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Dot-Grid Area Measurement on Panoramic Photographs

Precision of the panoramic measurements was found to decline outside the central 72-degree portion of the 120-degree panoramic photograph.

Abstract: *Ground area measurements made on high altitude panoramic photographs by use of a special equal-area dot grid were compared with dot-grid measurements made on conventional resource photography, and with planimeter measurements made on orthophoto quadrangles. Precision of the panoramic measurements was found to decline outside the central 72-degree portion of the 120-degree panoramic photograph.*

Introduction

Through the U.S. Forest Service's Houston-based Nationwide Forestry Applications Program, high altitude photography taken by U-2 aircraft of the National Aeronautics and Space Administration's Airborne Instrumentation Research Project has been increasingly available to resource managers during the past five years. Among the various types of U-2 photography, panoramic photographs obtained with the Itek KA-80A Optical Bar Camera have generated special interest because of the efficiency with which large areas can be covered at the medium scales needed for forest, range, wildlife, and watershed planning. Land managers accustomed to using conventional 9-inch square photographic prints have had to make some adjustments when confronted with 5 inch by 50 inch optical bar transparencies exhibiting considerable panoramic distortion. Various field and office viewing devices have been designed to facilitate use of panoramic photos, and a number of investigations have been undertaken to gauge the accuracy with which various kinds of measurements can be made on them (Hinkle, 1981). One significant aid to panoramic photo interpretation and training is the PANGRID computer program (Liston, undated), supported at the Forest Service's Fort Collins, Colorado Computer Center, which enables a user to produce transparent equal-area grid overlays that both illustrate and compensate for the panoramic distortion of KA-80A photographs. The program allows the user to specify any desired combination of aircraft altitude, scan limit, forward lap, grid cell size, and line weight. Square or dot grids may be generated. The grids are inexpensive (about $2) and reusable. A reduced portion of a typical PANGRID dot grid appears as Figure 1.

(In addition to PANGRID equal-area grids, Forest Service Geometronics personnel have produced terrain-registered panoramic grid overlays with the aid of digital terrain models. Terrain-registered grids compensate for topographic displacement as well as panoramic distortion. They are expensive—about $50 per grid—and each such grid is usable with only a single photograph; consequently, they have not seen general use.)

Since measurements of ground areas are among those most frequently made on aerial photographs by land managers, and since the dot grid is perhaps the most frequently used area measurement tool in land management offices, we thought it might be useful to compare area measurements made on standard resource photographs using a conventional dot grid against measurements made

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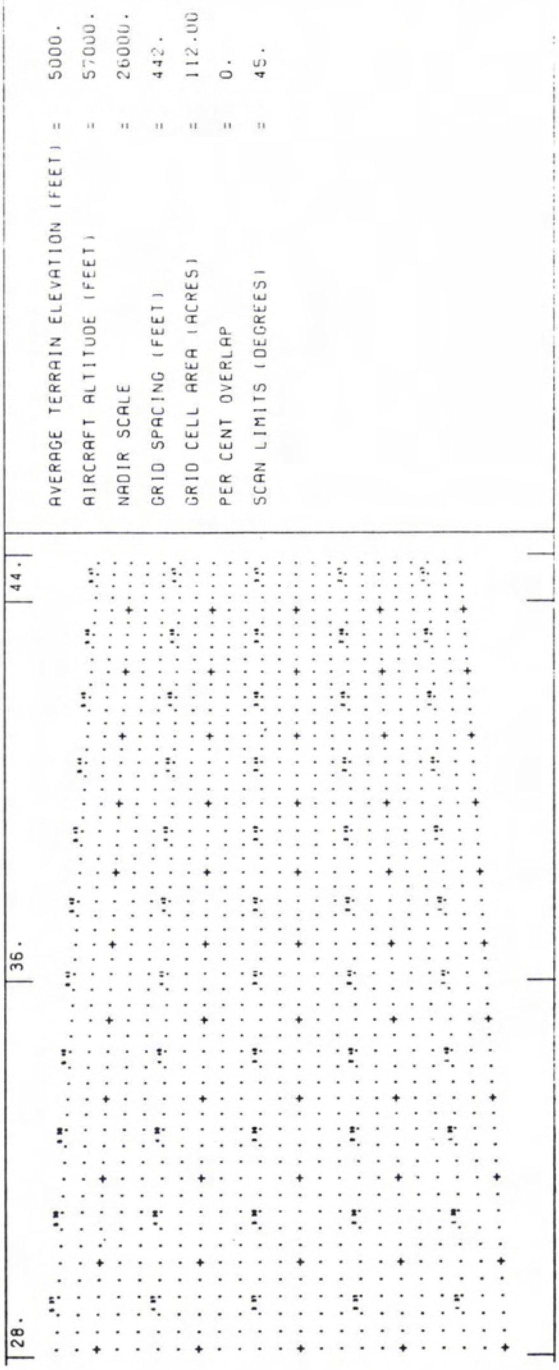

FIG. 1. Example of PANGRID-generated dot grid. Scale information shown is part of the transparent overlay. Numbers in the margin of the overlay indicate degrees of scan from nadir. The marginal ticks correspond to marks in the margin of the photography. Dot spacing decreases as scan angle increases, to compensate for panoramic distortion.

on KA-80A photos using a PANGRID-generated grid.

METHODS

Dot-grid area measurement is a means of estimating area by sampling. Conventional dot grids are transparent overlays having regular arrangements of dots, each dot representing some unit of area at any given scale. The sum of dots lying within a given polygon on a map or photograph, multiplied by the area equivalent of each dot, estimates the actual area of the polygon. Panoramic grids differ from conventional grids in their geometry: dot density increases with scan angle to compensate for scale change. Another difference is that panoramic grids cannot be randomly oriented to a photograph in repeated trials to increase precision of area estimates.

Available photography dictated the location of our study area. We possessed two sets of photos suitable for our intended comparison:

- First-generation duplicate transparencies of color infrared KA-80A panoramic photographs taken 3 July 1979 in the course of NASA-AIRP Flight No. 79-087. The U-2 aircraft flew at a nominal 60,000 feet above sea level. The KA-80A's focal length is 609.6 mm (24 inches), and the camera scans to 60° on either side of the nadir.
- Black-and-white prints from a nominal 1:24,000 scale mission flown for the Clearwater National Forest in August-September 1976. The camera used was a Wild RC-8 with a focal length of 153.08 mm.

These photographs covered a forested area northeast of Moscow, Idaho, with about 2500 feet of local relief. We chose 27 sites for measurement, on the following basis:

(1) Each site had to be wholly depicted on one panoramic photograph, one conventional photograph, and one U.S. Geological Survey 1:24,000 orthophoto quadrangle.

(2) The boundaries of each site had to be definite and observably identical on the 1979 panoramic photo, the 1976 Forest Service photo, and the 1975 orthophotoquad. Most of the selected sites were forest clearcuts; a few were agricultural fields.

(3) Because we expected the scan angle of the panoramic camera to have an important effect on area measurements, we grouped our sites into three sets, corresponding to three regions of panoramic scan: central (0°-12°), midscan (12°-36°), and endscan (36°-60°). These scan regions in turn correspond with the scheme by which KA-80A frames are often divided into 10-inch segments to facilitate handling (Caylor *et al.*, 1978; Befort *et al.*, 1980). U-2 panoramic missions are normally laid out so that nearly all of the endscan (36°-60°) region is in sidelap and redundant. None of our

plots in the endscan region lay beyond 45° of scan; this was the limit of the PANGRID grids available to us.

(4) As we also thought area measurement error might be affected by size of plot measured, the nine sites in each scan region were further subdivided into small (20-50 ac.), medium (50-100 ac.), and large (100-150 ac.) size classes, three of each within each scan region.

The 27 plots were distributed among 21 conventional photographs, 20 panoramic photographs, and 11 orthophotoquads. Each of the sites was measured on its orthophotoquad; an electronic planimeter accurate to 0.01 linear inch and equipped with a magnifying tracing head was used, and the mean of five observations was taken as the true area of a site. The plots were then numbered and outlined in color on the orthophotoquads, to enable interpreters to locate them and to eliminate ambiguity with regard to plot boundaries.

Along each conventional and panoramic flight line, linear photo measurements of objects of known size and elevation (chiefly agricultural fields) were made to determine actual flying altitudes, for conversion of dot counts into acreage. A conventional dot grid and a PANGRID dot overlay of approximately equivalent acreage per dot (about 2.5 ac/dot) were selected on the basis of these measurements. This was the densest PANGRID overlay we could readily obtain. This density of dots (about 40 per square inch for the conventional grid) was considered typical of the sort of grid likely to be employed in practical land management work. Frolov and Maling (1969) show the expected relative error of a conventional grid of this density to be about 3 to 4 percent for plane areas the size of ours. Bonnor (1975) predicts considerably higher errors, on the order of 10 to 20 percent. (Neither of these investigations considered the effects of aerial photographic displacements.)

Three experienced photointerpreters estimated the area of each test plot on standard photography with the conventional dot grid, and on KA-80A photography with the PANGRID overlay. The measurements were made monoscopically, at magnifications selected by the interpreter. Each interpreter made three dot counts on each plot and averaged the result to the nearest tenth; this mean became his estimate for the plot. Few dot counts varied by more than ± 1 dot from the averaged estimate.

Acreage equivalents per dot were calculated for each site on both types of photography, on the basis of average flight line altitude, elevation of the site, and focal length of the camera. Dot counts were converted to acreage estimates, and the differences of these estimates from "true" acreages and from each other were subjected to analysis of variance and paired comparison.

Results

First analyses of variance employed the difference between observed and true acreage as the dependent variable, and involved three main effects and all their interactions:

- "Type of photography." Four categories: conventional (9 by 9 inch), optical bar/center scan (OB-C), optical bar/midscan (OB-M), and optical bar/endscan (OB-E). Sample sizes were unequal, with 27 plots in the first category and 9 in each of the other three.
- Three plot size classes.
- Three interpreters.

Nowhere in initial analyses of variance did interaction terms involving the interpreter come close to statistical significance, so we dropped them from the model, substantially improving its significance. No main effects were found significant at the 0.05 level, but a significant interaction between type of photography and plot size was in evidence. The analysis of variance is given in Table 1, and the interaction is graphed in Figures 2 and 3.

Paired comparisons were carried out to determine which type-size interaction means differed significantly from zero and from one another. Significantly differing means are given in Figures 2 and 3.

Variances of difference from control were compared and their ratios tested by the F-statistic for the four different types of photography and the three different plot sizes. Results appear in Tables 2 and 3.

Conclusions

An interaction of "type of photography" with "plot size" is the only significant effect indicated by analysis of variance. Interaction means exhibit no clear trend when graphed. Significant differences between interaction means are few, and few of the means differ significantly from control.

However, variance comparisons indicate that

TABLE 1. ANALYSIS OF VARIANCE. PLOT SIZE IS THE ONLY MAIN EFFECT WHICH APPROACHES SIGNIFICANCE AT THE 0.05 LEVEL. TYPE × SIZE INTERACTION IS SIGNIFICANT AT THAT LEVEL.

Source	d.f.	SS	MS	F
Type of photo	3	271.53	90.51	1.51
Size of plot	2	282.09	141.05	2.35
Interpreter	2	117.05	58.53	0.98
Type × Size	6	812.43	135.41	2.26*
Error	148	8867.62	59.92	
Total	161	10350.72		

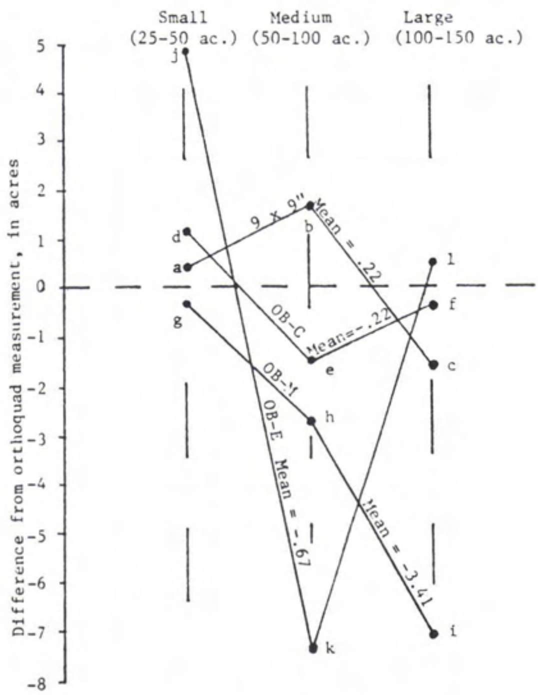

FIG. 2. Type × Size interaction plot. The four over-all type means are not significantly different from each other (Duncan's multiple-range test). Paired comparisons show no differences between type means in small plot estimates. Among medium-size plot estimates, OB-Endscan mean "k" is significantly different from zero and from 9 by 9 inch mean "b." In the large size class, OB-Midscan mean "i" is different from zero and from OB-Endscan mean "l" at the 0.05 level.

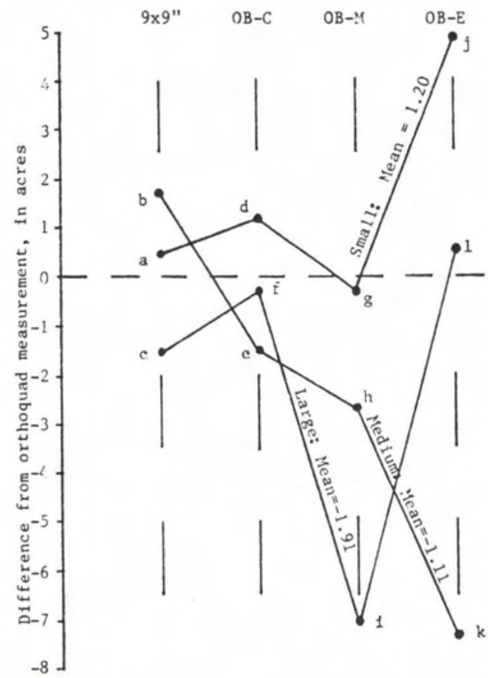

FIG. 3. Alternative graph of interactions for the three plot size classes with four different types of photography. The three size class means are not significantly different from each other. Paired comparisons indicate that OB-Endscan mean "k" (medium plot size) is significantly different from means "j" and "l" at the 0.05 level.

OB-Endscan area measurements are significantly more variable, and therefore lower in precision, than measurements made on conventional photographs or on other sections of optical bar photographs. Dot grid area measurements made beyond about 36° from nadir on KA-80A photography should therefore be treated with some skepticism, limitation in mind. If U-2/KA-80A missions are planned with flight lines about 17 to 18 miles apart (assuming flight altitudes of 60-65,000 feet above ground level), there will ordinarily be enough sidelap to obviate endscan measurements.

It should be remarked that the plots measured in this experiment lay in irregular terrain, and that flat terrain may be expected to improve precision of any airphoto area measurements.

TABLE 2. VARIANCES (s^2) AND VARIANCE RATIOS OF DIFFERENCE FROM CONTROL BY TYPE OF PHOTOGRAPHY. DOUBLE ASTERISKS INDICATE F SIGNIFICANT AT 0.01 LEVEL.

	OB-Center 35.05, 26 d.f.	OB-Midscan 33.06, 26 d.f.	OB-Endscan 202.21, 26 d.f.
9 × 9″ 38.06, 80 d.f.	1.09	1.15	5.31**
OB-Center 35.05, 26 d.f.		1.06	5.77**
OB-Midscan 33.06, 26 d.f.			6.12**

TABLE 3. VARIANCES (s^2) AND VARIANCE RATIOS OF DIFFERENCE FROM CONTROL BY SIZE OF PLOT. DOUBLE ASTERISKS INDICATE F SIGNIFICANT AT 0.01 LEVEL.

	Medium (50-100 ac) 45.01, 53 d.f.	Large (100-150 ac) 125.75, 53 d.f.
Small (20-50 ac) 19.22, 53 d.f.	2.34**	6.54**
Medium (50-100 ac) 45.01, 53 d.f.		2.79**

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