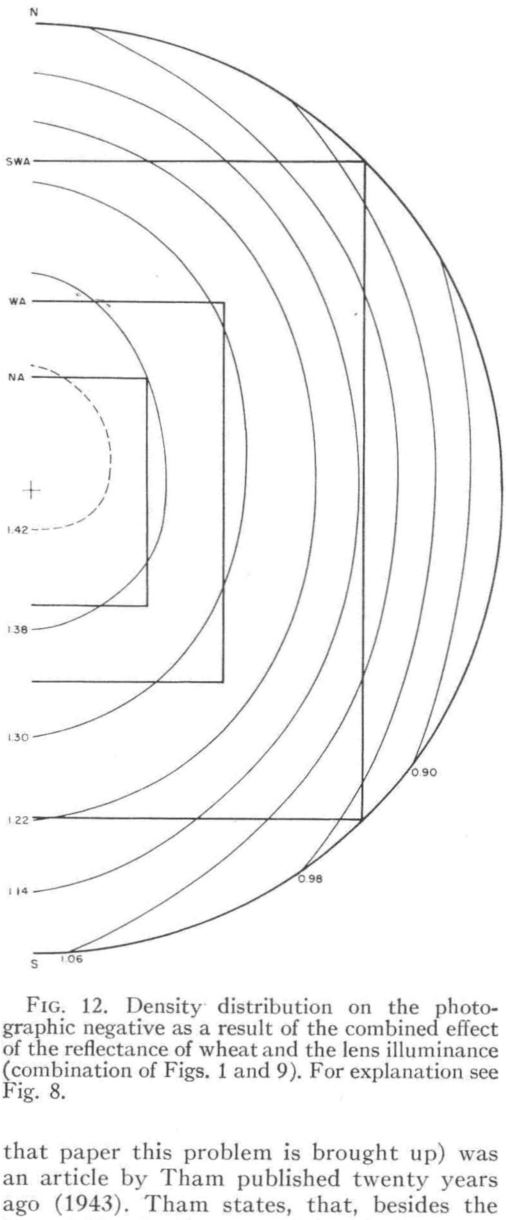


FIG. 12. Density distribution on the photographic negative as a result of the combined effect of the reflectance of wheat and the lens illuminance (combination of Figs. 1 and 9). For explanation see Fig. 8.

that paper this problem is brought up) was an article by Tham published twenty years ago (1943). Tham states, that, besides the loss of illumination caused by the lens, one should also take into consideration that the terrain creates an additional variation in illuminance.

On the basis of the reflection measurements graphs have been prepared which display isolines of theoretical negative density for two examples of cover types (grass in Figure 8, and wheat in Figure 9).[5] We have assumed that original contrasts are not distorted by haze and are reproduced over a film gamma of 1.0. Furthermore, the assumption was made that the distribution pattern will be essentially symmetric on both sides of the "meridian." Therefore, only half of the whole distribution has been plotted.[6] Also, it was not extended beyond 60° departure from the vertical. The heavier lines indicate the parts which would be covered by photographs taken with three different categories of lenses, namely a normal-angle lens (angular field of 60°), a wide-angle lens (90°), and a super-wide-angle lens (120°). The frames indicating the different photographs are oriented according to the "cardinal" directions, i.e., they show the situation as it would be for either "west-east" or "south-north" runs. It should be noted that the analysis for other orientations would give slightly different results.

Since the photographic density increases steadily off the center as shown by both graphs, it is at once clear that the larger the angular field of the camera the larger the variation of tones for one terrain cover type. If we were to take a photograph of say a large homogeneous field of wheat, a positive print would be darker in the center and lighter in the marginal areas. It also means of course that the same small plot showing up several times on overlapping photographs would appear with different tones on the different photos.

We regard the whole range of densities being broken up in a number of classes, the intervals given by the isolines plotted in Figures 7 and 8. The areas occupied by these classes can then be measured. This was done separately for each of the three photo types. From the class means and their frequencies (areas covered by the individual classes) it was then possible to calculate mean and variance for the whole density distribution in each case. The mean is given by

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[5] The control points for the isolines where, according to the directions investigated by the reflection measurements, all located on the main axes. The position of the isolines was determined by linear interpolation along these axes and along arcs of circles in the quadrants between the axes. To get greater reliability in the plotting of tone distribution future reflection measurements should include more than only the four "cardinal" directions.

[6] Sometimes deviations from symmetry can be observed as, for example, for small grain fields where all heads may have a certain orientation and cause an asymmetrical reflection pattern. It should be investigated whether such asymmetries are regionallly consistent or haphazard.

$$\overline{D} = \frac{\Sigma f_i D_i}{F},$$

and the variance by

$$s_D^2 = \frac{F\Sigma f_i D_i^2 - (\Sigma f_i D_i)^2}{F(F-1)},$$

where D_i is any of the interval midpoints, f_i the associated frequency, and F the total area.

The variance above is the variance of density resulting from the angular variability of terrain reflectance. In addition, we now have to take into consideration that each of the cover types will have, independent of the angle of observation, a certain basic variability in brightness which, in the case of vegetation, is due to differences in development. These differences in turn are caused by natural factors (variations in site quality) and human factors (non-simultaneity of sowing, harvesting, etc.). This is therefore an inherent or specific variance which under no circumstances can be eliminated. This specific variance may be different for different cover types or different for the same cover type at different times of the year. For the demonstration of the principles, however, we assume that this variance is a constant, namely 0.0025 (expressed in density units). From the densitometric analysis of a large number of negatives the authors could conclude that the specific variance will be of this order.

To get the theoretical total variance we can now add the specific to the reflection variance:

$$s^2_{\text{total}} = s^2_{\text{refl.}} + s^2_{\text{spec.}}$$

This procedure is a synthetic approach to the problem. The different sources of variation are each analyzed separately and their effects then combined to predict the likely total variation. It would be interesting to tackle the same problem analytically, i.e., to start with density measurements on photographs, and then subject these to an analysis of variance. If a large number of plots of the same cover type with different positions within many photographs were measured, a certain trend in density distribution would show up. This trend could be described by fitting a statistical surface to the data with regression techniques. The specific variance, including a certain error term, would then be given by residuals above and below this surface.

The total variance has been calculated for all three photo types. The results are shown in Figure 10 together with the mean densities. Naturally, since the off-axis densities grow larger and larger, the means increase with an increase in angular field. This increase is more pronounced for wheat, because the change in reflection intensity at oblique angles is here much greater than for grass. As for the variance we start with the basic specific variance of 0.0025 at the center of the photograph. With an increase in angular field the total variance begins to grow much more rapidly for wheat than for grass.

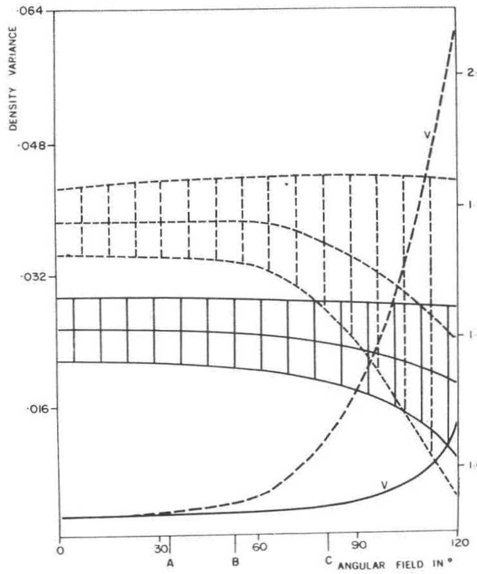

FIG. 13. Density means with variation belts and density variances for wheat and grass as a function of the utilized angular field (based on the density distribution in Figs. 11 and 12). For explanation see Fig. 10.

To show the ranges of tone variation we have drawn in Figure 10 a belt of $\pm 1.96\, s_{\text{total}}$ around the mean values, s being the standard deviation. These belts can be considered as containing 95% of all cases, or, with a 0.05 error probability, 100%, i.e., all cases.[7] For this we have to assume of course a normal distribution for the density values. An analysis of the frequencies shows that these distributions are not exactly normal, but the normal distribution seems to be at least a reasonable approximation to get an estimate for the distinguishability of cover types.

[7] In an exact analysis additional errors due to sampling variability should be taken into consideration too.

When comparing grass and wheat[8] one sees that the variation belts are first clearly separate, then become wider and wider with an increase in angular field, and finally overlap. From this it follows that grass and wheat can be separated completely on a normal-angle photograph, only partly on a wide-angle, and not at all on a super-wide-angle photograph—with the exception of the wheat belt lying outside of the overlap area. This situation, of course, holds only if measurements are taken indiscriminately everywhere on the photographs, which usually would not be done anyhow.

A restriction of the densitometric measurements to smaller areas on the photos lets the ranges of tone variation shrink and, therefore, improves the prospects of distinguishability. With the common overlap of 60% along the flight line and a sidelap of 30%, the minimum area for analysis is given when the overlap in each direction is divided in two and each of the halves assigned to one of the photographs. The improvement is shown in Figure 10 where we have indicated the angular fields which approximately correspond to these minimum areas with *A*, *B*, and *C*, respectively. The increase in separability is considerable but, even now, there is still a certain overlap of the two variation belts for the super-wide-angle photography.

The Tone Distortion as a Result of the Combined Effects of Both Terrain Reflectance and Lens Illuminance

Let us now have a look at the tone distribution resulting from a combination of the two main distorting factors, namely of the terrain reflectance and the lens illuminance. To demonstrate the extreme we assume that we have an illumination loss following the cost-function.

Figures 11 and 12 portray the isolines of density on the negative. The same procedure as before was applied again, i.e., the areas between the isolines were measured and means and variances calculated. The results are shown in Figure 13. Now the mean values decrease with an increase in area of investigation since the gain in light intensity at oblique angles of remission is overcompensated by the off-axis loss of lens illumination. Naturally, both the variances will still increase, but the situation is now reversed, and the variability of tones grows more for grass than for wheat. As a result, the possibilities of separation are very much the same as before.

The normal-angle photograph permits a total, the wide-angle a partial, and the super-wide-angle photo no discrimination—except again for those parts of the larger variation belt lying outside of the smaller one. The situation is also very similar to the previous case if, according to the overlap, the area of measurements is limited to the central portions of the photographs.

Conclusions and Possible Solutions of the Problem

Although, in this preliminary study, the analysis has been carried through only for two examples we feel that it is justifiable to draw the following conclusions. The larger the angular field used for the densitometric analysis, the broader the belts of variation for individual cover types, and the lower the changes of separating them successfully. Evidently, an improvement can only be obtained if the variability of tones is kept at a minimum. First of all, a time of the day has to be selected which guarantees minimum tone distortions. This is the case for high solar altitudes. To handle the remaining tone variation a solution can be sought along one of the following two lines: the angular field utilized can be restricted to a minimum, or the tone distribution in the focal-plane can be corrected in one way or another.

1. *Keeping the angular field small.* This can be achieved either by taking photographs with an overlap larger than usual or by employing tele lenses. Neither way, however, would be very economical, and it would seem that the otherwise advantageous super-wide-angle lenses could not be used at all for this purpose. A promising alternative would be the use of a continuous strip camera.

2. *Correcting the tone distribution.* If it is possible to introduce corrections and to re-

[8] The assumption is made that the tone variations for both grass and wheat are directly comparable, i.e., that the respective reflection measurements were taken at the same time of the year, at the same altitude of the sun, etc. The fact is that the sun's elevation is somewhat different, 45° for the grass and 40° for the wheat, and Krinov does not give any information as to the season in which the investigations were conducted. Nevertheless, we felt that this certain incomparability does not affect the validity of the principles which are demonstrated in this paper.

duce the variability of tones, the use of lenses of wider angles becomes feasible again. The difficulty is that the angular changes in reflectivity are different for different cover types. It seems possible, however, that an average function could be determined for general purpose photography. According to the type of terrain the best function to introduce for correction could be found by the least squares method. For various kinds of special photography different functions could be determined and used as well. A correction could be achieved basically in three different ways:

(a) The least involved solution seems to be the use of a compensating filter of the kind now used for balancing out the loss of illumination in lens systems. The general trend of lens manufacturing is going clearly in the direction of complete elimination of this loss. As can be seen from the results of our analysis, this does not provide optimum conditions as far as the tone variability is concerned. The optimum must lie somewhere between the two extremes, namely, the case with no lens illuminance fall-off and the case with full loss (according to the cost-function). The average increase in off-axis reflectivity should be compensated by a corresponding off-axis decrease in illumination. The mean density values of cover types would then tend to be constant rather than to show an upward or downward trend, and the variances could be kept within reasonable limits when the angular field utilized is expanded.

(b) The corrections could be introduced at the time the measurements are taken on the negatives by electronical means.

(c) Finally, one could feed the data output unchanged into a computer and have the computer make the necessary corrections.

Tone distortion not only has disadvantages but it might open new possibilities of photo interpretation as well. From our analysis at least two things can be concluded:

1. Since the tone distortion as a function of the angular reflectivity of the terrain is different for different cover types, it seems only logical to assume that it would be possible to determine the nature of cover types on the basis of these very differences. It would require that photographs be taken with a large overlap so that one spot could be measured several times on different photographs.
2. It is likely that certain cover types which are not distinguishable at the center of the photograph might be separable when seen under a specific angle. If this is so the solution would then be to take oblique photographs, preferably again with a continuous strip camera. For two or more cover types an analysis could be made by comparing the corresponding density distribution maps and plotting the isolines of density difference. From the portions of this new graph which show the largest differences the best angle and direction of photography could be determined.
3. As can be seen from Figures 2–7 the tone distribution patterns change as a function of the sun's altitude. Since this change is different for different cover types it is likely that there will be an optimum time of the day for each individual problem of separation. This is at least true for oblique angles. In this study it has been assumed that there are no changes in contrast between different cover types for the vertical upward reflection as a function of the sun's altitude. Measurements of vertical returns taken at different hours of the day (Boesch and Steiner 1959) have indicated that this is roughly true within a range of solar altitude of 30 to 60°. It may be expected, therefore, that the discrimination of cover types at and near the center of vertical air photographs is not affected by the time of the day. Whether this holds also for solar altitudes outside of this range has not been investigated.

It should be noted also that everything that has been demonstrated in this paper holds for flat terrain only. Naturally, in rough terrain increased difficulties due to terrain shadows would arise. It is not clear as yet how this problem could be overcome. A possible solution might be to take photographs under a high overcast only so that shadows would be absent. Belov (1959) describes the use of such photography for forestry purposes.

We hope that we have been able to give an outline of the problems and possibilities connected with the reflectivity of the terrain as a factor in tone distortion. Due to the scantiness of data any final and definite answers cannot be given at this time, however, and more research along these lines is badly needed.

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University of Illinois to Conduct Institute

Under the sponsorship of the Topographic Division of the U. S. Geological Survey, the Department of Civil Engineering will conduct an eight-week Institute during the summer of 1965. This Institute, the first of its kind, will present three courses: Geodetic Surveying, Surveying Adjustments, and Advanced Photogrammetry. The participants will be 24 engineers currently employed by the U. S. Geological Survey and will come from each of the four regional areas and both from field sections and photogrammetry.

The Geodetic Surveying course will consider the fundamental concepts of the shape of the earth and the principles of geodetic measurements. The latest in electromagnetic distance measuring devices will be made available for laboratory exercises. The Survey Adjustments course will consider the theory of least squares and employ matrix algebra in the solution of complex surveying problems and the adjustment of observations. This course is computer-oriented, and three computers—IBM 1620, IBM 7094, and the Illiac II—will all be available to the students. The Advanced Photogrammetry course will develop the concepts of analytical aerial photogrammetry. In addition to the usual plotters, the class will have an opportunity to use the WILD STK-1 Stereocomparator.

During the summer period, visiting lecturers from government, industry, and education will present talks and seminars to the group. It will be in this way that the technological principles can be related to the realities of engineering economy, political compromise, and the management of human activities.

1965 Summer Institute in Geometronics

The 1965 Summer Institute in Geometronics is being repeated at The School of Civil Engineering of Purdue University, Lafayette, Indiana June 20 to August 14, supported by the National Science Foundation. The institute has as its objective the advanced theoretical training of teachers who are engaged in the areas of surveying, geodesy and photogrammetry. Previous institutes supported by NSF were held at the University of Washington in 1963 and at Purdue University in 1964.

Participants will be selected for their ability to benefit from the program of the institute and their capacity to develop as teachers of surveying and mapping. Every participant should satisfy the following:

1. Possess at least a Bachelor of Science degree with emphasis on engineering or physical sciences.
2. Have a minimum of two years equivalent full-time teaching.
3. Have deficiencies in their theoretical background for teaching in the area of surveying, geodesy, and photogrammetry.
4. Have a prime interest in continuing his teaching in these areas.

Formal stipend application must be postmarked by February 15, 1965 to guarantee consideration. Stipend offers will be made on March 5, 1965 with the understanding that participants have until April 1 to accept or decline.