# IDENTIFICATION OF WATERLOGGED SOILS IN THE EAST-SLOVAKIAN LOWLAND BY APPLICATION OF LANDSAT DATA

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## INTRODUCTION

The East-Slovakian Lowland with an area of approximately 2600 sq. km. represents an important agrucultural area of the ČSSR /Fig. 1/. Considerable part of the 197,000 hectares of land

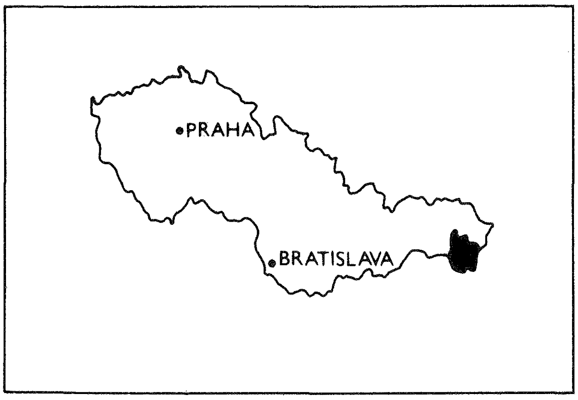


Fig. 1. Position of the area studied.

agriculturally cultivated, especially in the plain level, is marked for its hydrophysical properties negatively influencing the growing of agricultural crops. Particularly in the spring months, but also during the summer, or also in autumn, large areas of the land are usually waterlogged or flooded. Therefore it is very important, especially from the viewpoint of further effective development of agricultural production in the East--Slovakian Lowland, to make a detailed typification of the soils from an aspect of the dynamics of waterlogging intensity changes. We are to remark that solution of the problem mentioned in such an extensive territory is difficult attainable applying only conventional methods of the field research, since the soil waterlogging is marked for a striking variability in time and space. And that is why we have proceeded in solving the subject problem also to an application of data gained by the earth remote sensing methods. The crucial-point of our work in this sphere /4, 5, 9/ was concentrated on both setting up methodic procedures of analogue and digital interpretation, by means of which required information of the intensity of soil waterlogging may be obtained from aerospace photographs and images, and also on an analysis as well as practical application of the results of interpretation. The submitted work documents part of the results of an analysis of interpretation outputs.

Within the published works from the area mentioned especially different approaches to solving problems of direct determination or measurement of the soil moisture from the record of electromagnetic radiation taken by various types of sensing device aboard airplane or cosmic carriers /1, 2, 8, 12/.

The aim of this work is documentation of the results gained by interpretation of LANDSAT record MSS through an indirect identification of forms of surficial waterlogging of soils without vegetation by means of their relevant physiognomic characters.

CHARACTERISTICS OF THE PROBLEM

From the published works /6, 7/ it results that 2 basic types of depressions waterlogged occur in the East-Slovakian Lowland, being conditioned by both precipitation water accumulated and underground water level coming to surface. A third type of waterlogging occurs as a combination of the two mentioned. The difference between the basic types /from the viewpoint of their manifestation on aerospace photographs and images/ lies in the fact that the dynamics of changes of waterlogging areal extent will be in repeated sensing greater in the case, if this has been caused by precipitation water surficially accumulated than in the case underground water level coming to the surface.

Under the notion of physiognomic aspects of surficial soil waterlogging intensity we understand significant appearance characteristics of differently waterlogged soils /predominantly without vegetation/, manifestating themselves in coloured syntheses and images by means of a marked change in density and pixel values, or as the case may be, by means of a characteristic pattern.

The notion of soil waterlogging is defined for the working aim as a temporary of permanent flooding of all the pores of the soil with precipitation or underground water coming to the surface particularly in lowered sites.

The possibility of identification of waterlogged soils with different intensity goes out from the presupposition that both the surface water and the soil with differently waterlogged surface absorb radiation in the near infra-red spectral band /10, 13/. Consequently, for instance, in coloured syntheses made in a suitable combination of multispectral photograph or image channels both water on the surface or the soil waterlogged differ strikingly from the other objects by values of the density of syntheses and by those of pixels.

The interpreted image was obtained by MSS multispectral scanner aboard LANDSAT-3. The device is able to record the flux of reflected electromagnetic radiation within the visible and the near infra-red parts of the spectrum. Information encoded in data gained in this way are directly bound only to the surface layer of objects scanned, in our case, for instance, the soils without vegetation. From the mentioned it results that it is very questionable to obtain direct information of water contents also in subsurface layers of the soil profile in absolute values through application of photographs and images made by recording only the reflected radiation in the visible and near-red parts of the spectrum.

Since the waterlogging of an essential part of the monitored territory in the East-Slovakian Lowland is very striking, it has shown to be purposeful and necessary to delimitate soils waterlogged with different intensity and to characterize them by means of <u>physiognomic aspects of the waterlogging</u>.

Generalized physiognomic characteristics of the delimitated forms /classes/ of soils waterlogged with different intensity are illustrated in Fig. 2.

Form "V" represents a concentration of water on the surface, forming a continuous level. The area of the water level ranges from some decades of square metres up to hundreds of them. This form is unambiguously identifiable by marked changing pixel values /see Table 1/.

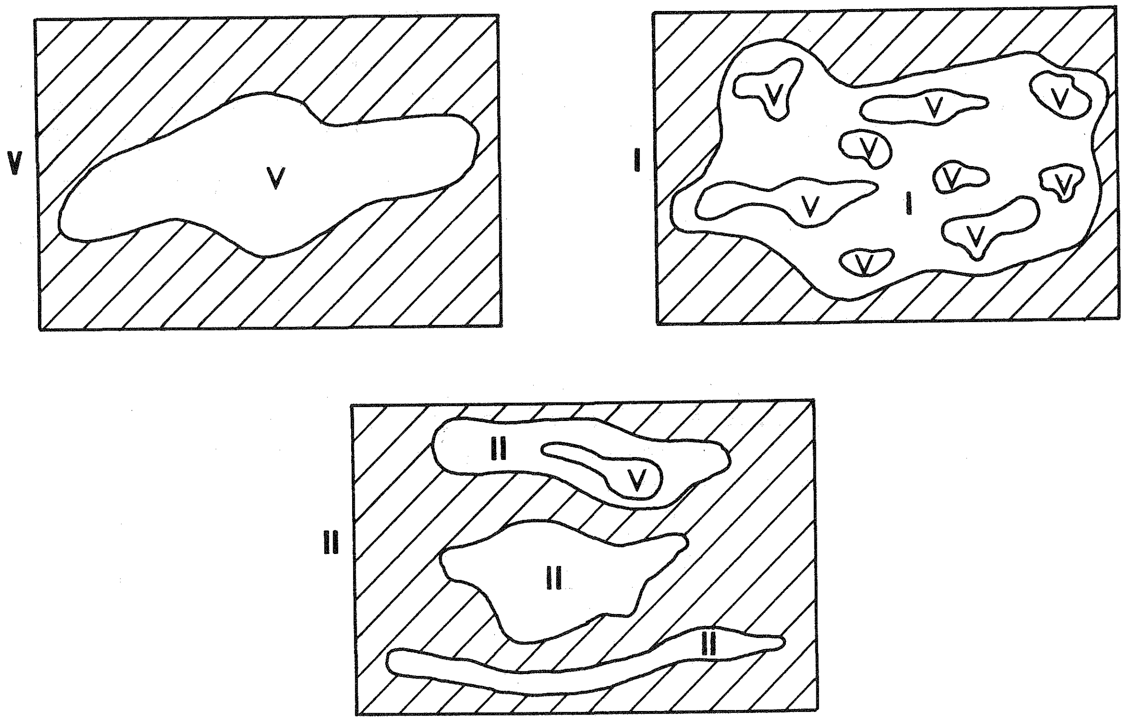


Fig. 2. Delimitated forms of the soils waterlogged to different intensity. V, I, II - the delimitated forms.

Form "I" - the intensively waterlogged soils - is represented by sporadic and smaller areas of water /some decades of square metres/ concentrated on the surface. The distribution of these areas forms a characteristic pattern formed particularly by ploughed land and water concentrated on the surface. By means of the patterns mentioned especially the bottom parts of depressions are illustrated. Physiognomically the form is very striking and separable, which is documented by Tables 1 and 2.

Form "II" - the less intensively waterlogged soils - - is represented by areas with very sporadic occurrence of water concentrated on the surface. Within this form areas with soils intensively waterlogged in upper parts of the horizon are dominant by area. The form mentioned is bound predominantly to little striking depressions, or also to an old river network. Physiognomically it is less striking and as documented in Tables 1 and 2 also only little separable from form III.

The other areas were considered as relatively dry, and are denoted as form III.

IMAGE INTERPRETATION

The LANDSAT-3 TM data made by MSS scanner on March 17, 1982, were worked up by PERICOLOR 2000. The applied methodical procedure of digital interpretation went out from the results of field investigation and from those of analogue interpretation of aerial multispectral photographs of two training areas, in which 4 forms of surface waterlogging of soils were identified. Since their extent in area is relatively small /some hundreds of square metres/, only a reduced number of "pure" pixels representing the appropriate forms /classes/ was selectable. These then represented a training set, the basic statistical data of which are quoted in Table 1.

| Class | $m_i$ | | | | $\sigma_i$ | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| V | 36 | 34 | 32 | 17 | 13.3 | 23.2 | 13.8 | 3.2 |
| I | 33 | 34 | 35 | 26 | 2.8 | 3.3 | 5.1 | 4.4 |
| II | 36 | 39 | 41 | 31 | 3.6 | 8.7 | 12.1 | 9.0 |
| III | 34 | 36 | 41 | 36 | 4.4 | 7.6 | 27.1 | 9.5 |

Table 1. Mean value $m_i$ and standard deviations $\sigma_i$ of spectral signatures of the individual classes.

Prior to classifying proper the couples of classes $R_i$ and $R_j$ were tested for their separability. In the operation mentioned factor $G_{ij}$ was used, being determined according to the relationship

$$G_{ij} = \frac{/m_i - m_j/^2}{\sigma_i^2 + \sigma_j^2}$$

where $m_i$, $m_j$ and $\sigma_i$, $\sigma_j$ denote mean values and deviations of classes $R_i$ and $R_j$. The size of $G_{ij}$ is proportional to the separability of classes $R_i$ and $R_j$ within the given spectral signature. This factor has been assigned for all the couples of classes in all the spectral bands. Its total magnitude obtained by summing within all the spectral bands is quoted in Table 2.

| Class / Class | I | II | III |
|---|---|---|---|
| V | 11.6 | 20.1 | 30.8 |
| I | | 7.5 | 8.8 |
| II | | | 2.4 |

Table 2. Magnitudes of factor $G_{ij}$ indicating the separability of classes.

It results from the table that water is, according to expectation, well-differentiable from all the other classes, classes II and III being differentiable worst. Significance of the individual spectral bands for differentiating the classes determined is documented in Table 3, in which the total magnitude of factor G for all the spectral signature is quoted. The 4th

| | Spectral Band | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| G | 0.47 | 0.65 | 1.47 | 10.96 |

Table 3. Summing magnitudes of factor G for each spectral signature respectively.

spectral band /near infra-red part of the spectrum/ is most informative, while the first two bands do not contribute to differentiating individual classes in a significant way. The similarity of some classes in the first, or also in the second belts is evident also from the graph in Fig. 4, where average values of chosen classes in bands 1 up to 4 are plotted. Consequently, the 1st spectral band has not been used for the classification and thus the classification has been realized only on the three-dimensional set.

The Bayesian classifier was used at classifying and the result has been fixed on a colour printer, system PERICOLOR 2000. Before visualizing the result had been still arranged by a post-classifying filter.

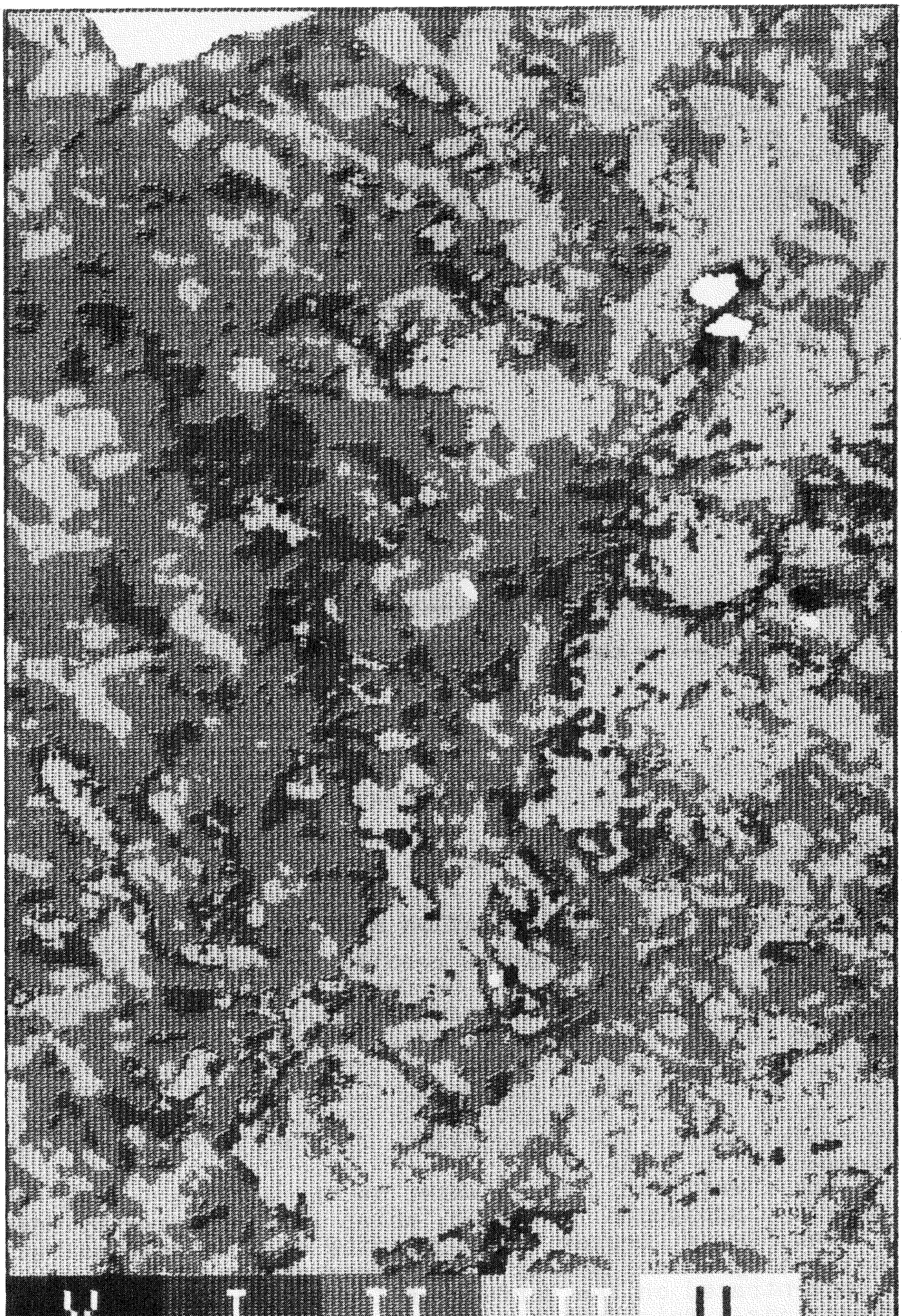


Fig. 4. Forms of surface soil waterlogging intensity in part of the East-Slovakian Lowland.

V - water concentrated on the surface, I - soils intensively waterlogged, II - soils less intensively waterlogged, III - soils relatively dry, U - unclassified areas.

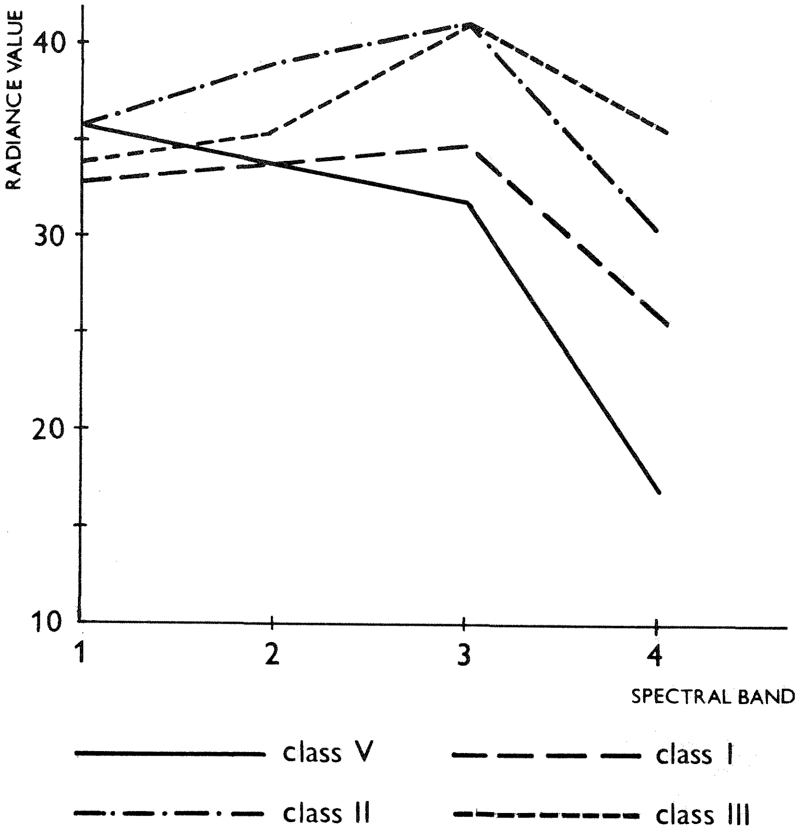


Fig. 3. Radiance characteristics of the delimitated forms /classes/ of surface waterlogging of the soils.

The results of digital interpretation are documented in Fig. 4. A territory of about 558 sq. km. is illustrated in the interpretation scheme.

CHARACTERISTIC OF THE INTERPRETATION RESULTS

On the basis of positive results in digital interpretation, reached on the training surfaces and published in the work /7/, which supported the possibility of identification of the defined forms /classes/ of surface soils waterlogging intensity by means of manifestation of their physiognomic characteristics, we proceeded to analysing the results of interpretation of major part of the East-Slovakian Lowland area. Results of successfulness in the classifying, reached in this territory, are documented in Table 4.

The identifiability of water on the surface - form "V" - - is nearly unambiguous in images, which is documented by both Table 1 and Fig. 4. Lesser distinguishing ability does not allow to identify unambiguously small areas of water /some sq. metres/ concentrated on the surface of lands /for instance, in old river beds/. This fact has been confirmed by confronting results of digital interpretation with those of analogue one as well as with those obtained by the synchronouc field mapping

| Class | Mapping accuracy /%/ |
|---|---|
| V | 100,0 |
| I | 90,2 |
| II | 97,2 |
| III x | 88,2 |

x relatively dry areas /areas with vegetation, forests, extremely dry land without vegetation/

Table 4. Mapping accuracy of classes computed from training set.

on training and testing surfaces. Water in the form of ice /as this had still been frozen to the term of scanning particularly in water reservoirs/ has been included to the class of "non-classified areas".

The soils intensively waterlogged - form "I" - are similarly as the previous well-identifiable, although confronted with results gained on training surfaces /7/ some inaccuracies have been found. Particularly flood-plain woods are those that have been included to this class ambiguously /the water surface interrupted with trees without leaves, or also interrupted with dry hygrophilous vegetation/. The identifiability of this form is successful in accordance with the amount of areas covered with water concentrated on the surface of land within its structure /see Fig. 2/.

The soils less intensively waterlogged - form "II" - are marked for only a sporadic occurrence of water on the surface, or as the case may be, for a more intensive waterlogging of the soil horizon. The given form includes almost all surfaces of arable land without vegetation /Fig. 4/, being close to this form with their reflection characteristics. If waterlogging is sufficiently marked and as to area it includes larger areas without vegetation, the form mentioned is identifiable.

Vegetation in different stages of development as well as humus contents, application of fertilizers, or soil liming and so on markedly influence the reflection characteristics of different-intensively waterlogged soils that can be interpreted as relatively dry surfaces - form "III". Also markedly humid meadows have been classified to this class /as particularly stalks and leaves of dry grass form a good reflection surface/.

Frozen water in reservoirs, markedly green winter cereals as well as waste products from a thermal power station form the class of non-classified objects.

CONCLUSION

The results of the analysis of LANDSAT data /Fig. 4/ document that they represent a suitable means of providing topical information of physiognomic aspects of the surface soil waterlogging intensity in the East-Slovakian Lowland when vegetation is missing.

On the assumption that interpretation is made of images gained in some time horizons suitably chosen /under minimum occurrence of vegetation and maximum occurrence of water concentrated on the surface/ the separability of forms /classes/, particularly of "II" and "III", can be improved and information acquired in this way utilized, for instance, in typifying the soils from the viewpoint of the dynamics of waterlogging changes.

The topical time-space information of the surface soil waterlogging intensity may successfully be utilized also directly in practice, for instance, in in projecting hydromelioration arrangements in areas of interest, or in monitoring the effectivity of existing drainage systems and so on.

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