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A PHOTOGRAMMETRIC SOLUTION FOR THE DETAILED STUDY OF EROSION PROCESSES AND LANDSLIDES

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A b s t r a c t

Lengths, surface, volumes a.s.o. of erosional formations and land slides have been repeatedly determined by using sequential aerial photographs of certain areas in three catchment basins; the photographs were taken along 10-15 years.
The evolution rate of the respective processes and the system of indicators required for the land reclamation design and execution were determined according to those very data.
The above mentioned elements were established by using aerial photographs and repeated metric measurements obtained by stereo plotting instruments.
The process employed permitted a superior retroactive analysis of the phenomena in the studied zone, reducing the duration of measurements to a very short time (several months). It showed that the photogrammetric methods are the only able to give a rapid solution for monitoring the process of erosion and land slides.

I n t r o d u c t i o n

The frequency, magnitude and variety of gully erosion in Romania as well as the complex problems raised by its development, suppose the availability of a quantitative indicator system for characterizing the gully evolution according to its stage of development and to its physico-geographical conditions.
In order to establish this indicator system, a more detailed study has been drawn up, referring to the evolution (under untreated and treated regime of the gully systems) formed in a) a relatively homogeneous lithological sublayer; b) altern-

ative permeable and impermeable strata.
The differentiated approach of gully systems, according to the lythological sublayer, is absolutely necessary, because in case of alternative strata the evolutive process of the gully is influenced by the presence of large and frequent bank slides, lateral cutting and slip slopes, land fall of banks a.s.o.
As important areas in Romania's hilly regions are defined just by such alternations, the present paper deals with the methodology of work and with some results obtained in connection with the gullies developed in this kind of lithological stratification.
The means employed so far to establish some indicators concerning the gully evolution are varied: direct measurements of some complex parameters (Thomson J.R. 1970), successive topographical surveys (Biolochev A. and Djingov A.G. 1962, Akiro Murato and Michio Hashiro 1971, Miller C.R. and collab. 1962), the determination of the eroded material volume by semiempirical calculation relations (Gaspar R. and Apostol A. 1971, Stănescu P. and collab. 1977), a.o. The above mentioned methods proved to be difficult, requiring a long time to be performed and their results were only approximate. Therefore, more modern methods based on photogrammetric devices have been used, correspondingly adapted, so as to make up for the defficiencies of classical methods and obtain superior results both qualitatively and quantitatively, in a relatively short period of time and with the least possible human and material efforts.
By processing the aerial and terrestrial photographs taken in the studied sectors (chosen in three important catchment basins with available repeated aerial photographs) quantitative values were obtained of features most significant for the rate of gully evolution and most useful in the design of anti-erosional works, namely for: a) the index of the gully length increase; b) the index of the gully surface increase; c) the index of the gully active area increase; and of the gully volume increase; d) the multiannual average volume of eroded solid material referred to the active area of the

gully, a.s.o.

We should like to mention that the result as regards the increase in accuracy is directly proportional with the time range from the initial to the final photogrammetric recording, to which there were added the recordings taken before and after the starting of some phenomena considerable from a quantitative point of view and as regards the rapid evolution in time.

W o r k m e t h o d

The metric elements required to estimate the indicators were obtained using the following methodology:

1. The available cyclic aerial photographs are analyzed directly and by means of an interpretoscope and the following facts are established for each portion: a) the limits of the zones taken into account by the study; b) the geometric and spectroradiometric range of each aerial photograph; c) the works necessary for photogrammetric processing and for the manner to obtain them (available location works, pairs of photographs working, works for the required aerotriangulation a.s.o.); d) possibilities to render the main geomorphological elements in the basin; e) the plotting scales, necessary, adequate and possible for photogrammetric working; f) the land use mapping; g) the conditions to be imposed for providing the correct superposition of the results obtained after each available cyclic recordings.
2. An orthophotomap is carried out for the studied zones, based on the available aerial photograph and on each individual orthophotomap: a) the sectors relatively homogeneous from the point of view of the main morphometric elements (opening, bottom, width, depth) are delimited; b) the positions of the cross profiles necessary for all analyzed stages are settled.
3. The studied formation is stereo plotted at an adequate scale (1/1000 - 1/2000), according to the most recent photographs (rendering with all attention the talweg, the active and stabilized banks, the prevailing processes).
4. There are read the levels of the characteristic points at

slope change and the tones delimiting the bank active portions or there are materialized the anthropical interventions.
5. There is calculated the value of the evolution rate in the coefficient of deep formation for the most recent recording.
6. The operations mentioned at points 2-4 are repeated.
7. The multiannual average values of the studied indicators (fig. 1, 2 and tables 1, 2) are calculated from the difference of the values proper to the analyzed stages.
8. Considering the results obtained in direct correlation with the determinant agents and factors of the development rate, the deep formations are included in the proper evolution class, establishing at the same time the recommendation necessary to choose the optimum solutions against their erosional development.

The direct analysis of the obtained cyclic photographs in an instrument of the interpretoscope type has allowed:

- the delimitation on the photo-assemblies or on the photographs of the area considered the object to be studied;
- the determination of the stereo photographs to be studied, the identification and the reciprocal transferring on all the different aerial photographs of the available pass and control points, as well as the carrying out of a unitary project aerotriangulation;
- the adoption of a common legend (topographer - specialized researcher - designer) to render unitarily each geomorphological element and also to differentiate their rendering for various stages of the aerial photograph taken for study.
- description in common of the analyzed zone (in general), as well as of the geomorphological elements (especially by the operator who has further provided the photogram stereoplotter and by the specialized researcher). Such a description of the basic available photogrammetric materials, at this stage, has on the one hand permitted an important reduction of the works superfluously stereoplotted, and on the other hand the concentration of the stereoplotting operator's attention especially on elements of strict necessity. This kind of work should be continued during the proper stereoplotting process.

- the determination of the cross profile position and of the size (length), of the kind of numbering them a.s.o. On this occasion the required profiles are located approximately on the photographs from the more recent aerial photographs and are transposed (by an interpretoscope) on the photograms from the other aerial photographs. Then, the position of the supplementary profiles necessary for the photographs from the aerial photographs are chosen, always transposing them on the basic materials.

The photogrammetric methods and proceedings used to work out the aerial photographs, the plotted maps and to mark and read the levelled points according to the aerial photographs employed are the usual ones - current in the specialized literature - but there appear specific problems related to the photographic image (in such cases the expert in photogrammetry should ask the counsel of the researcher he is working for), the provision of a correct superposing of the same product obtained for each stage of aerial photographing, as well as of the further processing of the obtained photogrammetric products (that is why the researcher should work in a close collaboration with the photogrammetrist).

Starting from the above mentioned facts, in the process of orthophotostraightening and stereoplotting, the following itsme were considered according to the various aerial photographs:

- the performance of a unitary work of aerotriangulation for all aerial photographs of a studied zone, based on the common points obtained; a) from determinations in terrain; b) from previous field works; c) from basic aerial triangulation work made for one of the studied aerial photographs, preferably of the one leading to the best association of the works' accuracy with their economicity (photographs at scales between 1/9000 and 1/12000 are most suitable).

In this way there were avoided the differences in rendering on the map some geomorphological elements which in fact have not suffered any modification, or to increase or diminish the modifications undergone by those elements;

- the performance of successive stereoplottings for every

site analyzed at the same scale;
- the use of the same stereoplotting operator when exploiting all the stereophotographs from various coverage for a certainn portion of the studied area. The respective operator has analyzed himself the respective stereophotographs with the specialized researcher and he has continued this comment at the plotting instrument in all situations where he had doubts in connection with the interpretation of the situations he had come across.
- the plotting of the main geomorphological elements (banks, strips, crests a.o.) has been first realized for the photograms derived from the most recent aerial photographs of from the one having the greatest scale (with as few generalizations as possible); wrong interpretation or genralization leading to error should be carefully avoided during the stereoplotting of the other aerial photographs;
- the proper location of all cross profiles chosen on the stereominute obtained by using the most recent aerial photographs or at the greatest scale, analyzing for each individual profile;
- the level reading and point numbering for every profile (the inscriptions for the significant points included), considering that the non-modified or apparently non-modified geomorphological elements should be identified in the repeated peofiles achieved.

C o n c l u s i o n s

The study carried out proves that there are still great possibilities in the field of inter-disciplinary co-operation which is based on rich informational data offered by photographs and the photogrammetric instruments; things are like that because in the case of the problem discussed:
- the correct and efficient solving of the problems related to the adequate development of the gully system supposes the existence of a system of quantitative indices for the estimation of the evolution rate and the methods so far employed for their estimation, proved to be difficult, expensive and of an approximate accuracy;

- the use of photogrammetric products and methods have numerous advantages - they save time, grant a high level of accuracy, they can be used in reconstituting the past situations a.s.o.
- the method proposed in a typical research method which permits the estimation of the volume of solid material eroded by gullies in any other zone, relying only on the surface measured by the most recent photographs and on the average rate of gully evolution, established with the methodology proposed for each characteristic zone of the country. Both from the point of view of the photogrammetrist and of the researcher or expert designer, the finding of correct data can be provided by a direct co-operation of all the concerned specialists along the period of study.

B i b l i o g r a p h y

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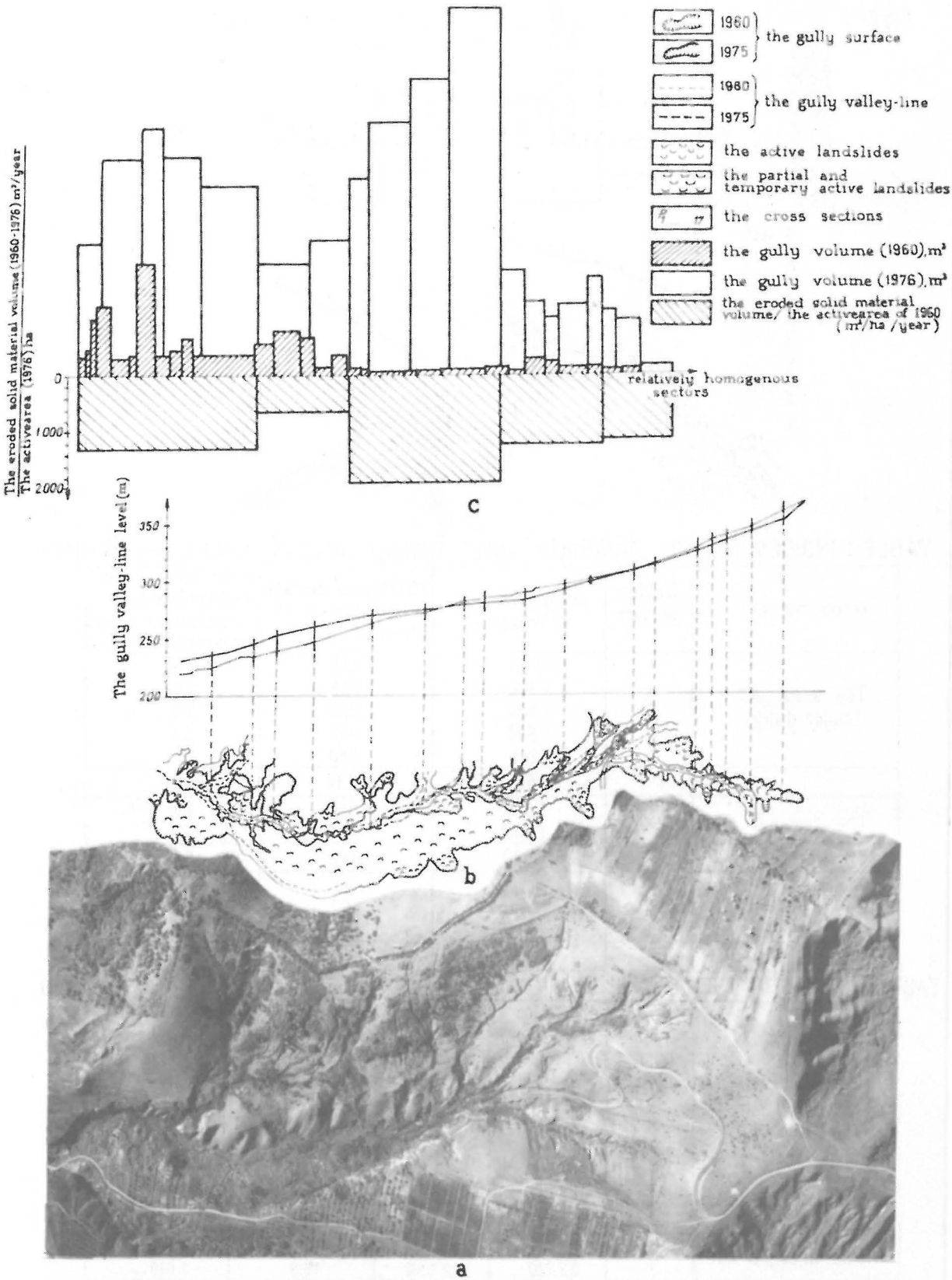

Fig 1 The Tătarului watershed, tributary to the Slănic river from the Buzău Subcarpathians the area „A" (the major gully)

a) the aerial photograph image of the major gully in 1976 ;

b) the orthogonal projection and longitudinal profile of the gully (1 : 2000) based on the aerial photographs obtained in 1960 and 1976 ;

c) the gully volume in 1960 and 1976 ; the ratio between the eroded solid material volume during the 1960-1976 period and the active area of the gully in 1976

Fig.2

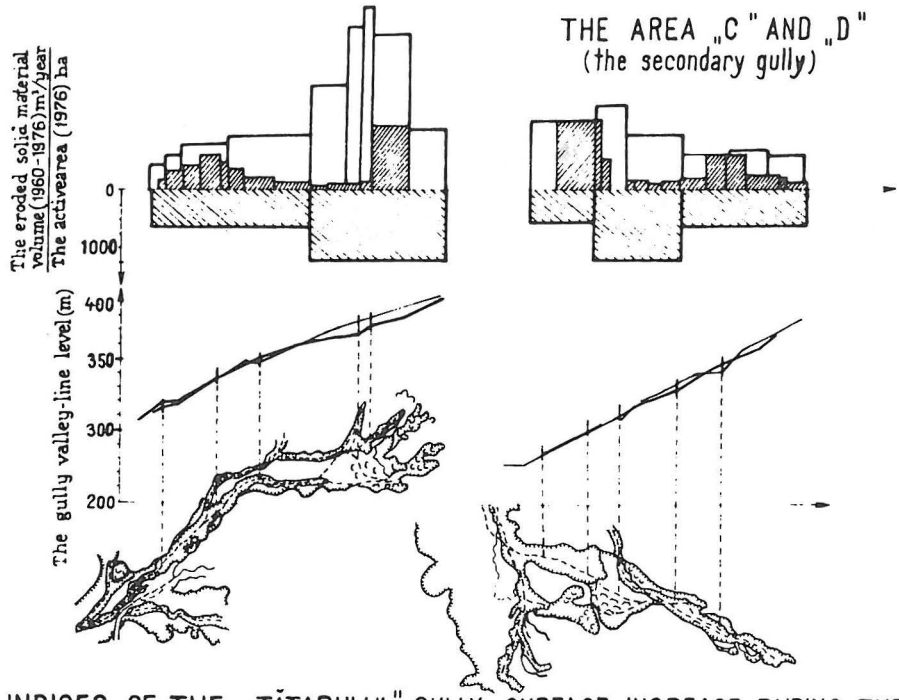

TABLE 1 INDICES OF THE „TĂTARULUI" GULLY SURFACE INCREASE DURING THE $\frac{1960}{1976}$ PERIOD

Area name	Sector number	Gully surface în 1960 (m^2)	Multiannual average rate of surface increase of the gully (m^2/year)	Ratio between the multiannual average rate of surface increase and the length in 1976 $\frac{m^2}{m/y}$
The area „A" (major gully)	1	10.000	2.125	5.6
	2	6.000	1.225	6.7
	3	4.800	1.250	5.0
	4	1.800	437	2.3
	5	1.200	200	1.5
		23.800	5.237	4.6
The area „B"	1	3.600	462	1.5
	2	2.400	600	3.7
		6.000	1.062	2.2
The area „C"	1	3.400	—	—
	2	1.400	362	2.7
	3	3.600	119	0.7
		8.400	481	1.1

TABLE 2 INDICES OF THE „TĂTARULUI" GULLY VOLUME INCREASE DURING THE 1960-1976 PERIOD

Area name	Sector number	Gully volume in 1960 (m^3)	Multiannual average vol. (m^3/year)	Ratio between the multiannual average volume and the length in 1976 (m^3/m/year)	Ratio between the multiannual average volume and the active area in 1976 (m^3/m/year)
The area „A" (major gully)	1	29.862	8.242	21.8	1.303
	2	12.117	2.234	12.3	676
	3	4.332	9.757	38.7	1.927
	4	5.698	2.091	11.0	1.231
	5	1.263	680	5.1	1.152
		53.272	23.004	20.3	1.355
The area „B"	1	10.317	784	2.5	516
	2	23.720	2.546	15.9	1.010
		34037	3.330	7.0	824
The area „C"	1	7.950	230	2.1	478
	2	2.114	764	5.7	991
	3	5.327	262	1.6	515
		15.391	1.256	3.0	714

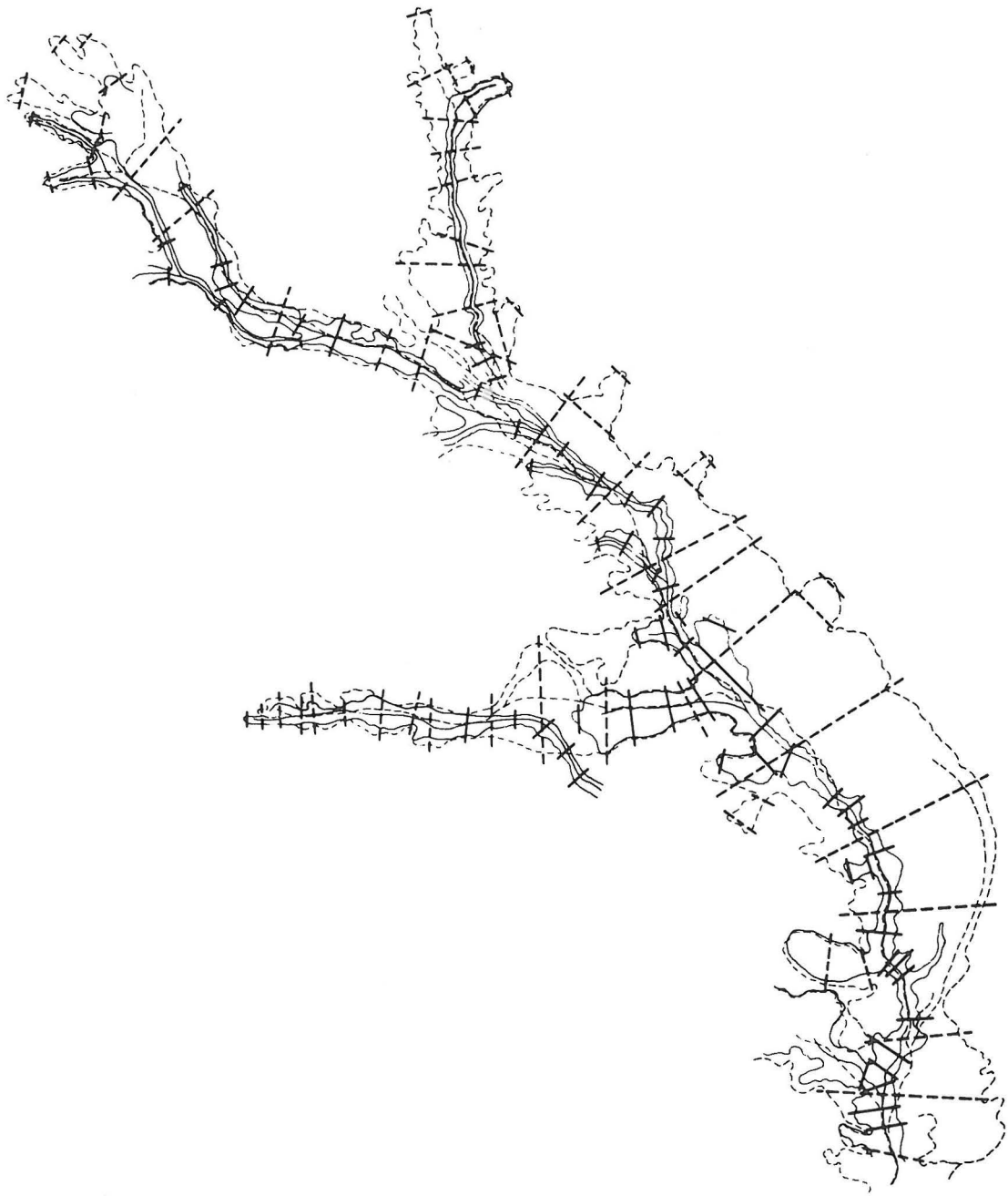

Fig. 3 THE SCHEEME OF THE USED PROFILES

a) ———— FOR THE SITUATION IN 1960

b) - - - - - - FOR THE SITUATION IN 1976