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A METHOD FOR TEMPORAL IMAGE ANALYSIS OF CONVENTIONAL ARCHIVES-PHOTOGRAPHS IN RELATION TO THE STUDY OF SOIL MARKS.

ABSTRACT : Zusammenfassung/Sommaire : Soil marks on aerial photographs at scale of 1/10.000 to 1/40.000 proved to be valuable indicators for detailed soil studies. Some of the soil marks are temporary others have a more permanent character, altough they are not always visible on the aerial photographs. Their detection is determined by ecological factors as well as phototechnical factors. The methodological problem is to combine the information contained in a large number of existing photographic coverages which have been registered mainly with mapping purposes and for which no specific ground truth is available. Five series, ranging from 1957 to 1973, taken in different seasons, have been used to combine the information concerning soil marks. A temporal analysis allowed to increase the amount of information succesfully. The amount of information, expressed as pattern density of the soil marks, ranged from 62-278 m/ha on the individual photoseries. After the temporal analysis a value of 625 m/ha could be obtained.

1. THE MEANING OF TEMPORAL IMAGE ANALYSIS OF CONVENTIONAL AERIAL PHOTOGRAPHS.

Landsat did not only mean a new step in the observation of the Earth, but was also the start of a new methodology for image interpretation. Temporal analysis is one of these methods. Such an evolution was obvious, considering the characteristics of the Landsat data : geometric and radiometric calibration of the imagery, relatively high temporal resolution and availability of techniques to combine the images.

None of these conditions exist for conventional aerial photography. Nevertheless, a temporal analysis of this kind of imagery could be profitable. Many Western countries possess several complete aerial coverages taken over a period of almost 35 years, reflecting the situation before the satellite registrations, and having a much higher spatial resolution. Most of these photographs had been taken with purely photogrammetric and mapping purposes.A complete interpretation of the information contained in these photoarchives still remains limited.
With the fast changing landscapes in our modern society,interest has been given to these old photographic coverages. Now, they are considered as detailed and complete inventories of past landscapes.

Temporal image analysis can be used in two ways. First, it can be used to study the dynamics of the observed phenomena. Secondly, it aims to complete the information concerning features which are registered only part on the single images. In the second case, the temporal analysis can be referred as temporal image completion.

The application of temporal image analysis on aerial photographs proved to be usefull, as shown by the photoarcheologists. They preferred to use their own oblique photographs instead of the available vertical mapping photographs, because they needed large scale imagery, a high temporal resolution and a precise control of the registration conditions. Although the goal was the detection of archeological sites, their experience results in a fundamental knowledge of all kind of soil marks and of their image formation in relation to observation characteristics, phenology and temporal conditions.

The goal of this study was to test the possibilities of a temporal image analysis of soil marks registered on conventional aerial photographs, in relation to detailed soil studies. Not all soil marks are registered on one single photo-set, and therefore temporal analysis has been used to complete the information. This examination was carried out on all available vertical aerial photographs over the Famenne Natural region in the southern part of Belgium.

2. SOIL MARKS AS TARGET

Most land use types do not show a homogeneous image on aerial photographs ; frequently changes of tonality, color and texture can be percieved within areas with same landuse. These differences are characterized by their spatial patterns and are related to changes in plant growth and phenology caused by stress, soil conditions and agricultural techniques. In the literature these patterns are referred to as <u>soil marks</u>, sites or patterns. French authors call them "signes" or "traces" and in the German literature they are known as "Merkmale". Their meaning for soil studies is widely recognized and many fundamental studies have been carried out. Nevertheless, their use in soil survey and mapping remains restricted. Indeed, the interpretation of soil marks is diffecult and hazardeous.

The appearance of the soil marks is determined by many interacting factors, which R.Agache (1970) calls "indices révélateurs". He describes also the influence of the contrast changes upon the shape and pattern. Four factors, causing these changes, are distinguised :

(1) the combined effect of pedological, hygrometrical and phytological factors ;
(2) temporal variations ;
(3) the lithology and the geology ;
(4) the observation point.

In 1972, H.Svensson developped a method of temporal interpretation of the soil marks, based upon deductive criteria and pattern analysis.
His general conclusions can be summerized as follows :

(1) soil marks do not give a constant, invariable photographic image. Specific local soil conditions and meteorological conditions have a great influence on the image formation ;
(2) optimal moments for registration do exist ;
(3) there is a certain delay between the action, causing the vegetation stress, and the moment on which it becomes visible as a soil mark ;
(4) the pattern of the soil marks is an important criterium for their interpretation ;
(5) soil marks are very sensitive indicators for soil conditions.

As already discussed, the detection of soil marks on aerial photographs depends on many factors and varies in time. Remote sensing theory holds us that phenomena are registered only when their image size is larger than the spatial resolution, and their contrast with the background is larger than the spectral resolution of the sensing system used. Besides contrast and image size (expressed as spatial frequency) are related to each other : contrast is a function of spatial frequency, which is also refferred to an modulation transfer function.

The smaller an object is imaged on a registration document, the less its contrast will be. With spatial frequencies of 8 L/mm and larger any object is represented too small to be recognized, and consequently will resolve into texture. Also, an increasing amount of non-significant noise will be added.

These thoughts are fundamental relating to the interpretation of soil marks, because on common aerial photographs, which have scales between 1 : 10.000-1 : 40.000, they are represented with critical high spatial frequencies. Consequently, a great influence of noise has to be expected, as well as an important loss of contrast, both resulting in a decreased detection.

As already discussed, the detection of soil marks on aerial photographs also depends on many ecological factors and varies in time. A temporal analysis of different series of photographs means also different images of the same soil marks have to be combined, each them having specific detection properties.

Therefore, the image analysis of the available photographs will be necessary.

3. THE IMAGE ANALYSIS OF THE SOIL MARKS

In this study, the available documents consisted of conventional vertical photographs with scale varying from 1 : 10.000 to 1 : 22.000. The emulsions used are panchromatic and color infrared. The photographs have been taken over a period of 16 years in various seasons. Most of them were available as paperprints, some as negatives and diapositives. In addition, one set has been enlarged to a scale of 1 : 5.000 and was printed on paper with a hard gradation in order to enhance the soil marks. Table 1 resumes the technical properties of the documents available. Several types of soil marks were recognized and sampled. The two most occuring types have been used for the image analysis : namely the litho-stratigraphical marks (type A) and the hydrographical marks (type B). The distinction between both is based upon their pattern. The analysis involved the use of densitometric point measurements, microdensitmetric scanning and density slicing.

3.1. The spatial frequency

The spatial frequency is defined by P.Meienberg (1966) as follows :

$s = \frac{1}{2b}$ where b : is the image width of the object, in this case the width of the soil marks. It is expressed in mm.

s : is the spatial frequency expressed in lines/mm.

In order to analyse the spatial frequency distribution the width of the soil marks has been measured in the enhanced set AS69V with scale 1 : 5.000. Tables 2 and 3 summarize the results.

Table 1.

Technical properties of the available photographs

Flight reference	MOW57	MGI69	MOW69	AS69	NFWO70	AS73
Data	05.03.57	29.03.65	01.04.69	08.08.69	24.09.70	28.08.73
Scale	1/20000	1/22000	1/15000	1/20000	1/16000	1/10000
Emulsion	(.................. Pan Aviphot 33 ....)				(color.IR,................ Kodak Ektachr. I R.)	
Resolution (in L/mm) (1)	(........................... (20) ....)				(............32..............)	
Max. gamma (2)	1.6	1.6	1.5	1.5	Y=3.8 ;M=2.6 :C=3.6	
Stereoscopic threshold (in cm) (3)	81	82	65	73	36	22
Image quality	old yellow paperprints	good	many development marks	great density difference between photographs	overexposed	important atmospheric haze

(1) The resolution is given for a low contrast target with a brightness range of 1.6 : 1 which corresponds with the low contrast scene of the landscape. Values between brackets are estimations. because no data were available by the film manufacturer.

(2) A gradation gamma greater than 1 indicates contrast enhancement. For color films it is given for each of the emulsion layers. i.a. yellow. magenta. cyanic.

(3) The stereoscopic threshold indicates the minimal height difference that can be detected by stereoscopic examination. It depends on the registration properties, mainly the base height ratio.

Table 2

Spatial frequency statistics of the soil marks of type A and B.

	Type A : litho-stratigraphical pattern	Type B : hydrographical pattern
Mean	3.82 L/mm	1.68 L/mm
Standard deviation	4.12 L/mm	1.73 L/mm
Coefficient of variation	108.0 %	103.0 %
Number of observations	43	20
Minimal width observed	0.03 mm	0.07 mm
Maximal width observed	5.02 mm	0.25 mm

Table 3

Minimal and maximal spatial frequency for type A and B on the available photoscales. expressed in l/mm.

Spatial frequency / Scale		1/5000	1/10.000	1/15.000	1/16.000	1/20.000	1/22.000
Type A.	min.	0.1	0.2	0.3	0.3	0.4	0.4
	max.	20.0	40.0	60.0	64.0	80.0	88.0
Type B.	min.	0.2	0.4	0.6	0.6	0.8	0.9
	max.	6.7	13.4	20.1	10.7	26.8	29.5

Important conclusions can be drawn from this analysis. First of all, the large values of the coefficient of variation shows that the effect of noise largely differ for the same soil marks, depending on the spatial frequency. Especially the soil marks of type A will be affected.

Secondly, comparing table 3 with the film resolution mentioned in table 1, it can be seen clearly that on the small scales some of the soil marks will not be detected and will resolve into the texture of the image. Consequently, a temporal analysis should start with the large scale photographs, even when the contrast of the soil marks is low. Step by step the information on the other photographs should be added.

3.2. The contrast

Because of the large differences in image quality between the series of photographs, the relative contrast (C) of a soil mark with its background should be taken into account. It is defined as :

$$C = \frac{Ds - Db}{Db} \cdot 100$$

where : Ds : photographic density of the soil mark ;
Db : photographic density of the background.

The relative contrast has been determined for soil marks visible on all photoseries, so that the influence of land use type, phenology and season could be determined. The results are given in table 4. Negative contrast indicates that the density of the soil marks is less than the density of the background.

Table 4

Relative contrast of the soil marks in relation with land use type, phenology and season.

Land use type and phenology	Relative contrast in		
	late summer	spring	winter
Young fodder crops and stubble-fields	-60% - -20%	-	-
Stubble-field with weeds and fallow land	+10% - +40%	-	-
Cereals : growing and mature	- -	-5% - +5%	0% - +2%
Grassland	-50% - +10%	-2% - 0%	-3% - 0%

Late summer gives the highest contrasts, and therefore must be considered as the best period for the detection of the soil marks in this area. These high contrast values are also due to the rapid respons to soil conditions by young fodder-crops and weeds in the stubblefields. The low contrast values in spring and winter are partly caused by the inferior image quality of the corresponding photoseries.

Absolute values for the contrast differ significantly between soil marks of type A and B and their statistics are given in table 5. Lithostratigraphical soil marks give a slightly higher contrast.

Table 5

Statistics of the absolute values of the contrast between soil marks and background for types A and B

	Type A : litho-strati-graphical	Type B : hydrographical
Mean	30.41 %	25.42 %
Standard deviation	17.64 %	11.49 %
Coefficient of variation	58.01 %	45.20 %

As already said the contrast of an object is related to its spatial frequency, the regression analysis between the spatial frequency and the contrast of the soil marks has been carried out. A low correlation, significant at 5 % level, do exist, confirming the theoretical expectation. The low value of the correlation coefficient is largely due to fact that differences in land use and slope exposition distort the general trend. The most important conclusion is that there is no one-way relationship between photographic contrast and object characteristics. To use density and contrast as a parameter to estimate field variables such as moisture differences, remains hazardeous.

3.3. The texture analysis

Due to their high spatial frequency, some of the soil marks are resolved into the texture of the image. A microdensitometric scanning allows the study of the texture parameters. Table 6 shows an example of a soil mark of type B in pasture land.

As can be seen, the mean photographic density, which is the reciproke of the transparancy, of the soil mark in grassland is significantly higher and its texture coarser. Texture analysis allows the discrimination of a soil mark from its background within one field.

On the other hand, equidensitometric analysis do not give results because of the between field variance being much more important than the within variance. Therefore, density slicing techniques are of no interest to enhance the soil marks on a photographic image.

Table 6

Texture parameters of a hydrographical soil mark (type B) in pasture land, determined from densitometric scanning

	Soil Mark	Background
Average transparency	21,5 %	26,6 %
Standard deviation	2,1 %	1,7 %
Coefficient of variation	9,8 %	6,4 %
Spatial frequency	0,9 L/mm	1,1 L/mm

3.4. The false color image of the soil marks

An objective determination of the color is only possible through densitometric measurements in each of the three emulsion layers, which is a very cumbrous procedure. A visual description and classification of the colors becomes possible using the color cards of the ISCC-NBS system (Manual of Color Aerial Photography, 1968). As tonality, color is largely influenced by the contrast position in the photographic image (L.Daels & M.Antrop,1978).

Therefore, color must be considered always as a relative parameter. For the given photosets, following observations could be made :

- By grassland soil marks have a more reddish hue and a higher saturation than the background ;
- By fodder crops they show always a deep red, very saturated color ;
- In the stubble-fields the saturation is very low and the hue is white or blue. Sometimes the marks appear as more saturated blue, in other cases as white and low saturated. This distinction allows more differentiation than panchromatic image ;
- Ploughed fields give a purplish reddish hue in which the soil marks appear with decreased brightness and pale hue ;
- Very wet grounds covered by hydrophile vegetation, have a soft orange and an orange-yellow hue with high saturation.

3.5. The pattern density

Visual image analysis uses immediately all information visible in the image. It is very likely the interpreter detects soil marks by interpolation of the recognized patterns in the neighbouring fields. Doing this he can increase the information rapidly.

In this study, the pattern density has been calculated starting from the soil marks detected by visual image analysis. This parameter is expressed in visible length of the soil marks per ha, and has been determined for each photoset and land use type. Table 7 summarizes the results for the sample-area Ronchi.

Table 7

Pattern density (D) and relative pattern density (%D) in the test area Ronchi (Halma) with relation to land use and photoseries.

Photoseries Data Scale	MOW 57 05.03.57 1/20.000		MGI 65 29.03.65 1/22.000		MOW 69 01.04.69 1/15.000		AS 69V 08.08.69 1/5.000		AS 73 EIR 28.08.73 1/10.000		NFWO 70 EIR 24.09.70 1/16.000	
Landuse types	(D)	(%D)	(D)	(%D)	(D)	(%D)	(D)	(%D)	(D)	(%D)	(D)	(%D)
Pasture land	253	34	251	16	49	20	280	17	112	6	146	10
Fodder crops	296	39	168	37	128	52	270	17	506	27	374	25
Cereals	185	24	156	35	69	28	381	24	-	-	-	-
Corn	-	-	-	-	-	-	388	24	654	34	614	42
Stubble-fields	-	-	-	-	-	-	267	17	341	18	297	20
Ploughed land	13	2	88	19	-	-	-	-	-	-	-	-
Potatoes	-	-	15	3	0	0	0	0	235	12	-	-
Orchards	10	1	0	0	0	0	0	0	58	3	48	3
Vegetable - Gardens	0	0	0	0	0	0	9	1	0	0	0	0
Total length	23.263 m		11.452 m		6.210 m		27.800 m		26.218 m		25.299 m	
Average pattern density	233 m/ha		115 m/ha		62 m/ha		278 m/ha		262 m/ha		253 m/ha	
Index	83.6		41.2		24.9		100.0		94.3		91.0	

It appears that the visibility of the soil marks changes a lot, resulting in pattern densities varying from 62 m/ha up to 278 m/ha. Some conclusions can be drawn with respect to the influence of phenology, scale, emulsion and meteorology.

Again, the late summer seems to be the most appropriate period to detect soil marks. Fodder crops, which of clover, luzerne and darnel, give the most constant value throughout the year, and the pattern densities are mostly greater than the average value for the area.

The values for pasture are high too, but show more variation, due to differences in grazing. Extremely high pattern densities appear for corn, but only on the false color images. The absolute value is not important, because corn covers only 3 % of the arable land. The high values in stubble-fields are caused by differential growth of the weeds. Soil marks in ploughed fields appear by color and moisture differences.

The enhanced photoset AS 69V gives the best detection, indicating that photographic enlargement with increased contrast may be a valuable processing technique. The meteorological conditions preceding each of the registration have been analysed too, and simultaneous field observations have been made in 1970 and 1973. The important influence of the weather conditions could be determined, especially during the periods of sowing, germination and maturation. Factors which influence the growth act especially in these periods, and the effect becomes visible only later on. Some of the hydrographical soil marks registrated on the photoset AS 73 EIR of august have been caused by washing out of the seed by heavy rains in march, resulting in unequal coverage and growing-speed.

A general conclusion was that extremely wet and extremely dry periods in respectively early spring and late summer increase substantially the detection os soil marks registered in the late summer.

4. THE TEMPRAL IMAGE COMPLETION

The image analysis of the soil marks on the different photographical images indicates the possibilities and the limitations of the information extraction by means of a temporal combination. This forms the basis for further temporal analysis. The procedure for the temporal image completion, used for the soil marks, consists of following steps :

1) The visual image interpretation seems to be the most profitable method. Indeed, the image of a soil mark is influenced by many factors. Some are related to the image formation, but others correspond with changing relations of the soil mark with its surroundings due to landuse, meteorological and phenological conditions. It is essential to understand its image formation ; deduction forms the basis interpretation tool.

2) The temporal completion should be based upon the image which has the highest information content. This has been expressed by the average pattern density (see table 7). Then, this set has been enhanced. A photographic enlargement on high-gamma film gave the best results.

3) The information of the other images has been added one at the time, always starting with the highest pattern density. This new information has been drawn on the first image.

4) All sequential images have been interpreted using the same procedure. The illumination and observation conditions were held constant using the Interpretoskop. Stereoscopy allowed to use the microrelief for better localisation. The image of each soil mark has been optically enlarged by a factor equal to its spatial frequency. Thus, their image size within the perception field remained constant and allowed optimal observation of their contrast and texture.

Finally, the result of the temporal image completion has been evaluated. Therefore, the pattern density was determined again for the same test area Ronchi. The combined pattern density varies now from 289-625 m/ha and has a mean value of 406 m/ha, which is a significant increase compared to the values of the separate photoseries (see table 7). The combined information concerning the soil marks proved to be relevant and a valuable indicator for a morpho-pedological landclassification as described by M.Antrop, (1979)

5. CONCLUSIONS

Altough a patient manual interpretation, the systematic temporal image completion of the soil marks, registered on conventional aerial photographs, proved to be valuable.
Generally spoken, the growing interest in the information contained in the aerial photographic archives makes it worthwhile to interprete the old photographs. Consequently, further research concerning systematic methods for visual image interpretation becomes necessary, especially related with temporal image analysis.

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