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○ Applications aux zones humides
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MAPPING OF THE SURFACE WATER LOGGING INTENSITY OF THE SOILS BY APPLYING LANDSAT TM DATA AND COMPLEX DIGITAL TERRAIN MODEL

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Abstract

A work documents basic parts of methodology in operative mapping of the surface water-logging intensity of the soils without vegetation by applying LANDSAT 5 TM data and complex digital terrain model. This one allows to simulate spatial distribution of morphometric parameters of relief forms in various hierarchic levels. By means of the map there is expressed a relation of morphometric terrain parameters with identified forms of surface water-logging intensity of soils.

A result of the paper is to determine basic steps of methodology for mapping the forms of surface water-logging intensity of soils by appling LANDSAT 5 TM data and complex digital terrain model:

a/ definition of forms of surface water-logging intensity of soils withouth vegetation,
b/ identification of forms of water-logging intensity of soils on training areas,
c/ delimitation of forms of surface water-logging intensity of soils on the basis of digital interpretation LANDSAT data and delimitation of area by means of digital terrain model simulating (functional) morphometric parameters,
d/ correlation of forms of surface water-logging intensity of soils with relevant morphometric parameters,
e/ presenting results of delimitation – forms of surface water-logging intensity of soils with morphometric terrain parameters – by means of map with relevant scale.

◆ Introduction

Research realised up to now in the area of identification of the surface water – logging intensity of soils without vegetation by applying multispectral aerial photographs (made by MKF-6, MSK-4 cameras) and LANDSAT 3 MSS data, have supplied us several positive results). They document that the forms of surface water-logging intensity of soils can be identified on photographs and images by means of their relevant physiognomic features. In the works quoted we didn't think of expressing the extent of terrain influence on the spatial differentiation of the surface water-logging intensity of soils. Understanding connections between morphemetric terrain parameters and forms of surface water-logging intensity of soils without vegetation is important, particularly form the point of view of determination their genetic and dynamic aspects. Obtainment of relevant information on the mentioned connections help to understand more complexly time – space changes in occurence of differently intensively water-logging intensity of soils in a landscape.

The aim of the work is to document basic parts of methodology in mapping the surface water-logging intensity of soils withouth vegetation by applying LANDSAT 5 TM data and complex digital terrain model. By means of it is possible to simulate spatial distribution of morphometric parameters of terrain forms in various hierarchic levels and with the aid of map to express their relation with identified forms of surface water-logging.

Experimental area on which we document results of works in question, is a part of Zitny ostrov Island. The Island is closed with main bed of the river Donau and Little Donau (Maly Dunaj) which is situated between Bratislava and Komárno. It is long about 100 km and wide 15 to 20 km with the whole area more than 1 600 km2 (6). Surface of Zitny ostrov Island is characterized with small denivelation (natural levees, interlevee depressions, beds of old river network). To their occurence shows height of ground water level wich comes up on surface or water-logging of soils. Prevailing angle of area with maximum altitude of 134 m a.s.l. and minimum altitude of 107 m a.s.l. is from NW to SE. Difference in altitude to the distance of nearly 100 km is only 27 m; that complicates mapping of the surface water-logging of soils only by applying conventional methods of field research. The whole area of Zitny ostrov Island is a typical young structural riverain plain (Luknis and Mazur, 1959).

◆ Characteristics of the problem of water-logging of soils

Possibility of identification differently intensively water-logging of soils withouth vegetation by applying remote sensing methods proceeds from the assumption that surface water and differently intensively water-logging of soil absorb electromagnetic radiation in the near infrared spectral band (Lillesand and Kiefer, 1979, Swain and Davis, 1983). Consequently pixel values of imageries of these objects get, in relevant spectral bands, low values.

A term water-logging of soils we define as far as work is concerned as a different degree of saturation of soil with water up to temporary or permanent floods of all its pores with rainfall or ground water coming to the surface particularly in lowered sites (morphometrically in concave-convex and further forms over its surface (Feranec and Kolar, 1988).

Individual forms of water-logging of soils were delimited on the basis of their physiognomy. Under the term physiognomic features of the surface water-logging intensity of soils we understand significant aspectual characteristics of differently intensively water-logged soils withouth vegetation showing themselves in images with considerable change of pixel values (Feranec and Kolar, 1988).

From the point of view of water-logging intensity of soils we have delimited the following forms:

– form "V" – water concentrated on the surface, forming a continuous level, its area ranges from some decades of square meters up to hundreds of them; this form is unambigously identifiable,

– form "I" – intensively water-logged soils – it is represented by more sporadic and smaller areas of water (some decades of square metres) concentrated on a surface; the distribution of these areas forms a characteristic pattern formed particularly by pbloughed land and water concentrated on a surface; physiognomically the form is very striking,

– form "II" – less intensively water-logged soils – it is represented by areas with very sporadic occurence of water concentrated on a surface; within this form areas with soils intensively water-logged in upper parts of the horizon are dominant by area; physiognomically it is less striking,

– form "III" – the other areas, they are considered as relatively dry.

◆ The data used

The data used were obtained by scanner TM (Thematic mapper) from LANDSAT 5 of April 12th, 1988 (first quadrant of a scene 188-27, which involves area in NW from junction of rivers Váh and Maly Dunaj (Little Donau). In the work we have used part of image in size 512x512 pixels which is adequate to the area of about 230 km2. The image was made during clear sky, in the year period when effect of water-logging was relatively striking. For processing there were used data from 6 channels in visible area and near infra-red part of spectrum.

◆ Delimitation of forms of surface water-logging of soils

It was realized by means of digital interpretation of LANDSAT 5 data on PERICOLOR 2 001 system. There were used supervised classification techniques with determinating maximum – likelihood classifier, under the assumption of normal distribution of measured data. For all mentioned forms of water-logging of soils were, on the basis of field mapping results, given representative pixels for training sets. Main statistical data on training set can be found in Table 1.

class	m_1 / σ_1	m_2 / σ_2	m_3 / σ_3	m_4 / σ_4	m_5 / σ_5	m_7 / σ_7
V	75 6,5	29 5,2	24 4,1	19 15,7	14 4,8	8 3,2
I	82 8,1	32 3,6	33 6,0	32 9,1	69 14,5	42 5,8
II	88 18,6	36 7,1	39 14,6	40 19,0	86 32,4	53 14,2

Table 1 : Composition of training set for classification, m_j is mean value and σ_j is standard deviation of values in given class in j channel

Suitability of representative pixels was, at the first stage, controlled visually on the scatter diagram arranged for 3rd and 5th channels. By interactive method we have eliminated from training data those pixels which were not, according to subjective appraisal, sufficiently near to chuster of relevant class.

At the second stage the measure of separability of representative training data was settled numerically by using statistical values of signatures of all 6 channels. Magnitude of separability $G_{ij}(n)$ of two classes i and j in given spectral signature n is:

$$G_{ij}\,(n) = \frac{(m_i - m_j)^2}{\sigma i + \sigma j}$$

Comprehensive measure of separability of two classes is in that case expressed by a total of all spectral separabilities $G_{ij}(n)$

$$G_{ij} = \sum_n G_{ij}\,(n)$$

Calculated values of separability for three classes in question can be found in Table 2.

	class V	class I
class I	304	–
class II	291	19

Table 2 : Measure of separability of determined classes from spectral signatures TM.

Table documents expected very good separability of class "V". Less separability of classes "I" and "II" can be seen also according to size of measured spectral values (Table 1). While class "V" is differentiated by falling course of values from 1st channel to 7th one, classes "I" and "II" are characterized with almost same course. Higher values are difference in all channels with class "II" and it is consequence of lower content of water. That's why for differentiation the classes "I" and "II" are the most important data from channels 5 and 7 which share with their separability of 63%.

◆ Digital terrain model – methodical aid for simulating morphometric parameters

In spatial differentiation of processes, which are running through landscape, as well as in water-logging intensity of soils participates expresively, in addition to other landscape components, also georelief expressed in its topographic area. Georelief has influence to spatial differentiation by means of its morphometric parameters, which are:

- z – height above sea level
- Δz_{ij} – relative height in the direction of gradient curves
- γ_N – angle of georelief inclination in the direction of gradient curves
- A_N – orientation (exposure) of georelief to cardinal points
- $\omega = (K_N)_n$ – normal georelief curvity in the direction of gradient curves which get values $\omega < 0$, $\omega = 0$, $\omega > 0$

$(K_N)_t$ – normal georelief curvity in the direction of tangentials to isolines of height.
$K_r = (K_N)_t/\sin \gamma_N$ – horizontal relief curvity of georelief which get values $K_r < 0$, $K_r = 0$, $K_r > 0$

On the basis of morphometric parameters ω, by K_r ar on the one hand characterized partial geometric forms $NF = (NF_x' NF_K)$, $K_rF = (K_rF_x, K_rF_K)$ and on the other one full geometric forms F.

At the same time NF are so called normal forms in direction of gradient curves in which NF_X are convex normal forms for which 0, NF_K – concave normal forms for which $\omega < 0$ and K_rF are so called horizontal forms where are convex horizontal forms for which $K_r > 0$ and K_rF_K are concave horizontal forms for which $K_r < 0$.

Full geometric forms F make set $F = (F_{xx}, F_{XK}, F_{KK}, F_{XK}, F_{XL}, F_{LX}, F_{KL}, F_{LK}, F_{LL})$, where individual first four constituents are characterized with the following basic total forms:

F_{XX} / NF_x ($\omega > 0$), K_rF_x ($K_r > 0$) / - convex -convex forms
F_{KX} / NF_K ($\omega < 0$), K_rF_x ($K_r > 0$) / - concave-convex forms
F_{KK} / NF_K ($\omega < 0$), K_rF_K ($K_r < 0$) / - concave-concave forms
F_xK / NF_x ($\omega > 0$), K_rF_K ($K_r < 0$) / - convex-concave forms

Further total forms of georelief are characterized:

F_{XL} ($\omega > 0, K_r = 0$) - convex-linear forms
F_{LX} ($\omega = 0, K_r > 0$) - linear-convex forms
F_{KL} ($\omega > 0, K_r = 0$) - concave-linear forms
F_{LK} ($\omega = 0, K_r < 0$) - linear-concave forms
F_{LL} ($\omega = 0, K_r = 0$) - linear-linear forms

Mentioned morphometric parameters of georelief were formulated definitevely and derived in detail in works (Krcho, 1973, 1990).

Georelief as a spatial area is then in each its arbitrary point A_i (x_i,y_i,z_i) expressed with set of morphometric parameters $(G_{RF})_i$ which are linked to this point i.e. $A_i / (x_i,y_i,z_i), (G_{RF})_i /$, where $G_{RF'i} = (z_i, \Delta z_{ij}, \omega_i, K_{r,i}, NF_i, F_i, ...)$, which can be cartographically modelled by means of complex digital terrain model – KDMR.

Surface water-logging of soils depends on forms F_{KK}, F_{KX}, which form depressions. Nevertheless, considerable influence has a relative height z_{ij} and the hierarchie level of these forms.

◆ Correlation of forms of surface water-logging of soils with relevant morphometric parameters of terrain.

Results of correlation documents map by technique of identifying points and the second-order polynomial transformation. Characteristics on heights above sea level were transformed to results of LANDSAT 5 data classification. From analysis of this map results that relation of forms of surface water-logging of soils to inexpressive lowered sites was confirmed. These sites correspond to old river beds or as the case may be to depressions between natural levees. Only in southern part of area is water on surface on raised site – natural levee. Occurence is conditioned on production of gravel.

7. Conclusion

Result of the work is determination of basic steps in methodology of mapping the forms of surface water-logging of soils by applying LANDSAT 5 TM data and complex digital terrain model:

- definition of forms of surface water-logging of soils without vegetation,
- identification of forms of surface water-logging of soils on training areas,
- delimitation of forms of surface water-logging of soils on the basis of digital interpretation of LANDSAT 5 data and delimitation of area by means of digital terrain model simulating (functional) morphometric parameters – height above sea level, angle, horizontal curvity, normal cuvity and similar (in our work the height above sea level only),
- correlation of forms of surface water-logging of soils with relevant morphometric parameters,
- presentation of results of delimitation – forms of surface water-logging of soils and morphometric terrain parameters – by means of map in a relevant scale.

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