SPACECRAFT IMAGERY ANALYSES

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Abstract

The new method of the author described in the paper, allows the following of the changes in space-observations. Between 1983—86 a dynamic land register of settlements air contamination of the total Hungarian territory has been prepared in a 10 years time base.

Introductory ideas

Now we are in the third year of the fourth decade of the Space Age. Recent years have seen an expansion of fundamental research and development of devices for and methodical studies on the remote sensing by means of Earth satellites on global scale and activities have started on the development of human oriented application systems. A starting point for investigations run by NASA and other international space agencies is the fundamental concept on the Earth as a dynamic system of biochemical circulation (biosphere). Basis of this system is the interrelationship of processes and phenomena, therefore it cannot be described solely by static, discrete data. An aim was set to reveal these basic interactions and describing their characteristics, by the end of the 20th century. A further task is the elaboration of research methods and analysis of their capability as to providing complex and up-to-date information on the dynamic terrestrial system. Necessary scientific knowledge, as it has been advocated by international recommendations, should be gained with a coordinated processing of data contained in global statistics and those extracted from digital information and imagery produced by orbital remote sensing. More exactly, a complex investigation into the dynamics of the different global models can be implemented by multithematic analyses of satellite images, their interpretation and subsequent mapping of the information acquired. On the basis of data returns orbital information can be drawn and its interpretation might be instrumental in building up information systems. Analysis of orbital data is carried out, local issues are studied on aerial photographs and data validation is performed using ground measurements and other reference data.

Indications identifiable on satellite imagery

Based on references from international literature on remote sensing and also on the experience gained during our own research a conclusion can be drawn that owing to the hyperaltitude imaging (from 200 km up to 36.000 km) orbital data acquired can be exclusively related to purposes of the "general analysis", according to the present day practice. It means determining certain parameters for countries, one country or a region within them.

Also according to international ventures, orbital observations provide indirect information on the solar radiation, the atmospheric situations, the Earth surface including waters, biomass, social and societal changes and neotectonic movements. Through these indirect signals a trend in the dynamics of the above listed phenomena can be traced. Simply saying, space imagery contains indications on the presence, abundance or absence of the selected phenomena and their distribution within an area in concern and also on the permanency or spatial and temporal changes of their state within the studied region.

Indirect features of images that can be instrumental for investigations of the above trends are called in the literature "indicator" phenomena. Conclusions drawn from our own investigations are formulated below. Indicator phenomena may differ in space, in time and in forms of appearance.

An overwhelming majority of changes (60—80 per cent) is rapid. A smaller proportion of them brings about slower progressing alterations. The most rapid processes are the ones occurring in the atmosphere and especially at low altitudes. Based on remotely sensed data returns global horizontal distribution of all observable phenomena and their temporal change e.g. atmospheric degradation of urban (industrial and transport) origin i.e. air pollution can be registered. Atmospheric phenomena such as air pollution, however, change instantaneously, that is why their survey should be accomplished on a comparative basis. The permanent or changing character of air pollution can be easily traced on multi-temporal images including areal coverage and its alterations. Changes of the surface waters within drainage systems, as velocity concerns, are basically similar to those of atmospheric phenomena and might be considered as image elements identifiable with high accuracy. Water surface, absorbing a significant amount of radiation, usually appears on the returns in dark tones and colours or blue, when it reflects the colour of the sky.

Very well traceable and somewhat in a simpler way recognizable changes are represented by seasonal variations of the biomass. Usually studies refer solely to the instant (at the moment of imaging) plant canopy because mass of grass, scrub and foliage levels are changing quickly as both the spatial arrangement and vitality are concerned. Vegetation cover type can be identified on space images with an accuracy of 80—90 per cent.

Next to vegetation cover interpretation proceed soil cover classification and study of denudational surfaces appearing in the form of image pattern variations.

Changes occurring on the surface can be both of natural origin (erosion, deflation or sedimentation, solar erosion) or artificial ones (technogenous impact, effect of land cultivation, transport, industry, mining, urbanization) such as open-cast mines, quarries, waste heaps, garbage disposal sites etc. An overwhelming part of the unfavourable changes occurring on the surface decreases the initial quality of the soil cover and they are called surface scars. These objects can be identified on any image of high resolution and taken in spring time, with a probability of 80—90 per cent.

Another major group of changes of man-made origin found on the Earth surface are e.g. the transport network and settlements, industrial plants which can be well recognized and make up the system of slowly altering phenomena. Their identifiability depends on the season of imaging, on snowy winter returns reaching 90 per cent, but during high vitality of vegetation it hovers between 35 and 40 per cent (as hidden by plant canopy). This group of elements together with the earlier mentioned vegetation, corresponds to the contour features on the base (topographic) maps.

On the space images, taken from considerable altitudes, owing to minor values of relative relief, landforms, although showing "monocular plastics" cannot be used for determining surface altitude data or for tracing contours. However, geological, geomorphological or orographic features such as lineaments, circular structures or systems of neotectonic fault lines etc. can be identified by highly qualified experts on interpretation. In other words, it is possible to recognize these phenomena, primarily using inverse interpretation.

Among the slowly changing features should be mentioned physico-geographical landscapes and areas of nature conservation, which can be delineated with a 95 per cent accuracy.

Finally, man-made objects serve as reference data for establishing a linkage between ground truth and remotely sensed data returns. These are the common elements encountered on images and reference maps which practically do not change their position, primarily airfield runways, sludge disposal sites, artificial lakes, dams and canal systems with concrete foundation. Existing topographic and thematic maps are applied for conjunction to geodetic network using the method of inverse interpretation (identical fields). Here mention should be made of phenomena disturbing spacecraft remote sensing. These are clouds and their shades which are frequently present on the images. Often encountered are fog, smoke, local haze caused by cloud formation and air pollution.

Summing up, data, identifiable on the basis of spacecraft image interpretation can be subdivided into:

— group of unstable (rapidly changing) elements (atmosphere, waters, vegetation, surface scars);
— group of stable elements: man-made features (transport system, settlement network, industrial objects) and those showing relatively slow variation: relief, physico-geographical landscapes, natural reserves etc.

From geodetic viewpoint the above two groups should be considered as those corresponding to observations of different weight.

The general content of imagery is shown by Figure 1 having been arranged into an information tree. Also figures 2, 3, and 4 contain information trees constructed from phenomena which are subject to rapid, seasonal and slow changes, respectively.

Interpretation of spacecraft images should be promoted by preparing and applying clues which include elements of the information tree associated with the general imagery contents.

Remote sensing of air pollution

Methods of passive remote sensing from satellites make it possible to monitor the global horizontal distribution of air pollution. Medium- and high resolution imagery taken by the Earth research satellites have been providing regular data on changes of the general characteristics of the atmospheric environment including those brought about by man-made impact. Spatial and temporal alterations in the state of the atmosphere can be observed and traced since 1972.

Methods for remote sensing of air pollution were elaborated considering the logical analogies of filtering effects based on aerial surveys of photogrammetric imaging, i.e. filters hold back the effect of atmospheric degradations. Actually, the recognition of applicable methods was the result of previous practical experience.

In the course of mapping-oriented analyses of remotely sensed space images and classification of image patterns related to cartographic content, revealed that among the various anthropogenic features 70 to 80 per cent of the settlements, 50 to 70 per cent of the main traffic lines and 40 to 60 per cent of industrial and mining zones were veiled by hazy, opaque masks. Multi-temporal (multi-seasonal) observations showed that this veil varied as to its spatial extent, density and colour (on the composites). A great variety of colour indications could be found on the images such as the spatially altering, semi-transparent deep-blue blurs, the strongly masking blackish-grayish spots or the lacteous light-blue bubble-like forms. Due to these phenomena the built-up area of settlements could be clearly identified for mapping. These experiments were continued to gain empirical knowledge by overcoming several

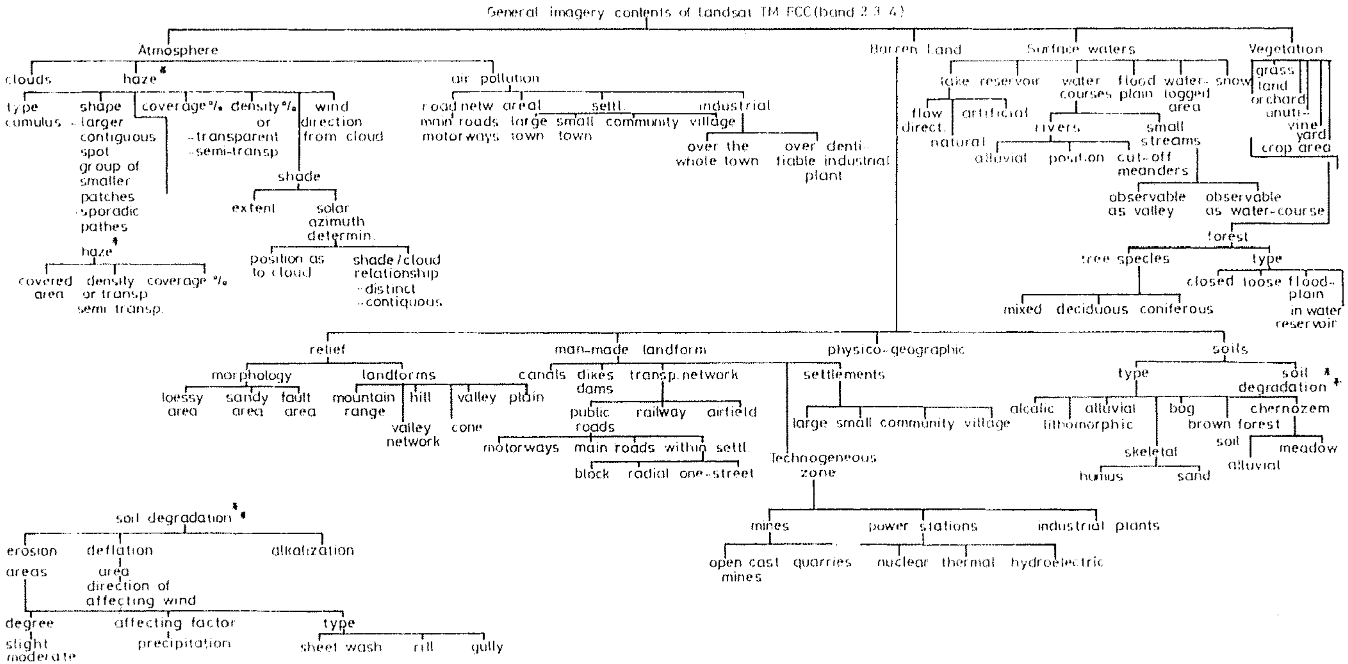


Fig. 1. **Phenomena statistically observable by Earth research satellites**

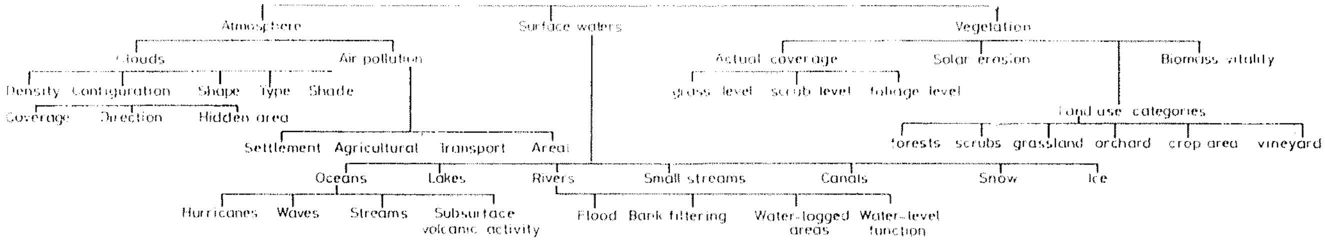


Fig. 2. Rapidly changing phenomena observable by Earth research satellites. Original scales: Original scales: $M_{picture} = 1 : 1\ 000\ 000$; 1 : 400 000. Enlargements: M = 1 : 150 000

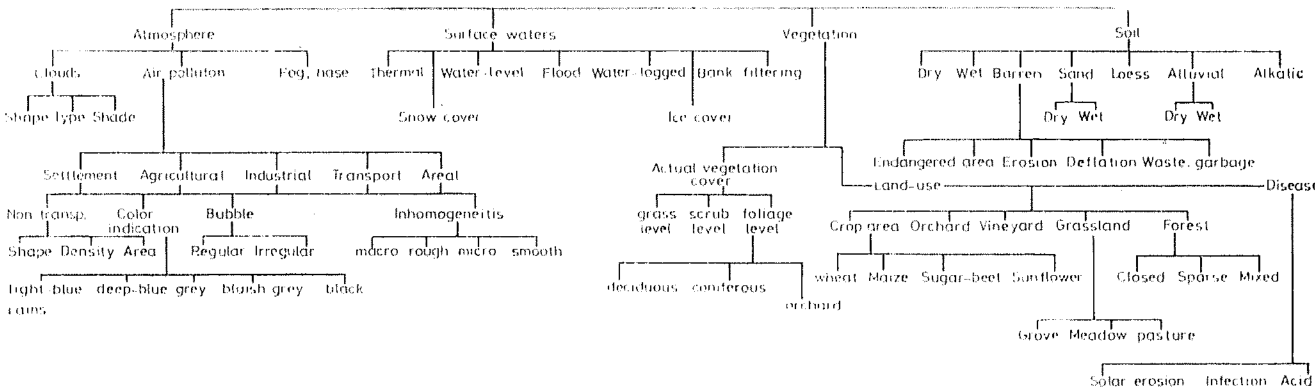


Fig. 3. Seasonally changing phenomena observable by Earth research satellites. Original scales: $M_{picture} = 1 : 1\ 000\ 000$; 1 : 400 000. Enlargements: M = 1 : 150 000

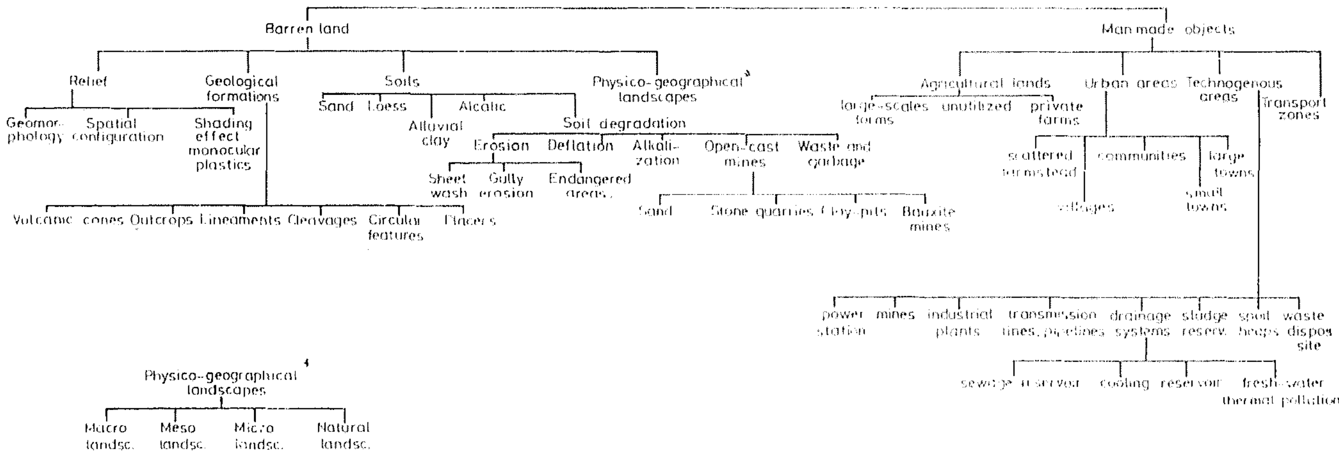


Fig. 4. **Slowly changing phenomena observable by Earth research satellites. Original scales: $M_{picture} = 1 : 1\ 000\ 000;\ 1 : 400\ 000$. Enlargements: $M = 1 : 150\ 000$**

failures and blunders by the end of the 1970s and in the beginning of 1980s. The eight-year-long practical interpretation has resulted in a suitable and economically effective technology for the remote sensing of air pollution.

The experimental phase lasted nearly 4 years, during which three researchers dealt with this topic regularly. The operative phase of the work started 3 years ago. Its main result is the survey of the dynamic state of air pollution over the settlements of the country for a 13 year time span, based on the interpretation of images taken by Landsat 1—5 missions. At present remote sensing of air pollution caused by industry and transport is dealt with, afterwards the air polluting effects of agriculture are to be interpreted. Below the steps of the actual work are outlined.

After an extensive and careful evaluation of satellite images of various type and scale related to image pattern and information bearing capacity focused on the recognition of air pollution, an image scale of 1 : 150 000 was selected for interpretation and elaboration since by that means maps and geometric references were available in the form of county maps. A survey of the base materials revealed that Landsat images produced by the Italian receiving station proved to be more suitable for air pollution interpretation than those of American origin. As far as the seasonal features of the images are concerned it proved to be expedient to choose a winter MSS series, possibly showing snow cover and a false colour composite from a contrast enhanced negative, printed on glared or semiglared paper. Comparison of a May image with an August one of different years and their analysis can also be instrumental. Air pollution of a given area (city, settlement or industrial zone) can only be defined as permanent or altering based on the multi-temporal (and multi-seasonal) interpretation of the images. The best materials for interpretation are the "composite mosaic maps" of counties. All the settlements and industrial zones must be identified and registered by applying the theory of convergency of evidency. Areas can be classified into five major categories, such as:

- severely polluted (reference base: Budapest)
- heavily polluted (reference base: Vác and the Tata Basin)
- moderately polluted (e.g. Gárdony, Pusztavám, Fertőszentmiklós)
- slightly polluted area (e.g. Petőháza, Sopronkövesd)
- no pollution observed (e.g. Dömös, Vértessomló).

The final product drawing is carried out on a transparent overlay fixed on the composite mosaic. Various solutions for drawing have been elaborated. The simplest is the so-called guide contour cover. Settlements are registered on the overlay from the county map and the different settlement types marked with characters of different size according to the mapped area. This reprocessed overlay is placed then on the composite mosaic of the county and the evaluation and classification is performed. Results are tabulated in an alphabetic list of settlements (numbers or indications of the evaluation).

In this way using a single guide contour cover several images taken at different times can be interpreted. The disadvantage of the method is that the areal parameters of the air pollution cannot be determined.

Somewhat more complicated but from the standpoint of mapping a more valuable method is the following: variations of tones and texture of the space image are delineated on the overlay fixed on the composite mosaic, thus the visible air pollution above settlements or industrial zones is registered and, if there is no pollution, contours of the built-up area can be identified. Various surface symbols can be used to mark the extent of pollution on the overlay and it is possible to sum up the classification in form of tables as well. The territorial parameters of air pollution can be defined and also the alterations of the density of pollution above given areas.

It has to be noted that before making decision in favour of the rather labour-intensive visual interpretation method, the processing by analogue instruments and the digital image processing techniques were also tested. The analogue method is perfectly suitable for interpretation (using stereometrograph) with a map as a final product, but the interpretation, evaluation (classification) and the registration of results in tabulated forms still have to be performed following the instrumental processing. Most unfavourable experiences were gained during the digital interpretation. The varying density and chemical composition of air pollution, the location and structure of settlements, the impact of the vegetation canopy and the occasionally present industrial plants make the effective identification of settlements or the air pollution above them practically impossible when using digital image processing. Below some of the conclusions of the analyses of air pollution are summarized.

Air pollution above settlements, and also caused by transport and industrial activity can be recognized on colour and black-and-white imagery using the following methods:

- through identification of colour indication or alteration, occasionally discolouration,
- through changing in image texture (the built-up areas of settlements differ from the outskirts due to a more grainy pattern),
- identification on the basis of the bubble-effect (the warm, polluted air over settlements forms a glass-ball like cover hanging, above the built-up area; a circular spot can be observed),
- the identification of settlements is expedited by winter, snowy images, where the road network of settlements or industrial plants are clearly recognizable as a spider web formation, the core of settlements or industrial

zones being much warmer than their environment. In photogrammetric terminology it is called "radial pattern".

The expert on interpretation should be able to recognize the differing colour indications of physical conditions on the Italian and American image products. Colour indications of settlements on Landsat 1, 2 and 3 images are very much similar to those on false colour infrared air photos, namely from light blue to deep-dark blue all tones can be found, depending also on the season. Since 1985 the colouring of the American Landsat MSS colour composites is consistent with the colouring system of imagery, acquired from the Italian receiving station. On these images the air pollution of settlements appears in black, dark grey, bluish grey, violet-blue, purple and pink colours. The scale of images produced by the Swedish receiving station is also different, but closer to the Italian system. Interpretation of the high resolution Landsat 5 TM images is more complicated than that of the MSS imagery.

The recognition of settlements and industrial plants is greatly influenced by terrain configuration. In mountain areas it is mostly possible based on colour tonality, while on flatlands it is the structure that promotes identification. The moderately polluted or non-polluted settlements can only be located by the use of topographic maps, and subsequently their pollution be evaluated. It means that the appearance of settlements or industrial plants on the remotely sensed images (colour or grey-scale tones) depends upon air pollution. In our experience there are no general rules determined for air pollution interpretation since each remotely sensed image bears different features.

The contour cover interpretation revealed that the area of air pollution appearing on the images in often more extensive than the mapped size of the settlements or industrial plant. The scale of discolouration is varied above heavily polluted large cities or industrial zones, for the saturation of pollution is also inhomogeneous. The different degrees can easily be separated and mapped. Generally speaking, the cores of settlements are more polluted and the enclosed industrial zones can also easily be identified.

Finally, some information will be given on the time consumption of interpretation work. For example, the interpretation of satellite images of Pest County, comprising 179 settlements for three different dates, lasted one month for one researcher. It is necessary to mention that during the experimental phase three researchers worked independently on the same area, and the final results were extracted from their evaluations showing identity.

Based on the interpretation of space images a general overview of the horizontal distribution of air pollution could be obtained to complement the information provided by the less than 200 measuring stations over Hungary. Since there are nearly 3000 communities in Hungary, the measuring network provides information only about 6 to 7 per cent of them. The implementation

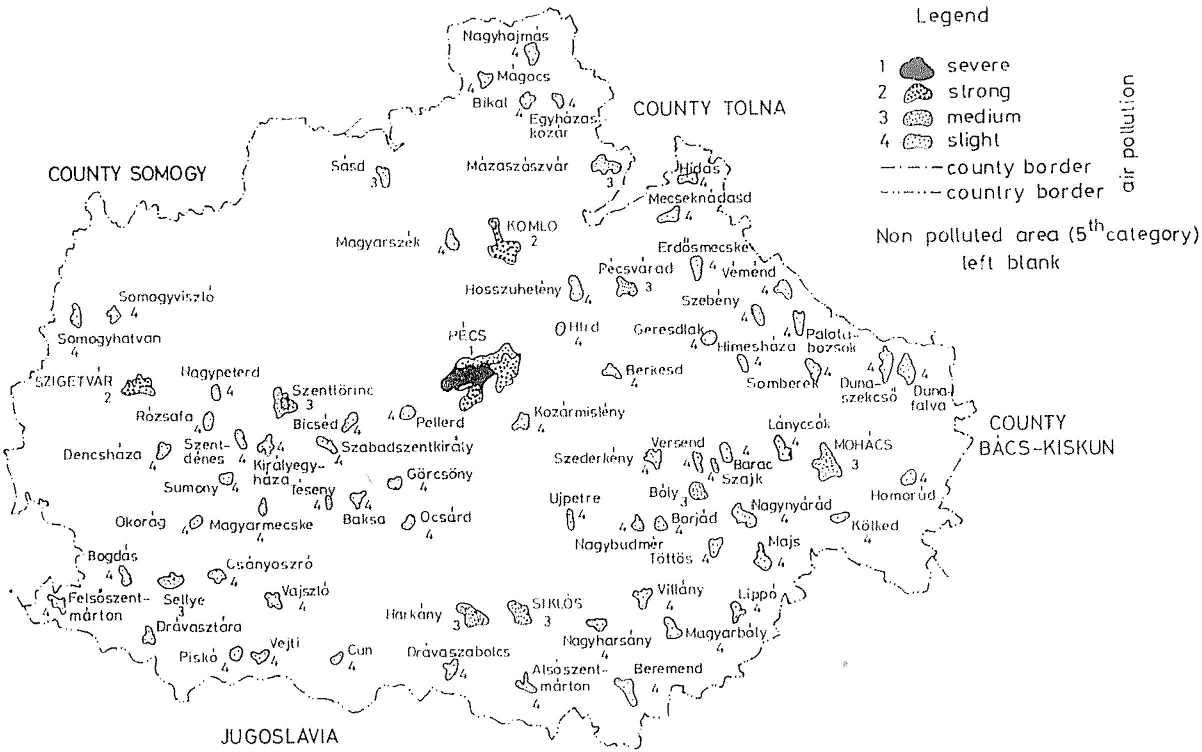


Fig. 5. **County Baranya. Air pollution map on the basis of LANDSAT-MSS imagery Compiled at the Dept. of Photogrammetry Institut of Geodesy BTU, in 1986. Project leader: Dr Mária Domokos, associate prof. Interpreted from Landsat-TM 188-28/1, 188-28/2, 188-28/3 188-28/4, images taken on 04.04.1985.; Geometric reference based on the county map at scale 1 : 150 000**

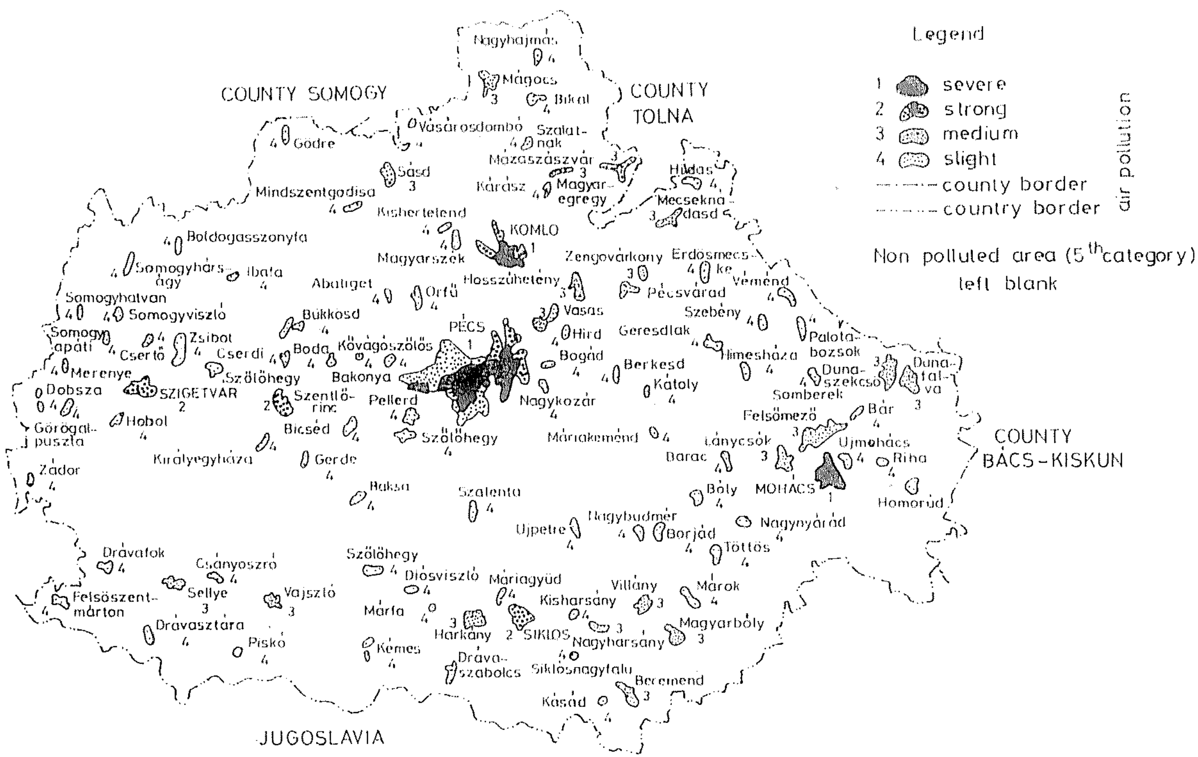


Fig. 6. County Baranya. Air pollution map on the basis of LANDSAT-TM imagery (FCC) M = 1 : 500 000. Compiled at the Dept. of Photogrammetry Inst. of Geodesy BTU, in 1986. Project leader: Dr Mária Domokos, associate prof. Interpreted from Landsat-MSS image taken on 23.02.1978. Geometric reference based on the county map at scale 1 : 150 000

Fig. 7. County Pest. Air pollution map on the basis of LANDSAT-MSS imagery M = 1 : 500 000. Compiled at the Dept. of Photogrammetry Inst. of Geodesy BTU. in 1986. Project leader: Dr Mária Domokos, associate prof. Interpreted from Landsat-MSS image taken on 22.02.1978. Geometric reference based on the county map at scale 1 : 150 000

of a complete network would cost 2 to 3 hundred million forints, and its operation nearly as much.

The cost of the interpretation work on satellite images for a 13 year time span has amounted to 7 to 8 million forints. It can be repeated each year for the whole country with an expense of 2 to 3 million forints. Expenses have been covered jointly by the National Committee for Technical Development,

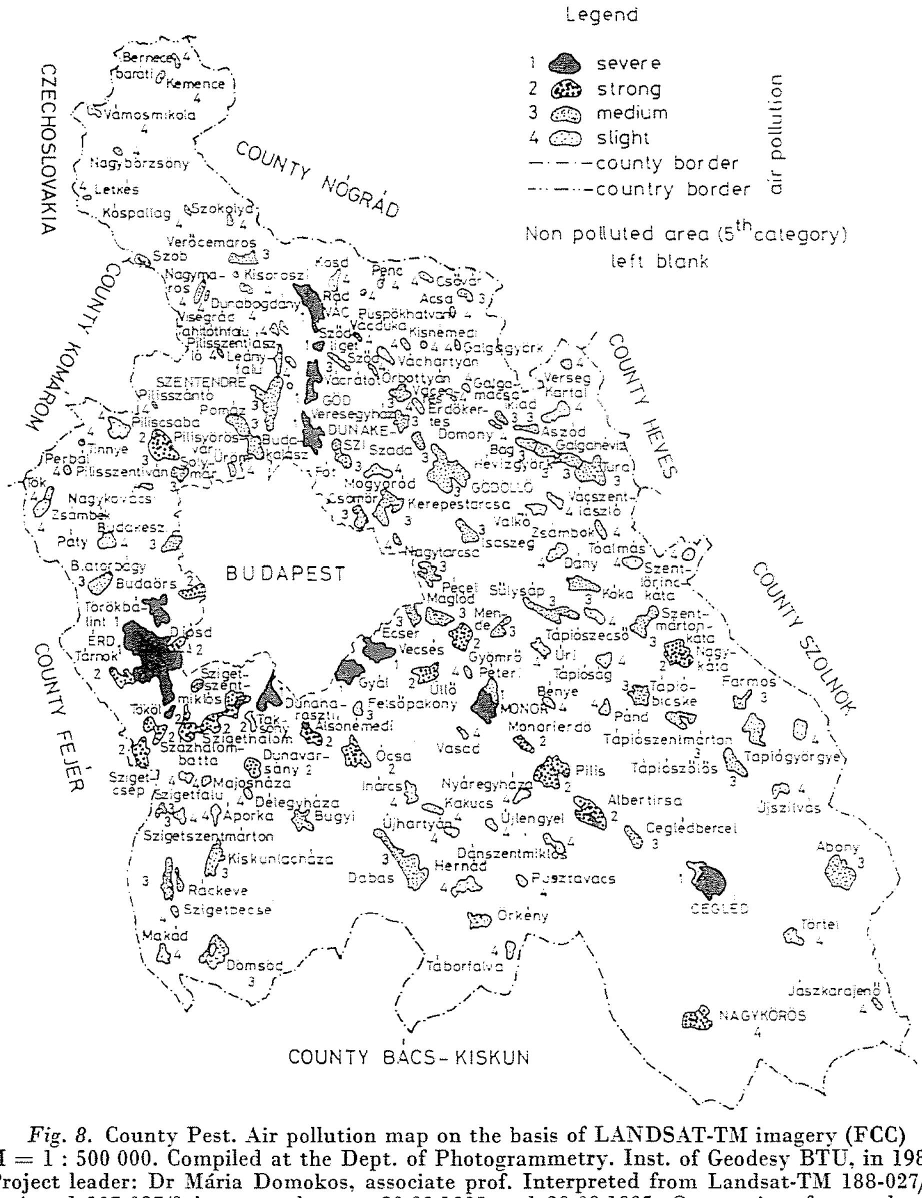


Fig. 8. County Pest. Air pollution map on the basis of LANDSAT-TM imagery (FCC) M = 1 : 500 000. Compiled at the Dept. of Photogrammetry. Inst. of Geodesy BTU, in 1986. Project leader: Dr Mária Domokos, associate prof. Interpreted from Landsat-TM 188-027/1, 2, 4 and 187-027/3 images taken on 20.09.1985 and 20.09.1985. Geometric reference based on the county map at scale 1 : 150 000

Table 1

A irpollution survey in Budapest based on Landsat imagery

District	Date of imaging										
	31.10. 1973	18.11. 1973	22.02. 1978	12.04. 1979	13.09. 1979	27.10. 1979	06.02. 1981	14.03. 1981	06.04. 1982	04.04. 1985	27.02. 1986
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
I.	2	2	2	2	3	1	2	2	3	2	3
II.	4	4	4	4	4	4	4	4	4	3	1
III.	4	4	4	4	4	3	4	3	3	3	3
IV.	3	3	2	2	3	2	2	2	2	2	3
V.	1	1	1	1	1	1	1	1	1	1	2
VI.	1	1	1	1	1	1	1	1	1	1	1
VII.	1	1	1	1	1	1	1	1	1	1	1
VIII.	2	2	1	1	2	1	1	1	1	1	1
IX.	2	2	1	2	1	2	2	2	1	1	1
X.	3	3	3	2	3	2	2	2	2	2	2
XI.	4	4	2	4	3	2	3	4	3	3	2
XII.	4	4	4	4	4	4	4	4	2	3	3
XIII.	3	2	1	2	2	1	2	2	2	2	1
XIV.	3	3	2	2	3	1	1	2	4	2	1
XV.	3	3	3	3	4	3	3	3	2	2	2
XVI.	4	4	4	3	4	4	3	4	3	3	2
XVII.	4	4	4	4	4	4	4	4	4	4	4
XVIII.	3	3	3	3	4	3	4	3	3	3	2
XIX.	2	2	1	2	3	1	1	2	2	1	1
XX.	4	3	3	3	3	2	4	3	2	2	2
XXI.	4	4	2	3	3	2	3	3	2	2	1
XXII.	4	4	4	4	4	4	4	4	4	4	4

the Budapest Technical University and the National Office for Environmental and Natural Protection and also in the framework of research projects.

Thematic maps and tables summarizing the results achieved through investigations carried out for some counties are shown on the following pages.

Air pollution survey of Budapest based on landsat MSS imagery for the time span between 31.10.1973. to 27.02.1986.

Data acquired through the survey based on space imagery interpretation are summarized in Table 1.

From the evaluation of the data the conclusion can be drawn that Budapest (with more than 2 million inhabitants) was the most severely polluted settlement of the country over the time period investigated.

Pollution burden is changing with districts. Air quality was the lowest in districts V, VI, VII and VIII. The situation was somewhat better in districts I, IX, XIII, XIV, XIX. The next class was represented by districts IV, X, XXI, XV, XVIII. Districts II, III, XI, XII, XVI, XVII, XXII. were classified as slightly polluted.

Table 2

Dynamic data as results of air pollution survey based on space

	Date of imaging					
	22.02.1978					
	Administr. area (square km)	Number of settl.	Percent. polluted settl.	Areal correct. (square km)	Polluted area (square km)	Percent. polluted area as of county area
1. Severely polluted	61.6	1	0.3	—	61.6	1.4
2. Heavily polluted	7.4	1	0.3	—	7.4	0.2
3. Moderately polluted	38.8	8	2.7	+0.9	39.7	0.9
4. Slightly polluted	87.7	66	22.3	+5.9	93.6	2.1
5. No pollution found	130.1	220	74.4	—	—	—
Total	325.6	296	100.0	+6.8	202.3	4.5

Number of settlements investigated: 22.02.1978: 296 pieces, 04.04.1985: 296 pieces
Percentage administrative area of settlements as to the total area of the country: 7.3%

Table 3

Baranya County
Percentage area by pollution classes

Date of imaging	Air pollution classes					Settlement not interpretable	Number of settlements
	Severe	Heavy	Moderate	Slight	No pollution found		
22–23.02.1978 MSS	1	1	8	66	220	—	296
13.04.1979 MSS	2	1	1	25	267	—	296
13.09.1979 MSS	1	1	1	19	273	1	296
07.04.1981 MSS	3	—	4	27	243	19	296
06.04.1982 MSS	2	1	2	30	261	—	296
04.04.1985 MSS	2	1	3	31	259	—	296
04.04.1985 TM	3	3	18	67	205	—	296
14.09.1986 TM	3	2	9	14	66	172	296

magery Summary of multitemporal data County Baranya

	Date of imaging					
	04.04.1985					
	Administ. area (square km)	Number of settl.	Percent. polluted settl.	Areal correct (square km)	Polluted area (square km)	Percent. polluted area as of county area
1. Severely polluted	83.0	3	1.0	—	83.0	1.8
2. Heavily polluted	13.6	3	1.0	+0.4	14.0	0.3
3. Moderately polluted	39.9	18	6.1	+1.9	41.0	0.9
4. Slightly polluted	77.2	67	22.6	+3.8	81.0	1.8
5. No pollution found	111.9	205	69.3	—	--	—
Total	325.6	296	100.0	+6.1	219.8	4.9

Percentage polluted area as to the total area of the country: 4.7% (average value)
Number of settlements within the county: 296; administrative area: 325.6 km²

Table 4

Baranya County
Percentage area by pollution classes

Date of imaging	Air pollution classes (%)					Settlement not interpretable	%
	Severe	Heavy	Moderate	Slight	No pollution found		
22– 23.02.1978 MSS	0.3	0.3	2.7	22.3	74.4	--	100
13.04.1979 MSS	0.7	0.3	0.3	8.5	90.2	—	100
13.09.1979 MSS	0.3	0.3	0.3	6.5	92.3	0.3	100
07.04.1981 MSS	1.0	—	1.4	9.1	82.1	6.4	100
06.04.1982 MSS	0.7	0.3	0.7	10.1	88.2	—	100
04.04.1985 MSS	0.7	0.3	1.0	10.5	87.5	—	100
04.04.1985 TM	1.0	1.0	6.1	22.6	69.3	—	100
14.09.1986 TM	1.0	0.7	3.0	14.9	22.3	58.1	100
07.05.1981 MSS	—	1	14	17	47	35	
04.04.1985 MSS	—	4	29	36	24	21	
27.02.1986 MSS	1	1	9	6	9	89	
09.20.1985 TM	2	8	24	47	33	—	
04.16.1986 TM	4	4	18	34	21	33	
19.06.1986 TM	1	1		7	9	6	90

Table 5

Dynamic data as results of air pollution survey based on space

	Date of imaging					
	21.02.1978					
	Administ. area (square km)	Number of settl.	Percent. polluted settl.	Areal correct. (square km)	Polluted area (square km)	Percent. polluted area as of county area
1. Severely polluted	25.4	2	1.1	+ 2.8	28.2	045
2. Heavily polluted	70.1	7	3.9	+ 6.0	76.1	1.2
3. Moderately polluted	158.0	29	16.0	+33.2	191.2	3.0
4. Slightly polluted	181.8	69	38.1	+26.1	207.9	3.3
5. No pollution found	103.1	74	40.9	—	—	—
Total	538.4	181	100.0	+68.1	503.4	7.9

Number of settlements investigated: 12.02.1978: 181 pieces, 04.04.1985: 181 pieces
Percentage administrative are of settlements as to the total area of the country: 8.4%

Table 6

Pest County
Distribution of settlements by pollution classes

Date of imaging	Air pollution classes					Settlement not interpretable	Number of settlements
	Severe	Heavy	Moderate	Slight	No pollution found		
21.02.1978 MSS	6	2	14	44	114	—	181
31.05.1978 MSS	8	8	21	51	93	—	181
12.04.1979 MSS	2	7	29	69	74	—	181
19.07.1979 MSS	5	7	30	59	80	—	181
26.10.1979 MSS	5	12	30	62	72	—	181
04.05.1984 MSS	7	5	11	51	107	—	181
05.04.1985 MSS	5	8	38	52	78	—	181
27.02.1986 MSS	7	14	38	55	62	5	181
20.09.1985 TM	10	16	32	46	26	51	181
16.04.1986 TM	11	20	41	74	27	—	181
19.06.1986 TM	4	21	35	80	26	15	181

imagery Summary of multitemporal data County Pest

	Date of imaging					
	04.04.1985 (20.09)					
	Administ. area (square km)	Number of settl.	Percent. polluted settl.	Areal correct. (square km)	Polluted area (square km)	Percent. polluted area as of county area
1. Severely polluted	100.0	11	6.1	+ 7.4	107.4	1.7
2. Heavily polluted	82.7	20	11.0	+11.1	93.8	1.5
3. Moderately polluted	207.7	49	27.1	+ 9.0	216.7	3.4
4. Slightly polluted	122.0	74	40.9	+ 0.4	122.4	1.9
5. No pollution found	26.0	27	14.9	—	—	—
Total	538.4	181	100.0	+27.9	540.3	8.5

Percentage polluted area as to the total are of the country: 8.2% (average value)
Number of settlements within the country: 181; administrative area: 53.8 km²

Table 7

Pest County
Percentage area by pollution classes

Date of imaging	Air pollution classes (%)					Settlement not interpretable	%
	Severe	Heavy	Moderate	Slight	No pollution found		
21.02.1978 MSS	3.3	1.1	8.3	24.3	63.0	—	100
31.05.1978 MSS	4.4	4.4	11.6	28.2	51.4	—	100
12.04.1979 MSS	1.1	3.9	16.0	38.1	40.9	—	100
19.07.1979 MSS	2.8	3.9	16.0	32.6	44.2	—	100
26.10.1979 MSS	2.8	6.6	16.6	34.3	39.8	—	100
04.05.1984 MSS	3.9	2.8	6.1	28.2	59.1	—	100
05.04.1985 MSS	2.8	4.4	21.0	28.7	43.1	—	100
27.02.1986 MSS	3.9	7.7	21.0	30.4	34.3	2.8	100
20.09.1985 TM	5.5	8.8	17.7	25.4	14.4	28.2	100
16.04.1986 TM	6.1	11.0	27.1	40.9	14.9	—	100
19.06.1986 TM	2.2	11.6	19.3	44.2	14.4	8.3	100

Explanation for classes is as follows:

1. Severely polluted area
2. Heavily polluted area
3. Moderately polluted area
4. Slightly polluted area

Values for the individual districts are averaged data, because over their area several degrees of pollution can be found (see Figs 9—13).

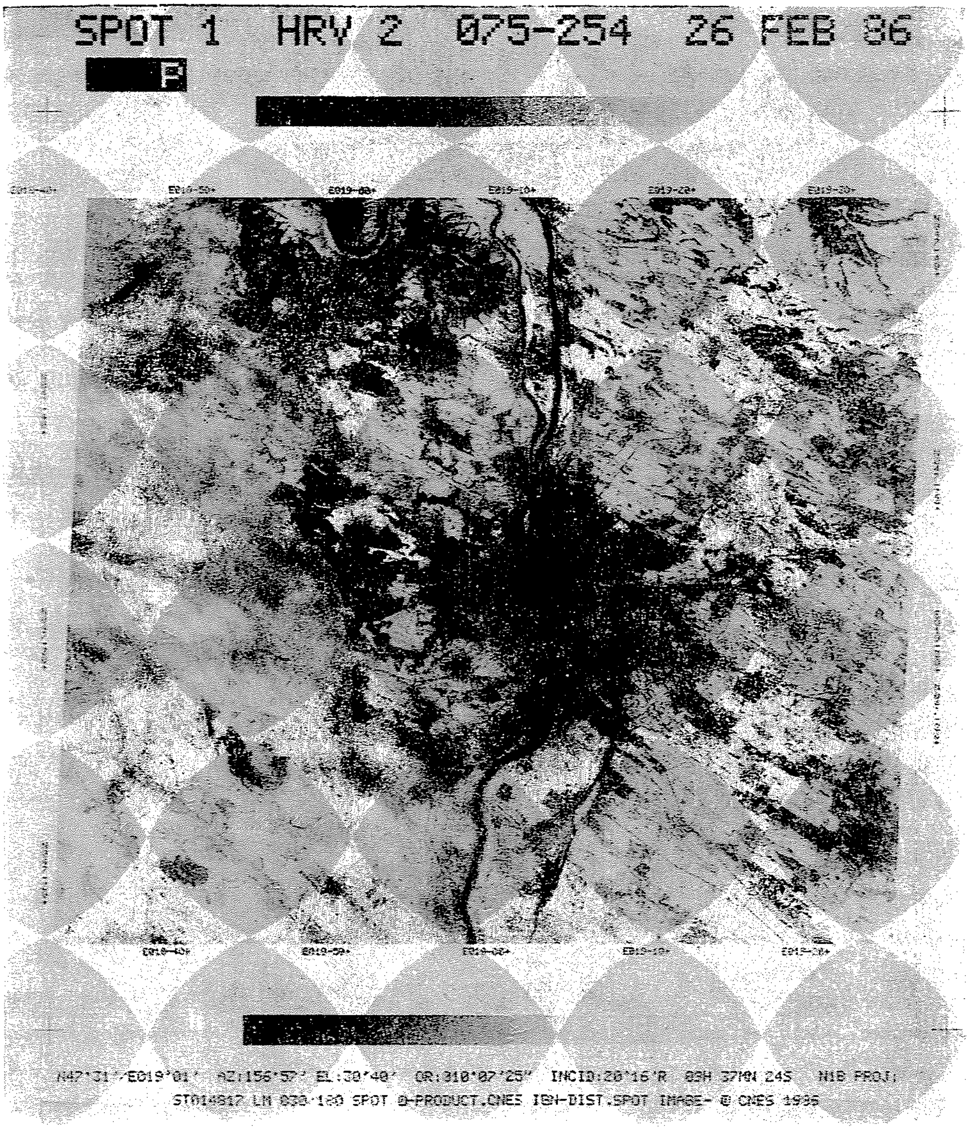


Fig. 9

Changes registered for the 13 year time interval, regrettably, show a steady deterioration of the air quality for each district (with the exception of XVII they fell into a lower class). Maximum deterioration is represented by the XII district (3 classes lower than the initial state), then by districts IX, XI, XIII, XIV, XVI, XX (2 classes lower). Deterioration of the air quality of the capital is primarily associated with urban transport and secondly with the emission from industrial plants numbering as many as 4358.

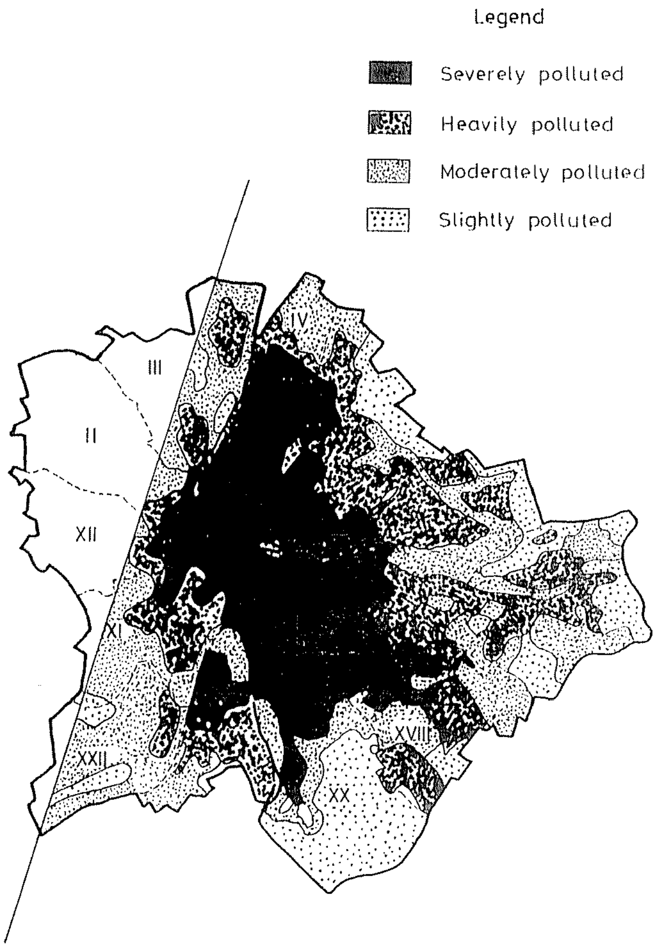
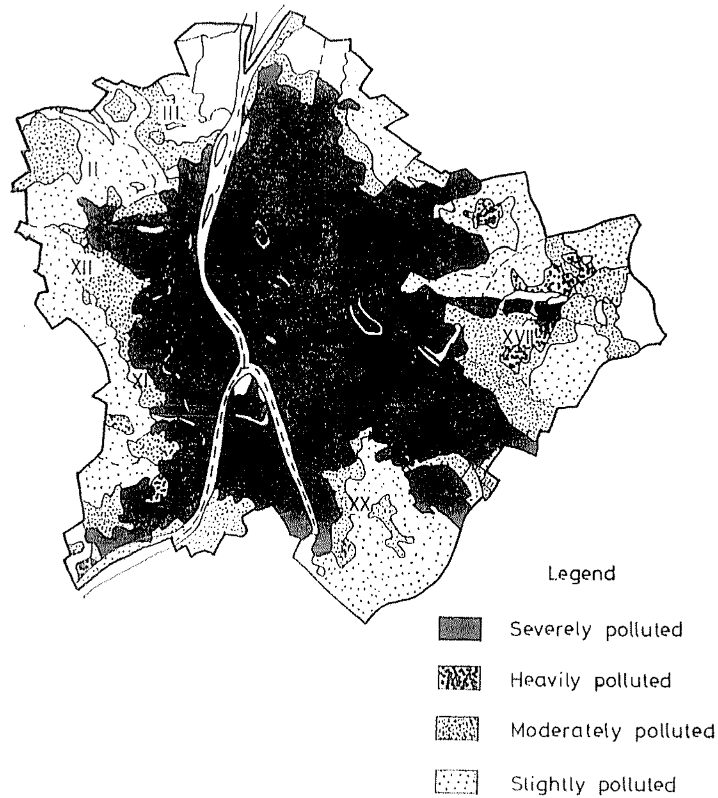


Fig. 10. Budapest 27.02.1986. LANDSAT 5-187-27



Fig' 11. Air pollution survey of Budapest. Based on a SPOT-1 075 254 image interpretation. Date of imaging: 24.02.1986.

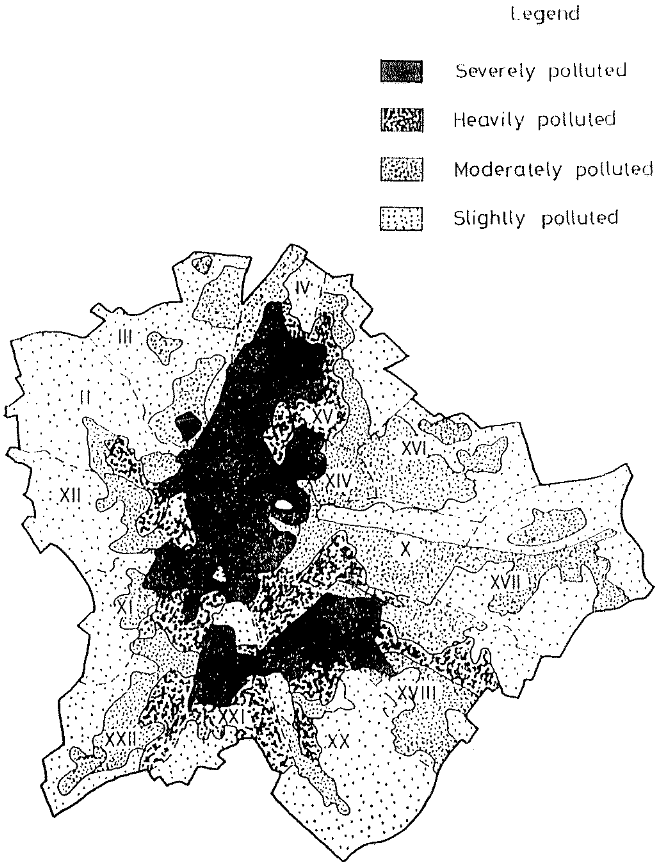


Fig. 12. Budapest 22.02.1978. LANDSAT 2-202-27

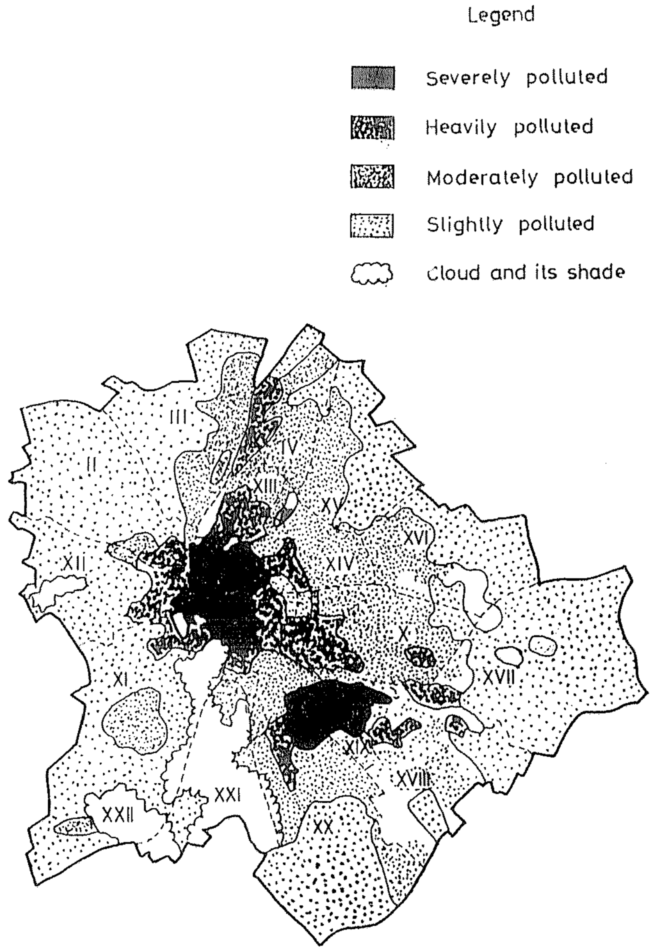


Fig. 13. Budapest 18.11.1973. LANDSAT 1-202-27

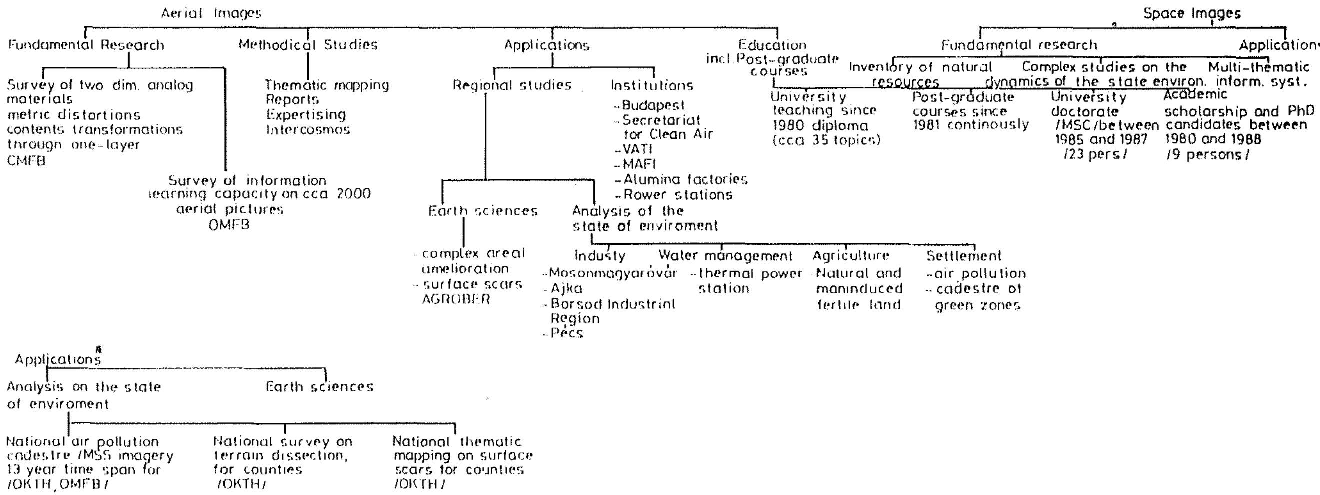


Fig. 14. **Investigations based on remotely sensed imagery, accomplished at the Department of Photogrammetry, Institute of Geodesy, Budapest Technical University between 1969 and 1988**

OMFB — National Committee for Technical Development
OKTH — Nat onal Office for Nature Conservation and Environmental Protection
AGROBER — Company for Agricultural Investment
VÁTI — Institute for Town Planning
MÁFI — Hungarian State Geological Institute

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