SENSITOMETRIC ASPECTS IN AERIAL PHOTOGRAPHY - A STUDY

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ABSTRACT

The Reports of Planning Commission, Government of India brought out that black & white aerial photography is the most effective tool for data acquisition needed in the fields of Urban & Rural Studies, Oceanography, Water Resources, Cartographic representation, Geology, Agriculture and Forestry. Black & white aerial photography in Indian conditions costing about 0.1% of the total cost of an irrigation project, forms the least expensive part of mapping but the most significant factor contributing towards savings in cost, effort and time. In a good aerial photographic image, all the terrain features of interest appear in distinguishable densities. Densitometry is the practical application part of sensitometry. Results and analysis of sensitometric studies covering the main processing stages in aerial photography are presented in this paper. These studies cover parameters like minimum density, maximum density, average density and contrast. The study includes evaluation of densitometers and rewind processing method with reference to density as a means of image interpretation. Tone reproduction and gradient error curves have been drawn and analysed for negative and positive processes of aerial photography and also in respect of processing stages in orthophoto mapping. The main aim of this paper is to demonstrate the importance and scope of sensitometry at various stages in the process of transformation of terrain luminances into photographic densities distinguishable in shadow areas, as well as highlight areas, the critical part in any aerial photographic mission.

KEY WORDS: Aerial photography, Terrain luminances, Density, Laboratory processing, Sensitometry, Image quality.

INTRODUCTION

The Planning Commission, Government of India constituted Task Forces for specific Application Fields, viz. Agriculture, Water Resources, Forestry, Soil & Land Use, Urban & Rural Studies, Geology, Oceanography & Marine Resources and Cartographic Reproduction of Data in 1982 which addressed themselves to various aspects concerning employment of Remote Sensing Techniques. Another Task Force on **National Natural Resources Information System** was set up in 1984 which drew heavily from the earlier Task Force Reports. According to this Report, submitted in 1988, "At the present stage, aerial photography forms the backbone of gathering primary information which is supplemented by minimum ground verification including semantic information". The report further states "While the application and utility of aerial photography has found wide acceptance by the community of scientists dealing with different disciplines, the newly emerging applications of satellite data has still to be fully appreciated. The presently available Satellite Data because of the limitations on the resolution and the associated Data Processing Techniques can only be used to supplement information derived from the ground surveys and Aerial Photographs" (Planning Commission Report, 1987, 1988).

In Survey of India, the national Surveying and Mapping Organisation, Aerial Photography (B&W) is still the main input source for various types of mapping. In any major irrigation project, the cost of Surveying and Mapping is about 2% and the cost of aerial photography is about 5% of the cost of Surveying and Mapping. Thus the aerial photography which constitutes approximately 0.1% of the total cost of the project, is the least expensive component of the total project. Though its cost is insignificant, the use of aerial photography results in huge savings in effort and money besides ensuring high accuracy as established from surveys based on aerial photography in India during the last several decades. Therefore, black and white aerial photography being economical and a proven technology, will continue to be used extensively for medium and large scale surveys for years to come.

While space imagery has influenced small scale mapping, Digital Systems are influencing the processing and output stages of photogrammetric mapping. Since changes in photogrammetric instrumentation have long time constants it is fairly safe to predict that aerial photography will remain the dominant data source for medium and large scale mapping for foreseen future (Elizabeth A. Fleming, 1984).

SENSITOMETRIC QUALITY

Objects in the terrain receive light rays from the Sun and reflect to the camera in the form of reflectances recorded as densities on the aerial negative which form the basis for further photographic products like diapositives and prints. In good quality aerial photography, all the terrain luminances are recorded in distinguishable densities particularly the features in shadow and highlight areas. In this process of transformation of terrain objects into photographic densities, sensitometry, the science of study of the response of light-sensitive materials to light, assumes vital importance.

The characteristic curve representing the relationship between Log exposure values and the corresponding density values forms the basis for sensitometric studies. The tones of terrain objects with low and high reflectance values recorded in toe and shoulder regions respectively of the curve have the tendency for compression on the negative. The objective of sensitometric monitoring is to ensure that all the scene luninances of interest are recorded on the negative at the appropriate density levels with good tone separations. This assumes relevance in terms of quality of aerial photography as density forms the basis for interpretation of details on the photograph.

It is not possible to achieve the same level of resolving power throughout the image area. In fact, resolving power attains a maximum value in a very limited range of exposure values and resolving power falls for values of low and high exposures. Therefore, the useful range of exposure suffers restriction with increasing demand for better resolution. Thus, the need to use the best and limited part of characteristic curve to ensure optimum resolution.

The sensitometric aspects are being continuously studied in various organisations with a view to optimise the conditions for the production of best quality image in certain given conditions.

Information available with regard to some adopted standards are summarised below:

Reference	Minimum D_{MIN}	DENSITY Maximum D_{MAX}	Range D_R
G.C. Brock (1952)	0.3	1.55	1.25
I.A. Eden (1964)	0.3	1.20	0.9
Stewardson (1978)	-	-	0.70 (orthophoto)
Corten (1986)	0.1 to 0.3	-	-
Graham & Read (1986)	0.4 to 0.6	-	-
Istomin (1961)	0.6 to 1.0	-	-
Gerencser (1979)	0.2 to 0.4	-	-
National Land Survey of Sweden	0.5	1.4	0.9

Aerial Negative is the basic source material for different applications and it has to meet varying demands. Information of the terrain lost at the aerial negative stage cannot be regained in the subsequent stages of processing. Therefore, the exposure should be such that the subject luminances are recorded on the characteristic curve so that the original tonal variaticns are maintained in the final reproduction.

TONE REPRODUCTION CURVES

From sensitometric point of view, tone-reproduction curves provide a practical approach for evaluating image quality objectively at each stage of reproduction and for drawing direct comparison of the final image with the subject. Vissar rightly refers to the attempt to achieve optimum degree of image contrast through a suitable combination of exposure and development as **Curve Engineering** (Visser J, 1980).

As the contrast increases, effective speed of the film also increases as indicated in the results given below in respect of an aerial negative film.

Development Time (Minutes)	$\bar{G}$ Average Gradient	Effective Film speed (ASA)
2	0.21	20
4	0.37	65
8	0.67	88
16	0.94	160
32	1.03	175

In the case of Conventional Photo Mapping, a diapositive is produced initially from the Aerial Negative. In an Ortho-photo equipment, an Ortho-negative is produced from the diapositive. This Orthonegative forms the basis for the production of a final positive.

Considering the need to produce a diazo paper print from the final positive, experiments have been carried out to produce a final positive with a density range of about 0.7 to match the Log exposure range of the diazo paper of 0.8.

Two different standards of Sensitometric processing have been adopted as shown in fig. 1. The standard with a lower D_{MIN} value of around 0.2 was considered as **conventional** and the standard with D_{MIN} value around 0.4 has been referred to as **trial**. Tone Reproduction Curves corresponding to the stages referred in fig. 1 have been constructed as shown in fig.2.

The Tone Reproduction Curves clearly bring out how at various stages of processing different parts of the curve are in use for transformation of terrain luminances into density values. It can be seen that in the 4th quadrant, direct comparison between the final positive and the subject is possible. This type of study helps in determining the appropriate contrast values at different stages with a view to ensure utilisation of straightline portion of the curve. The contrast lost at negative stage can be recovered through appropriate contrast pattern in the toe, straight line and shoulder regions of the characteristic curve.

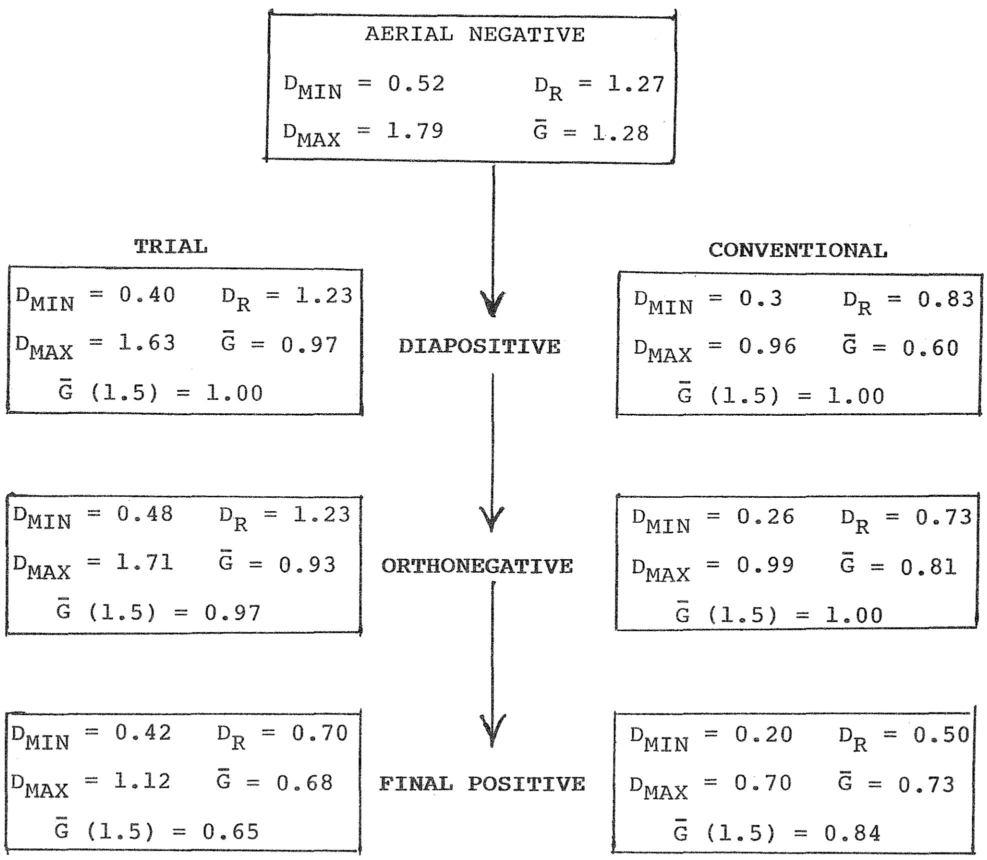

Fig.1 Flow Chart of Reproductions from Aerial Negative

D_{MIN} = Minimum Density; D_{MAX} = Maximum Density

D_R = $D_{MAX} - D_{MIN}$

$\bar{G}$ = Average gradient with reference to points corresponding to D_{MIN} & D_{MAX} on the Characteristic Curve.

$\bar{G}(1.5)$=Average gradient with reference to points on Curve corresponding to D_{MIN} and 1.5 units along E axis.

Note: All density values are inclusive of Base & Fog density.

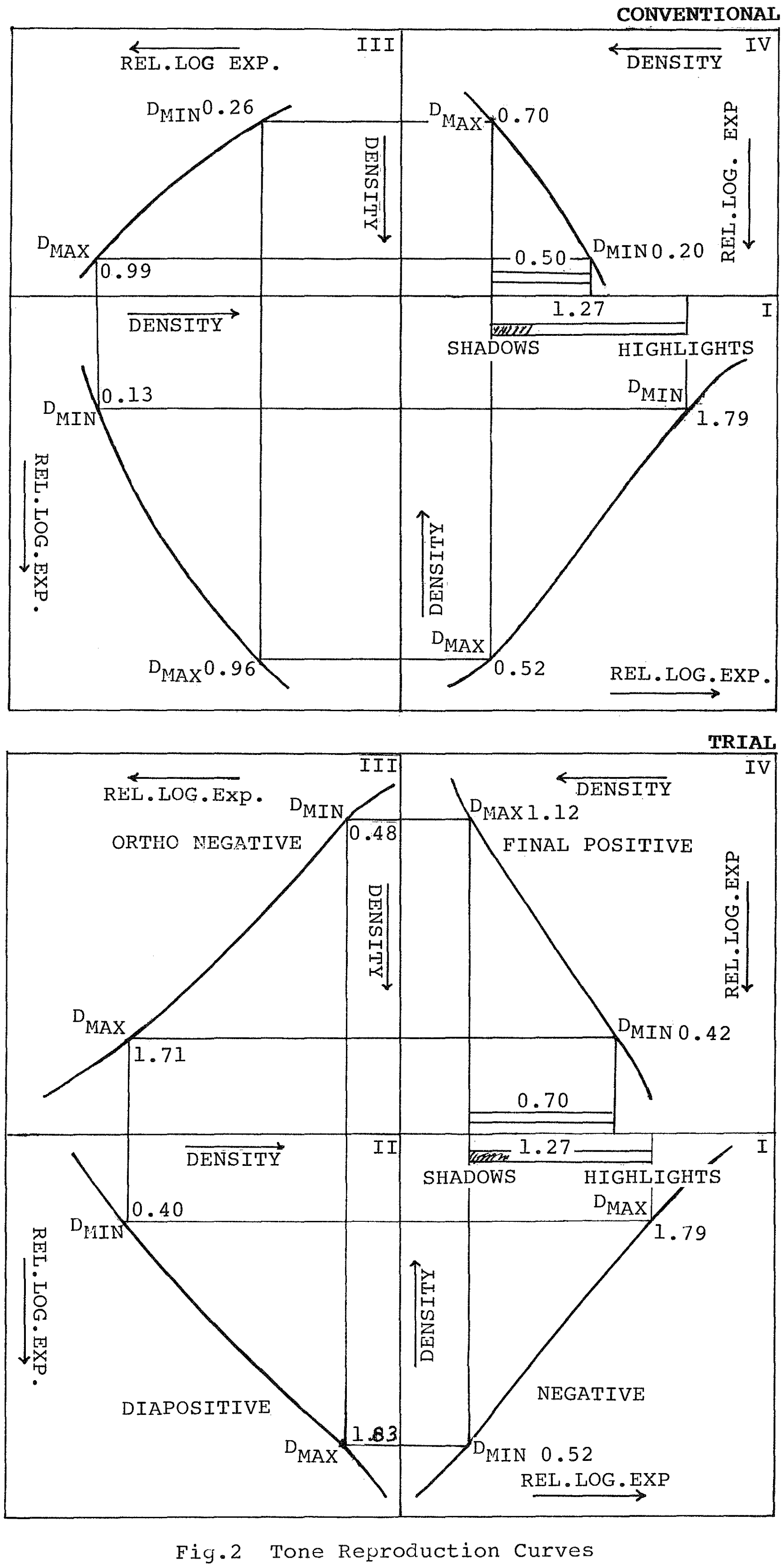

Fig.2 Tone Reproduction Curves

GRADIENT EVALUATION

Through slope product rules, it is possible to choose appropriate slope values at various stages. This type of information is very useful in planning the exposure for any aerial photographic mission. Andres Boberg has drawn Tone Reproduction Curves in respect of aerial photographs having quality score of 7 (very best) and score of 5 & 3 (just acceptable) according to the National Standards of Sweden. Information derived from these curves is summarised below (Andres Boberg, 1988).

The portion of the curve above slope value 1.0 indicates gain in contrast and the portion below represents loss of contrast. It can be seen, in the trial case that the contrast in the range of interest increases and then decreases with a narrow peak. In the conventional case the peak is flattened with loss of contrast. It is obvious that in trial case best part of the curve has been used. Similar observations are derived from the gradient curves for orthonegative and final positive.

Image Quality Score of aerial photographs	Subject Luninance range	Negative		Positive		Gamma Product (N P)
		Density range	Gamma N	Density range	Gamma P	
7 (Best Quality)	0.8	1.3	1.8	1.6	1.6	2.9
5 (Lower Quality)	0.9	1.1	1.1	1.5	3.3	3.7
3 (Quality acceptable)	0.7	0.7	1.1	1.5	3.9	4.4

High Gamma product is obtained for lower quality image. The examination of Tone Reproduction diagrams clearly brings out that, at the positive reproduction stage, in respect of images with score 5 &3, some part of the density range falls in the toe region of the curve below the linear part. This probably is due to under exposure. The author suggests rightly, increased exposure and a shorter development time i.e. lesser contrast for better results.

Numerical values of contrast derived from the Characteristic Curve of each stage provide useful information for sensitometric evaluation. $\bar{G}$ is the average gradient with reference to the two points corresponding to D_{MIN} & D_{MAX} on the Curve. $\bar{G}$ (1.5) is the gradient with reference to the points corresponding to D_{MIN} and the point corresponding to 1.5 units along log E axis. From the data in fig.1. it can be seen that in the **trial** case the values of $\bar{G}$ and $\bar{G}$ (1.5) for all the three stages are more or less same. In the **conventional** case there is significant variation between the $\bar{G}$ values of each stage. This clearly shows that in the **trial** case most of the straight line portion has been utilised whereas in **conventional** case the lower G values indicate utilisation of considerable portion of toe region of the curves causing distortion of density pattern in that region.

Gradients at the points on the characteristic curve corresponding to 0.1 units of intervals on log E axis have been measured and curves constructed between log exposure and gradient values. A_0 B_0 corresponds to subject luninance range. Fig.3 shows gradient curves for diapositives.

REWIND PROCESSING

Continuous processing equipment and rewind processing equipment are in use for processing aerial negative rolls. Density variations produced in rewind processing (Bromide Streamers) can be as large as 0.64 in the high density region in the ends of the film (Kumar G.S., 1976). If upto 9 metres of film is wasted at each end of the roll as leaders and trailers, results can be consistent.

Roller Transport processing is more efficient as it gives even processing results. But rewind processing also is used because of the advantage of its portability. Therefore in sensitometric studies involving laying down standards or analysis of density values, the effects of rewind processing have to be considered, as applicable.

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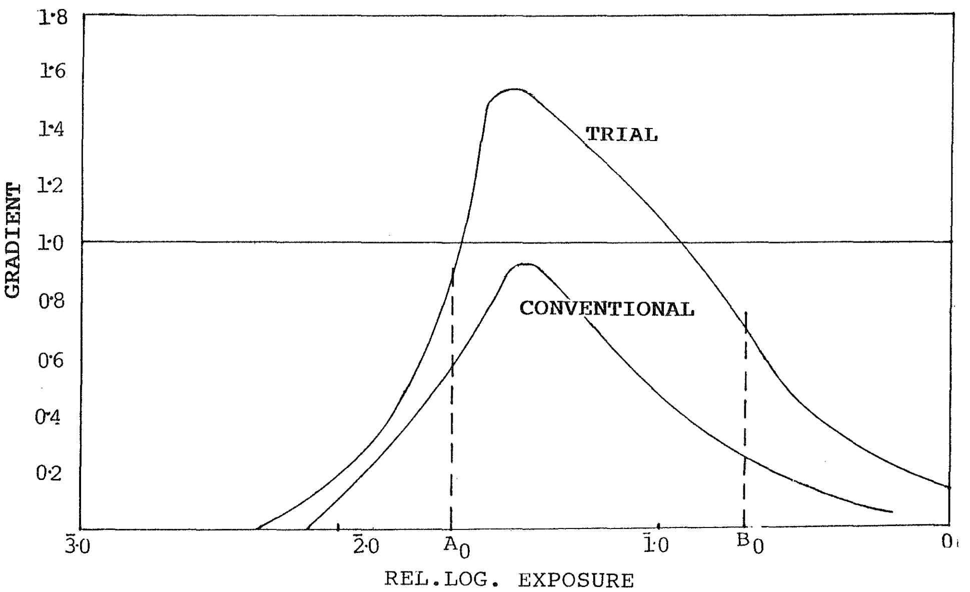

FIG.3 **Gradient curves**