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JÁN FERANEC*, JAN KOLÁŘ**

PHYSIOGNOMIC ASPECTS OF THE SURFACE WATER-LOGGING INTENSITY OF THE SOILS IN THE EAST-SLOVAKIAN LOWLAND IDENTIFIED BY AEROSPACE PHOTOGRAPHS AND IMAGES

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This article presents results of an analysis of possibilities of the use of multispectral aerial photographs made by MKF-6 camera and digital LANDSAT 3 data, identifying indirectly the surface water-logging of soils without a vegetation. Particular forms of intensity of the surface water-logging of soils are identified on the photographs and images by means of relevant physiognomic features. Results of an optic-analogue and digital interpretation are documented from 2 experimental surfaces of the East-Slovakian Lowland.

INTRODUCTION

The East-Slovakian Lowland with an area of approximately 2600 sq. km. represents an important agricultural area of the ČSSR (Fig. 1). Considerable part of the 197,000 hectares of land agriculturally cultivated, especially in the plain level, is marked for its hydrophysical properties negatively influencing the growing of agricultural crops. Particularly in spring months, but also during the summer, or also in autumn, large areas of the land are usually water-logged 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 water-logging 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 water-logging 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 applica-

* RNDr. Ján Feranec, CSc., Geografický ústav CGV SAV, Obrancov mieru 49, 814 73 Bratislava, ČSSR.

** Ing. Jan Kolář, CSc., Stavební fakulta ČVUT, Laboratoř DPZ, Thákurova 7, 166 29 Praha 6, ČSSR.

tion of data gained by the Earth remote sensing metsods. The crucial-point of our work in this sphere [2, 3, 4] was concentrated on both setting up methodic procedures of analogue and digital interpretation, by means of which required information of the intensity of soil water-logging 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.

Fig. 1. Position of the area studied.

The aim of the work is to document possibilities of the use of multispectral aerial photographs (made by MKF-6 camera) and images (made by multispectral scanner MSS), where the intensity of surface water-logging of the soils without a vegetation is indirectly identified, and subsequently also to identify the forms of intensity of the surface water-logging of soils by means of their relevant features.

CHARACTERISTICS OF THE PROBLEM

A generalization of two basic types of the water-logging of depressions in the East-Slovakian Lowland is shown in Fig. 2. The water-logging is conditioned by precipitation water accumulated and also coming to the surface as level of the underground water. A third type of water-logging comes into consideration as combined from the both mentioned. We suppose that in substance the difference between the basic types (from the viewpoint of thier manifestation in aerospace photographs and images) is in that the dynamics of changes in water-logging extent should be greater in the case with the accumulated precipitation water than in that with the underground-water level coming to surface in taking photographs repeatedly (1').

Under the notion of *physiognomic aspects of the intensity of surface water--logging of soils* we understand significant aspectual characteristics of soils water-logged with different intensity (predominantly without a vegetation), manifesting itself with a striking change in density and pixel values, or also with a characteristic pattern in coloured syntheses and images.

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

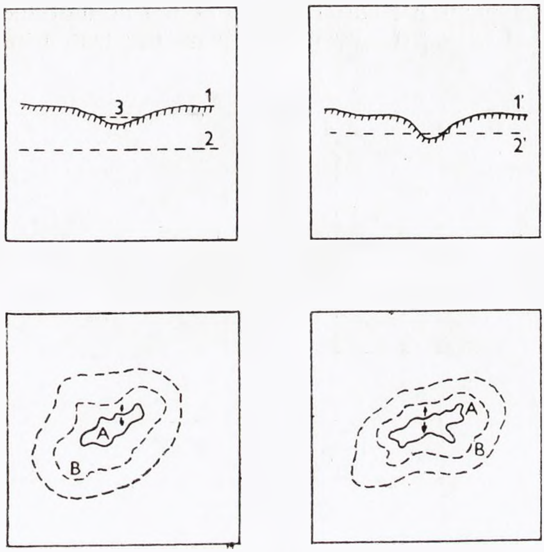

Fig. 2. A scheme illustrating the relationship between the water-logging of depressions in the East-Slovakian Lowland and the accumulated precipitation and underground water (3). *1,1'* — soil horizon; *2,2'* — underground water level; *3* — precipitation water accumulated; *A* — contours of the surface water illustrated in the photograph; *B* — contours of the soil water-logged to different intensity, illustrated in the photograph.

The possibility of identification of water-logged soils with different intensity goes out from the presupposition that both the surface water and the soil with differently intensity of water-logging absorb radiation in the near infra-red spectral band (5, 7). Consequently, for instance, in coloured syntheses made in a suitable combination of multispectral photograph or image channels both water on the surface or soil water-logged differ strikingly from the other objects with values of the density of syntheses and with values of pixels.

The interpreted multispectral photographs and images were obtained with MKF—6 camera aboard aerial laboratory AN—30 and MSS multispectral scanner aboard LANDSAT—3. Both the devices are able to record the flux of reflected electromagnetic radiation within the visible and 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 photographed, 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 infra-red parts of the spectrum.

Since the water-logging 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 water-logged with different intensity and to characterize them by means of physiognomic aspects of the water-logging.

Generalized physiognomic characteristics of the delimitated forms (classes) af soils water-logged with different intensity are illustrated in Fig. 3.

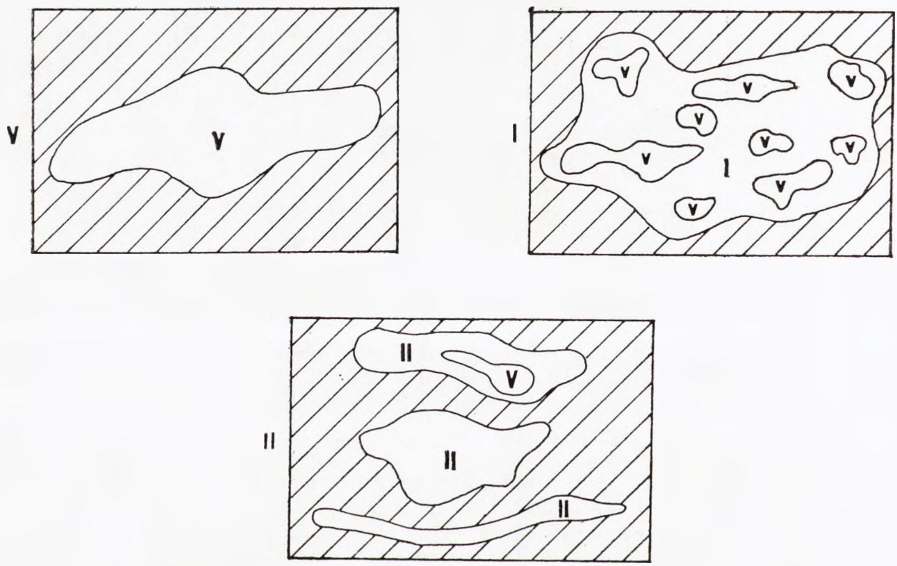

Fig. 3. Delimitaied forms of the soils water-logged to different intensity. V, I, II — the delimitated forms.

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 in the way of changing density in coloured synthesis (on the negative shown in striking light hues) and also in the way of changing pixel values strikingly (see Tab. 1).

Form „I“ — the intensively water-logged soils — is represented by sporadic and smaller areas of water (some decades of square metres) concentrated on the surface. The distribution of the 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 Tabs. 1 and 2.

Tab. 1. Mean value m_i and standard deviation σ_i of spectral signatures of the individual classes

Class	m_i				σ_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

Form „II" — the less intensively water-logged soils — is represented by areas with very sporadic occurrence of water concentrated on the surface. Within this form areas with soils intensively water-logged 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.

THE PHOTOGRAPH AND IMAGE INTERPRETATION

In interpreting multispectral aerial photographs made by MKF—6 camera, namely on March 16, 1982, multispectral projector MSP—4 was used. The coloured syntheses were formed from negatives of the 4th channel 640—680 nm and the 6th channel 790—890 nm combined with green and red filters. The methodic procedure of analogue interpretation is documented in works (1, 2).

The LANDSAT—3 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 water-logging 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 Tab. 1.

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 σ_i, σ_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 to all the couples

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

Class \ Class	I	II	III
V	11,.6	20.1	30.8
I		7.5	8.8
II			2.4

Tab. 3. Summing mangitudes of factor *G* for each spectral signature respectively

	Spectral band			
	1	2	3	4
G	0.47	0.65	1.47	10.96

of classes in all the spectral bands. Its total magnitude obtained by summing within all the spectral bands is quoted in Tab. 2. 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 Tab. 3, in which the total magnitude of factor *G* for all the spectral signature is quoted. The 4th 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.

In the classification the Bayesian classifier was used 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.

Results of an interpretation from two training surfaces are documented in Fig. 5. The interpretation schemes have been arranged to a scale approximately 1:25,000 so that there would be a possibility of comparing results of the digital interpretation (Fig. 5b) and those of the analogue one (Fig. 5a).

CHARACTERISTIC OF THE INTERPRETATION RESULTS

The results of interpretation on the testing surfaces (Fig. 5) confirm the possibility of identifying the defined forms (classes) of intensity of the surface water-logging of soils by means of the manifestation of their physiognomic characteristics illustrated in multispectral photographs and images. The results of analogue interpretation correspond to those of digital one. Dissimilarities in the shape of the areas of delimitated forms is caused both by the fact that the data used, the photographs and images, obtained in both photographic and non-photographic way of taking, and also by a great difference in the scale. The original scale of the digital image is 1:3,336,000 and that of the multispectral aerial photographs 1:50,000.

The identifiability of water on the surface — form „V" — is nearly unambiguous in the multispectral aerial photographs, similarly as in the images. Nevertheless, its lesser distinguishing ability does not allow to identify unambiguously small areas of water (some sq. metres, or also some decades of sq. metres) concentrated on the surface of lands (for instance, in old river beds), which is confirmed by the results quoted in Tab. 1 as well as in Fig. 5.

The soils intensively water-logged — form „I" — are similarly as the previous well-identifiable, which is conformed by the results attained. The delimitation of this form is successful the more, the more areas with water concentrated on the surface within its pattern there are (see Fig. 3).

The soils less intensively water-logged — form II — are marked for only a sporadic occurrence of water on the surface, or as the case may be, for a more intensive water-logging of the soil horizon. If, however, the water-logging is sufficiently striking and as to the size if it covers larger areas of the soil without vegetation (or as the case may be, with only a sporadic developed vege-

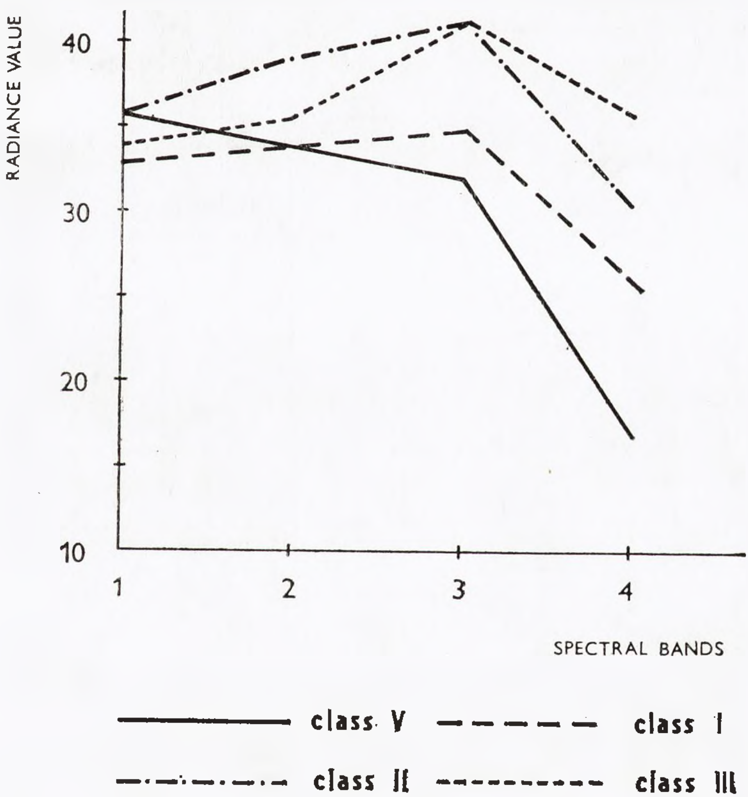

Fig. 4. Radiance characteristics of the delimitated forms (classes) of surface water--logging of the soils.

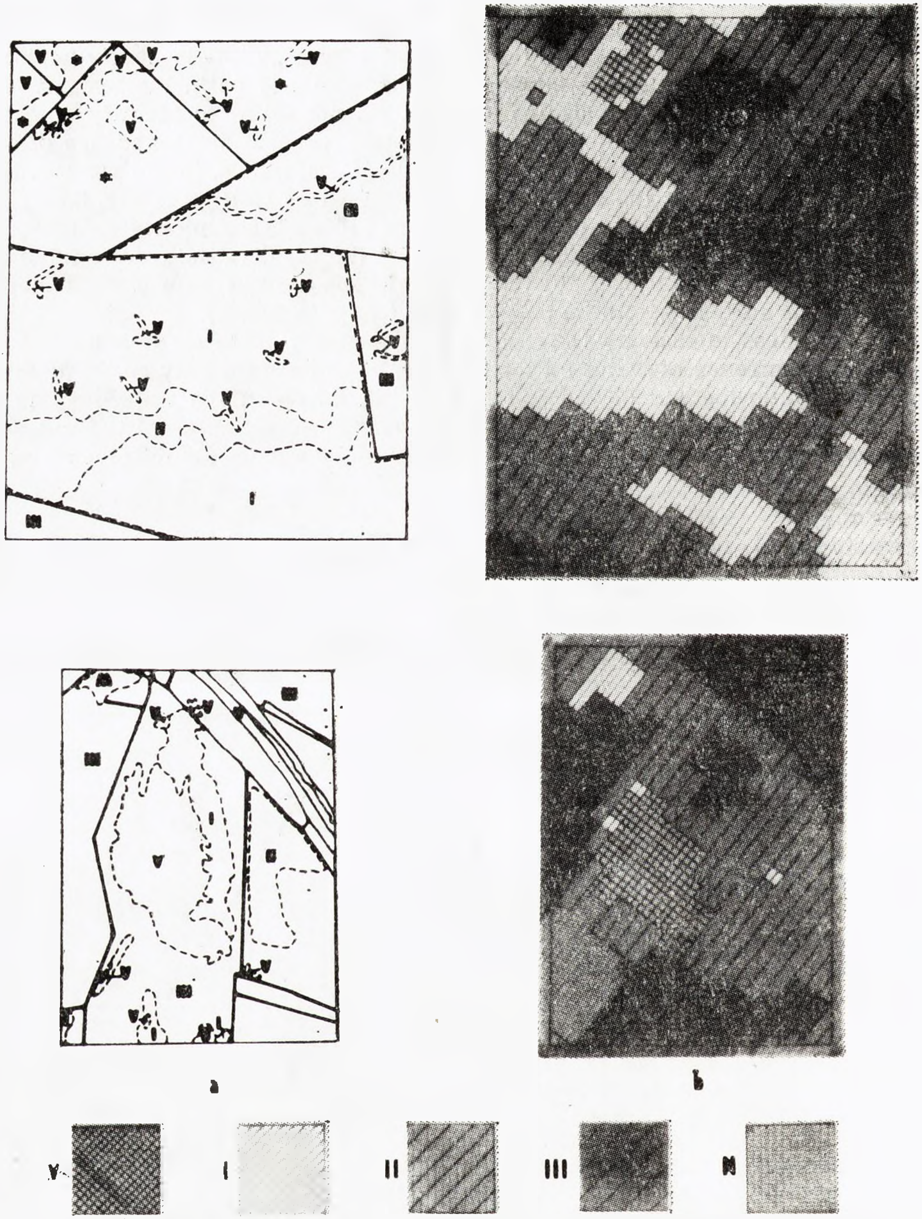

Fig. 5. Results of the analogue (5a) and digital (5b) interpretation in a form of interpretation schemes to a scale of approximately 1:25,000. *V* — water concentrated on the surface, *I* — soils intensively water-logged, *II* — soils less intensively water-logged, *III* — soils relatively dry, *N* — non-classified areas, *M* — swamps, * — bottom of a water reservoir under construction. A note: In the original coloured interpretation, schemes made by a printer, system PERICOLOR 2000, the individual forms of soil water-logging have been emphasized with manual hatching.

tation, for instance, still not expressive winter corn), the form mentioned is identifiable.

The vegetation in its different stages of development as well as the contents of humus, applying artificial fertilizers and soil liming and so on, these all only obscure the reflex characteristics of the differently water-logged soils and thus they may be interpreted as relatively dry — form „III“, or also as non-classified areas. It is necessary to be acquainted perfectly with the factors mentioned and eliminate them on the basis of a correct field research on the training surfaces.

CONCLUSION

On the basis of the results reached up to this time within the subject sphere it may be stated that multispectral aerospace photographs and images represent a suitable means for providing topical information of physiognomic aspects of the intensity of surface water-logging of soils (predominantly without a vegetation) in the East-Slovakian Lowland.

The results of the image analysis (Tabs. 1, 2 and Fig. 5) have confirmed that an image contains information of the defined forms (classes) in the soils water-logged to different intensity.

Supposing the interpretation of images obtained in several time horizons suitably chosen (under minimum occurrence of vegetation) it is possible to improve separability of the defined forms (classes), especially „II“ and „III“ and information obtained in this way then to employ, for instance, in typifying the soils from the viewpoint of the dynamics of water-logging changes.

The topical time-space information of the intensity of surface water-logging of the soils may successfully be employed also directly in the practice, e. g. in projecting hydromelioration arrangements of the territories of interest; in monitoring the effectiveness of draining systems existing and so on.

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Ján Feranec, Jan Kolář

FYZIOGNOMICKÉ ASPEKTY INTENZITY POVRCHOVÉHO ZAMOKRENIA PÔD VÝCHODOSLOVENSKEJ NÍŽINY IDENTIFIKOVANÉ APLIKÁCIOU AEROKOZMICKÝCH SNÍMOK A OBRAZOVÝCH ZÁZNAMOV

Značná časť poľnohospodársky obrábanej pôdy Východoslovenskej nížiny, najmä v rovinnom stupni, sa vyznačuje hydrofyzikálnymi vlastnosťami, negatívne vplývajúcimi na pestovanie poľnohospodárskych kultúr. Preto je veľmi dôležité, najmä z hľadiska ďalšieho efektívneho rozvoja poľnohospodárskej výroby na nížine, urobiť detailnú typizáciu pôd z aspektu dynamiky zmien intenzity ich zamokrenia. Vyriešenie uvedeného problému na tak rozsiahlom území aplikáciou iba konvenčných metód terénneho výskumu je ťažko dosiahnuteľné, nakoľko zamokrenie pôdy sa vyznačuje výraznou premenlivosťou v čase a priestore. Preto sme pri riešení predmetného problému pristúpili k aplikácii údajov získaných metódami diaľkového prieskumu Zeme. Ťažisko našich prác v tejto oblasti (2, 3, 4) sa sústredilo jednak na zostavenie metodických postupov analógovej a digitálnej interpretácie, pomocou ktorých možno získať z aerokozmických snímok a obrazových záznamov požadované informácie o intenzite zamokrenia pôd a tiež na analýzu a praktické aplikácie výsledkov interpretácie.

Cieľom práce bolo dokumentovať možnosti využitia leteckých multispektrálnych snímok (urobených komorou MKF-6) a obrazových záznamov (urobených multispektrálnym riadkovacím rádiometrom typu MSS) pri nepriamej identifikácii intenzity povrchového zamokrenia pôd bez vegetácie. Formy intenzity povrchového zamokrenia pôd identifikovať prostredníctvom ich relevantných fyziognomických znakov.

Pod pojmom fyziognomické aspekty intenzity povrchového zamokrenia pôd rozumieme signifikantné vzhľadové charakteristiky rôzne intenzívne zamokrených pôd bez vegetácie, prejavujúce sa na farebných syntézach a obrazových záznamoch výraznou zmenou hodnôt denzity a pixelov, prípadne charakteristickou štruktúrou.

Pojem zamokrenie pôdy definujeme pracovne ako dočasné alebo trvalé zaplavenie jej všetkých pórov zrážkovou alebo podzemnou vodou, vystupujúcou najmä v znížených polohách nad jej povrch.

Možnosť indentifikácie rôzne intenzívne zamokrených pôd vychádza z predpokladu, že povrchová voda a rôzne intenzívne zamokrená pôda absorbujú radiáciu v blízkej infračervenej časti spektra (5, 7). V dôsledku toho, napr. na farebných syntézach, vytvorených vo vhodnej kombinácii kanálov multispektrálnych snímok alebo obrazových záznamov, voda na povrchu a zamokrená pôda sa výrazne odlišujú od iných objektov hodnotami denzity syntéz a hodnotami pixelov.

Pri interpretácii multispektrálnych leteckých snímok, urobených komorou MKF — 16.3.1982, bol použitý multispektrálny projektor MSP-4. Obrazový záznam urobený multispektrálnym riadkovacím rádiometrom MSS z paluby družice LANDSAT 3, 17. marca 1982, bol spracúvaný na zariadení PERICOLOR 2000. Pred vlastnou klasifikáciou boli triedy — formy intenzity zamokrenia pôd testované na separabilitu. Pri klasifikácii sa použil Bayesov klasifikátor.

Na dvoch experimentálnych plochách Východoslovenskej nížiny sme identifikovali aplikáciou aerokozmických snímok a obrazových záznamov tieto formy intenzity povrchového zamokrenia pôd: voda koncentrovaná na povrchu, vytvárajúca výraznú, súvislú hladinu; pôda intenzívne zamokrená; pôda menej intenzívne zamokrená a ostatné plochy.

Na základe doteraz dosiahnutých výsledkov možno konštatovať, že multispektrálne aerokozmické snímky a obrazové záznamy sú vhodným prostriedkom na poskytnutie aktuálnych informácií o fyziognomických aspektoch intenzity povrchového zamokrenia pôd Východoslovenskej nížiny.

Obr. 1. Poloha študovanej oblasti.

Obr. 2. Schéma znázorňujúca vzťah medzi zamokrením depresií Východoslovenskej nížiny a akumulovanou zrážkovou a podzemnou vodou (3). *1,1'* — pôdny horizont; *2,2'* — hladina podzemnej vody; *3* — akumulovaná zrážková voda; *A* — kontúry vody na povrchu, zobrazenej na snímke; *B* — kontúry rôzne intenzívne zamokrenej pôdy, zobrazenej na snímke.

Obr. 3. Delimitované formy rôzne intenzívne zamokrených pôd. V, I, II — delimitované formy.

Obr. 4. Radiačné charakteristiky delimitovaných foriem (tried) povrchového zamokrenia pôd.

Obr. 5. Výsledky analógovej (5a) a digitálnej (5b) interpretácie vo forme interpretačných schém v mierke približne 1:25 000.
V — voda koncentrovaná na povrchu, *I* — pôdy intenzívne zamokrené, *II* — pôdy menej intenzívne zamokrené, *III* — pôdy relatívne suché, *N* — neklasifikované areály, *M* — močiare, ∗ — dno budovanej vodnej nádrže.
Poznámka: na originálnych farebných interpretačných schémach, urobených tlačiarňou systému PERICOLOR 2000, sú jednotlivé formy zamokrenia pôd zvýraznené ručným šrafovaním.

Tab. 1. Stredná hodnota m_i a smerodajné odchýlky σ_i spektrálnych príznakov jednotlivých tried.

Tab. 2. Veľkosti faktora G_{ij} udávajúce separovateľnosť tried.

Tab. 3. Sumárne veľkosti faktora G pre každý spektrálny príznak.

Ян Феранец, Ян Коларж

ФИЗИОНОМИЧЕСКИЕ АСПЕКТЫ ИНТЕНСИВНОСТИ ПОВЕРХНОСТНОГО ЗАБОЛАЧИВАНИЯ ПОЧВ ВОСТОЧНОСЛОВАЦКОЙ НИЗМЕННОСТИ, ИДЕНТИФИЦИРОВАННЫЕ ПУТЕМ ПРИМЕНЕНИЯ АЭРОКОСМИЧЕСКИХ И СКАНЕРНЫХ СНИМКОВ

Значительная доля сельским хозяйством возделываемых почв Восточнословацкой низменности, находящихся, главным образом, на равнине, отличается гидрофизическими свойствами, влияющими отрицательно на выращивание сельскохозяйственных культур. Поэтому является важной, преимущественно с аспектов дальнейшего эффективного развития сельскохозяйственного производства на низменности, разработка детальной типизации почв с точки зрения динамики изменений их заболачивания. Решение данной проблемы для такой обширной территории путем применения лишь конвенционных методов полевых исследований является трудно достижимым, поскольку заболачивание почв отличается отчетливой изменчивостью во времени и в пространстве. Для решения данной проблемы мы, поэтому, привлекли данные, полученные методами дистанционного зондирования Земли. Основные усилия в этой области (2, 3, 4) нами сосредоточены на разработку методик аналоговой и цифровой интерпретации, путем применения которых по аэрокосмическим и сканерным снимкам можно получать требуемые информации о интенсивности заболачивания почв, а также на анализ и практическое приложение результатов интерпретации.

Цель наших усилий — документировать возможность применения мультиспектральных аэроснимков (полученных камерой МКФ-6) и сканерных снимков (полученных мультиспектральным сканерным радиометром типа МСС) для косвенной идентификации интенсивности поверхностного заболачивания почв лишенных растительности. Далее — идентифицировать формы интенсивности поверхностного заболачивания почв посредством их существенных физиономических признаков.

Под физиономическими аспектами интенсивности поверхностного заболачивания почв нами подразумеваются сигнификантные визуальные характеристики в разной степени заболоченных почв без растительности, проявляющиеся на полученных синтезированных цветных снимках и на сканерных снимках отчетливой сменой значений плотности и значений пикселей, или же характеристической структурой.

Под заболачиванием почвы нами, в рабочем порядке, подразумевается временное или постоянное заполнение всех пористых отверстий осадочной или подземной водой, выступающей, главным образом на заниженных участках над ее поверхность.

Возможность идентификации разной степени заболоченных почв основывается на предпосылке, что поверхностная вода и в разной степени заболоченная почва поглощают радиацию близкую к инфракрасной зоне спектра (5, 7). В результате этого, например, на синтезированных цветных снимках, полученных при подборе подходящей комбинации каналов мультиспектральных снимков или же сканерных снимков, поверхностная вода и заболоченная почва отчетливо отличаются от других объектов значениями плотности и значениями пикселей.

В процессе интерпретации мультиспектральных аэроснимков, полученных камерой МКФ-6 (16 марта 1982 г.), нами применялся мультиспектральный проектор МСП-4. Сканерный снимок, полученный мультиспектральным сканерным радиометром МСС на спутнике ЛАНДСАТ 3 (17 марта 1982 г.), обработан с помощью прибора ПЕРИКОЛОР 2000. До классификации классы-формы интенсивности заболачивания почв проверялись на сепаративность. В процессе классификации был применен Байесовский классификатор.

В результате применения аэрокосмических и сканерных снимков на двух экспериментальных участках Восточнословацкой низменности нами идентифицированы следующие формы интенсивности поверхностного заболачивания почв: вода концентрирующаяся на поверхности, образующая отчетливое и непрерывное зеркало; почва интенсивно заболоченная; почва менее интенсивно заболоченная и остальная поверхность.

На основе до сих пор полученных результатов в данной области можно отметить, что мультиспектральные аэроснимки и сканерные снимки представляют собой подходящее средство для предоставления актуальных информаций о физиономических аспектах интенсивности поверхностного заболачивания почв Восточнословацкой низменности.

Рис. 1. Местоположение изучаемой области.

Рис. 2. Схема отображающая связь между заболачиванием депрессий Восточнословацкой низменности и застаивающимися осадочными и подземными водами (3).
1,1' — почвеный горизонт; *2,2'* — уровень подземных вод; *3* — застаивающиеся осадочные воды; *A* — контурная линия поверхностных вод, изображенных на снимке; *B* — контурная линия разной интенсивности заболоченных почв, изображенных на снимке.

Рис. 3. Выделенные формы разной интенсивности заболоченных почв. V, I, II — выделенные формы.

Рис. 4. Радиационные характеристики выделенных форм (классов) поверхностного заболачивания почв.

Рис. 5. Результаты аналоговой (5a) и цифровой (5b) интерпретации в виде интерпретационных схем в масштабе приблизительно 1:25 000.
V — застаивающиеся на поверхности воды, *I* — почвы интенсивно заболо-

ченные, *II* — почвы менее интенсивно заболоченные, *III* — почвы относительно сухие, *N* — неклассифицированные ареалы, *M* — болота, * — дно строящегося водохранилища. Примечание: на оригинальных цветных интерпретационных схемах, отпечатанных печатным устройством системы ПЕРИКОЛОР 2000, отдельные формы заболачивания почв добавочно заштрихованы вручную.

Табл. 1. Среднее значение m_i и стандартные отклонения σ_i спектральных признаков отдельных классов.

Табл. 2. Величины фактора G_{ij}, определяющие сепаративность классов.

Табл. 3. Суммарные величины фактора G для каждого спектрального признака.