ISSN: 2312-3370, Agricultural Science and Practice, 2014, Vol. 1, No. 1

UDC 631.4 : 631.47: 631.459

Space Technologies in Agri-Environmental Monitoring System

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Received on Feb 24, 2014

The contemporary development of the remote space survey systems and elements of geoinformation technologies offers the fundamentally new possibilities of control, forecasting and interpretation of the data obtained from agroecological monitoring. **Aim.** To describe natural and climatic conditions of the various zones within the territory of Ukraine, its agricultural acquirement and risk of the soils' erosive degradation manifestations in the meaning of climate changes. To determine the factors influencing upon the spectral characteristics of the eroded soils for their identification, deciphering, and also the cultivated lands and land tenure systems degradation monitoring according to satellite data. **Methods.** The logical model of water erosion determination and identification according to the data of the Earth remote sensing (ERS) of high spatial resolution is developed on the basis of classification in basic deciphering signs and the procedure of molding of the training samples forming. The materials of the Landsat 8, SPOT, ASTER and RapidEye space surveys, map materials and data of full-scale ground observations on the test objects were used for identification of the processes of sheet and linear erosion. The soil erosion was determined according to two approaches. The first one is based on the plowed soil and the second – on soil covered with plants. The soil erosion class was determined according to the spectral characteristics and humus content, while gully rate – by reference to gullies' length and square. **Results.** The humus content in soil was proposed to be determined according to the spatial distribution of spectral characteristics within the limits of uniform regions and corresponding mathematical-statistical models. The opportunities of linear and sheet erosion classification according to the ERS data, and also their use in the system of monitoring and evaluating the ecological state of agrolandscapes and land tenure systems are shown. **Conclusions.** The space monitoring data of the soils erosive degradation and agrolandscapes in whole provide the opportunity of more effective use of soil resources due to the strategic determination of degradation processes with the subsequent planning and workout the measures for the optimization of the erosive dangerous agrolandscapes structure, and also introduction of the ground water-guarding systems of soil management.

Key words: soil resources, erosive deterioration, remote sensing, monitoring, climate.

INTRODUCTION

Under serious climate changes the marks of the water erosion and deflation are strengthened. This, first of all, is connected to an increase in the shower nature of sediments [1], significant expansion of the areas of such field crops as corn, sunflower and soy [2], including in the Polissia zone, for which the low anti-erosion stability of soils is typical. Together with the sheet erosion the risks of the gully formation intensification grow, which is especially dangerous for the large gully systems. Deflationary dangerous territories occupy in some years to 5−6 million ha.

The territory of Ukraine is subdivided into three large natural climatic zones:

The Polissia zone is characterized by the predominance of sediments above evaporation. Average long-standing amount of precipitation composes 500–630 mm. Soil cover is mainly acid sod-podzol types of light particle size distribution. Natural land occupies up to 50 per cent of territory, among which are marshes, forests and meadows.

The Wooded-Steppe zone is characterized with intensive agrarian production. Amount of precipitation varies from 450 mm in the east to 760 mm in the west. More than 50 per cent of the cultivated areas are planted with corn, sugar beet, sunflower, soy; the rest of the arable earth – under the spiked cereals and feed crops. Soil cover consists of chernozems and gray forest soils. The complex relief is typical for the zone; that fact combined with high ploughing rate of agricultural land creates conditions for the water erosion development.

The Steppe zone is characterized with the predominance of evaporation above the sediments and arid phenomena. Amount of precipitation varies from 310 mm in the southern part (dry steppe) to 500 mm in north adjoining to the Wooded-Steppe zone. Because of the moisture scarcity and high risk of arid phenomena, the yield of all crops in the majority of years appears sufficiently low without irrigation. Soil cover is chernozems and chestnut soils. The combination of sufficiently complex relief, shower nature of sediments, and in some years – the intensive wind regime creates high risks of both the water erosion and deflation.

Erosive deterioration of soil resources negatively influences on the fertility of soils and yield of agroecosystem. The intensification of agrarian production manifested in increase in the areas of sowing field crops, strengthening the shower nature of sediments and wind regime strengthens the risks of erosive processes and arid phenomena in the enormous territory – to 15−16 million ha, *i. e.*, on half of the arable earth areas. In such conditions the creation of up-to-date system for monitoring the above mentioned negative phenomena, also using the data of the Earth's remote sensing (ERS) becomes urgent.

Traditionally the aerial survey materials together with ground observations were used for the detection of erosive processes. However, the space photos are more widely used since the starting of space surveying systems. The current availability of the high spatial resolution images obtained from the surveying systems of land satellites – Landsat 8, SPOT, ASTER, RapidEye – makes it possible to identify the three-dimensional erosiveness of soil cover and gully systems. Exactly that caused the need for development and approval of the water erosion classification models for agrolandscapes using the data of the multi-area high spatial resolution space survey.

The aim of the current research consisted in the data analysis obtained from the space survey for monitoring and strategic estimation of agrolandscapes and soil management systems erosive deterioration.

MATERIALS AND METHODS

For identification of the objects of sheet and linear erosion the data of the Landsat-8 2013 space survey (US Geological Survey website – http://earthexplorer.usgs.gov/) and the materials of the ASTER and RapidEye space surveys, also literal and map materials and data of full-scale ground observations are drawn.

The research was performed through the random network of the agrarian testing areas (ATA), which ensure the territorial ecological monitoring system within the limits of administrative units. At the same time the ATA random network was used for the training data obtaining, necessary for developing the target processing algorithms for the materials of remote survey in course of the inspection of large territories within the limits of homogeneous regions.

The erosive receptivity of soil was determined according to such properties as the agrophysical properties, humidity, moisture permeability, density, roughness and organic matter content. It was also considered that the spectral characteristic was caused by the humus content, the presence of moisture, oxides of iron and ground minerals. The regularity, which consists in the dependence of a change in the spectral indices of soil on the loss of humus and connections to iron from the upper layer, was also taken into account. The mother rock becomes gradually visible on the surface of eroded soils, what causes its brightening. In course of the quantitative determination of similar changes through the spectral indices, according to the data of multi-area space surveys, the three-dimensional estimation of the soil cover erosiveness was carried out, and so, the intensity of erosive processes was determined.

Scientific rationale for the methods of soils remote explorations is described in the works of many scientists in 1970−1990 years [3−8]. The basic factors influencing a change in the spectral parameters of soils are determined, which made it possible to identify not only their basic varieties, but also erosiveness rate [9−16].

As a result, the prerequisites for development and applying of methods and technologies of the eroded earth automated classification are created. The combining of the data from various surveying systems and regression models of the erosion and its intensity determination from the values of spectral reflection gives opportunity to determine the spatial distribution of the soil erosiveness in the agrolandscapes sufficiently satisfactorily.

For detection the sheet erosion applying space data two approaches connected to the state of the earth's surface were used: the plowed soil and covered with plants. The first approach resides in the definition of such decoding signs as the spectral characteristics of soil depending on the humus content and other characteristics, i.e., the basic object of study is the surface of soil directly [7, 8, 10, 13, 14, 16], while the second one is based on determining of the vegetation spectral properties caused by the soil erosiveness and consists in the estimation of the plants biomass [11, 12, 17, 18]. It is stated that complex use of both approaches is reasonable for the determination of soil erosiveness. They supplement each other, and also reflect various, though tightly interconnected manifestations of erosive processes and state of vegetation completely and thoroughly.

The degree of the gully erosion development was determined according to the indices of gully rate within the territory, thickness, density and length of gullies [19].

The *gully rate* was determined as the ratio of the gullies area (ha) to the area of the arable earth (1 km/km^2), *density* – as a quantity of gullies to 1 km^2; while the gully rate is calculated for the total area, *gullies length* – for the overall length of gullies per unit of area.

RESULTS AND DISCUSSION

On the basis of the literature review and completed researches analysis the logical model for soil water erosion determination and identification was developed on the ERS data of high spatial resolution. It is based on the complex use of the space survey data, current map-

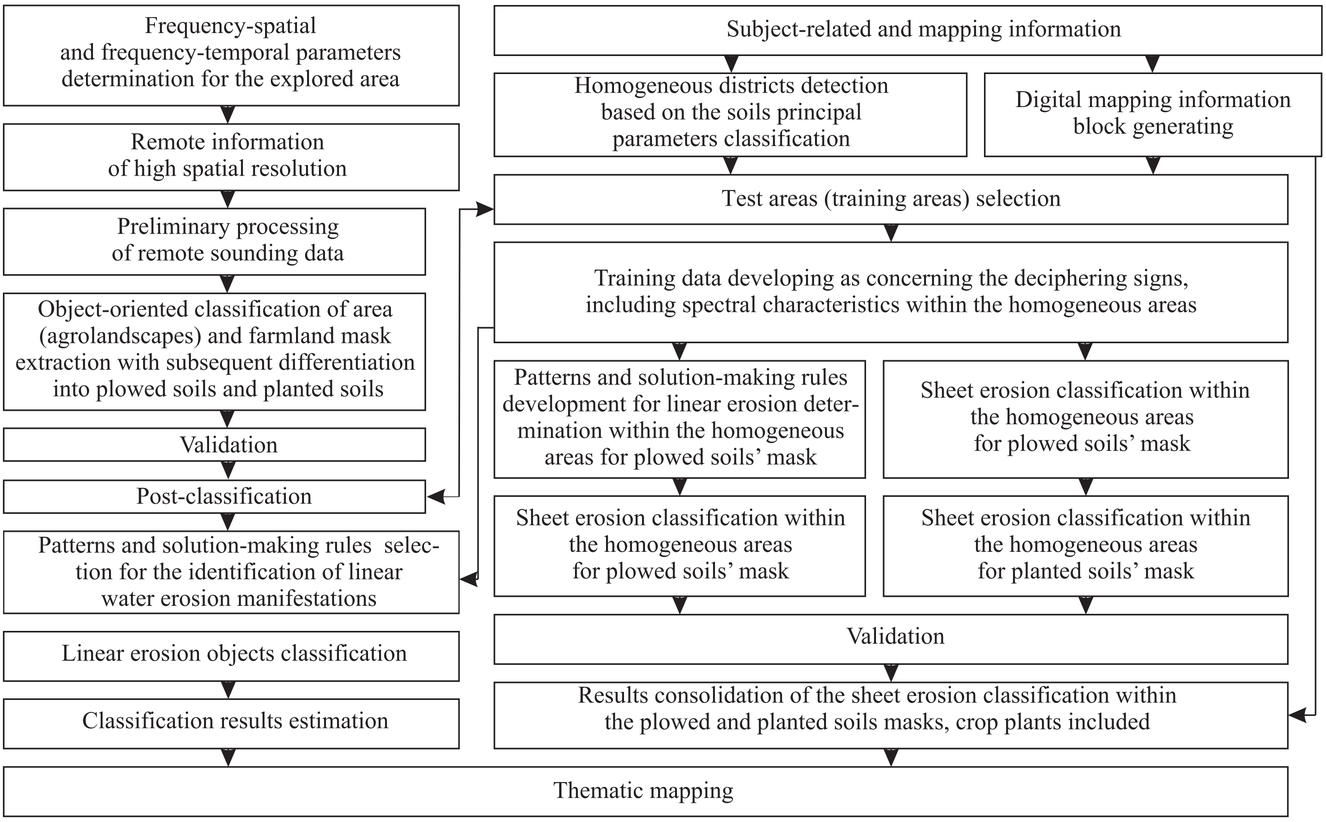


Fig. 1. Logical model of soil water erosion classification based on material obtained from remote survey of high spatial resolution

ping information and reference subject data relative to the characteristic of soil cover (Fig. 1). Water erosion was identified on the basis of classification according to the basic deciphering signs within the limits of optically uniform characteristics of soil areas, geostatistical analysis and mathematical simulation of the humus content at various erosiveness rates of soil with the subsequent three-dimensional mapping simulation of erosive deterioration.

During the first stage of the model implementation the object-oriented classification is carried out on the base of the formalized expert knowledge concerning the signatures of signs (spectral, structural, textural and contextual) for identification of the agricultural land class (mask) with subsequent differentiation to the classes “plowed soil”, “crop planted soil” and “wild planted soil”.

It is reasonable to use both the images of the multi-area space shots and NDVI and textural indices prepared in the stage of ERS preliminary processing as the initial informative layers for the solution of the task – the object oriented classification of the agricultural lands mask [20]. Having shaped the hierarchy of classes and established solution-making rules and threshold values for each class, classification is accomplished at the levels, which, for example, identify sowing of winter cultures and natural vegetation, at that false single objects are moved away.

The next stage of classification is the development of the solution-making rules for determination and identification of the water erosion manifestations based on the ERS materials. In this respect the procedure of the training samples obtaining becomes necessary. It is the required technological element of aerospace explorations and used for creating of regression models and determination of decoding signs.

Afield, diagnostics of the soil erosiveness gradations is carried out through their morphological signs – soil washing degree of various genetic horizons. At the moment the approaches to the classification of the eroded soils are divided into two large groups: the procedures establishing the soil washing degree on the decrease of their genetic profile, and the procedures determining the soil erosiveness degree on the humus content decrease.

For the standard of diagnostics of the eroded soils according to the soil washing degree the similar “typical image” of the complete-profiled soil is accepted, which, as a rule, is typical for the plateau. Performing the mapping, for example, of chernozem soils a diagram of soil classification according to the erosiveness degree is used basing on their coloring: for weak erosiveness – slightly-light, average – light, and strong – bright.

Taking into account that there are no standard models for the indication of the typical soil differences

Fig. 2. Gully erosion manifestations from the high spatial resolution materials: 1-rain channels; 2-top cutting-in; 3-, 4-micro-gully erosion; 5-sheet erosion (satellite survey SPOT, spatial resolution – 5 m, April 2013)

erosiveness according to the spectral signs, general approach to the determination of these signs (indicators) is obtaining the data directly at the test areas and topographic profiles within the explored territory. The selection of the massif of points for the training samples and validation of the results of deciphering is achieved within the optically uniform soils at the territories. They are formed on the basis of clustering the data in the content of physical clay in the soils located within the explored territory.

But a significant quantity of soil patterns, necessary for the training samples, and also large volume of analytical works never ensure the effectiveness of obtaining the data. It appears to be more acceptable the determination of the humus content from the spectral characteristics directly afield using the calculated mathematical-statistical connection models. The volume of the training samples under these conditions is decreased by the data reduction, necessary for calculating models. The rest of the training samples' volume for identification of the eroded areas is determined directly according to the data of field spectrometry. During the application of this technology the expenditures and duration of work performing on the three-dimensional determination of the soil cover degree erosiveness decrease.

Linear erosion classification. The classification opportunities of the linear forms of erosion, according to the data of the aerospace survey of high spatial resolution, are determined by their geometric and optical characteristics and three-dimensional and radiometric permission of the remote survey systems.

Components and forms of the gully erosion are possible to be obtained only from the space shots of the highest spatial resolution (up to 5 m) in the form of the narrow, notched, sharp contours. Due to the washout of soils, the tone of the image of the growing gullies is usually very bright (Fig. 2). It is possible to judge about the stage of their development and degree of the erosive processes activity from the shape, size and special features of the gullies image. Intensive growing water-ruts and gullies at the initial stage of their development have wide oval top with the steep rear wall, while the ravines completed their linear increase – the plane-pointed top and more gently sloping turfen slopes.

As a rule, the components of the hollow system are not reflected in the space photographs with the separation power of more than 10 m, but the network of gully relief with an elongated twisting treelike form is well separated. Both bottom and slopes of gullies are usually covered with the natural vegetation, thicker and more hydrophilic in the lower parts of the slopes and at the bottom, which causes the darker tone of their image. The treelike figure of image caused by the intensive

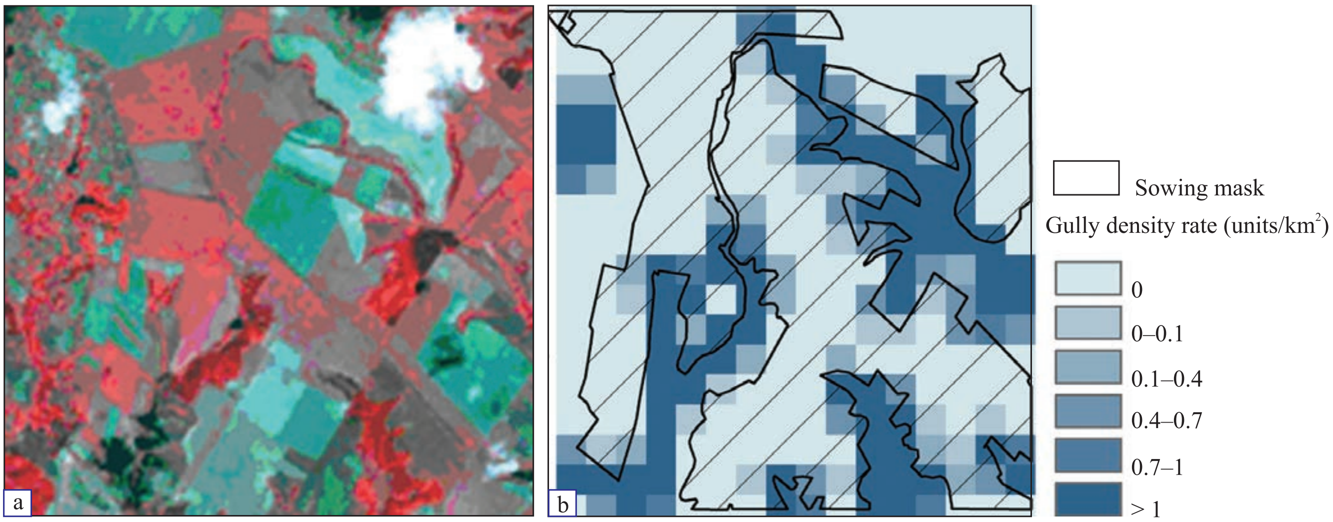


Fig. 3. Results of gully network deciphering at the high spatial resolution space shot: (a) ASTER shot, spacial resolution – 15 m, May 2003; (b) gully density map charted on the results of deciphering within ATA

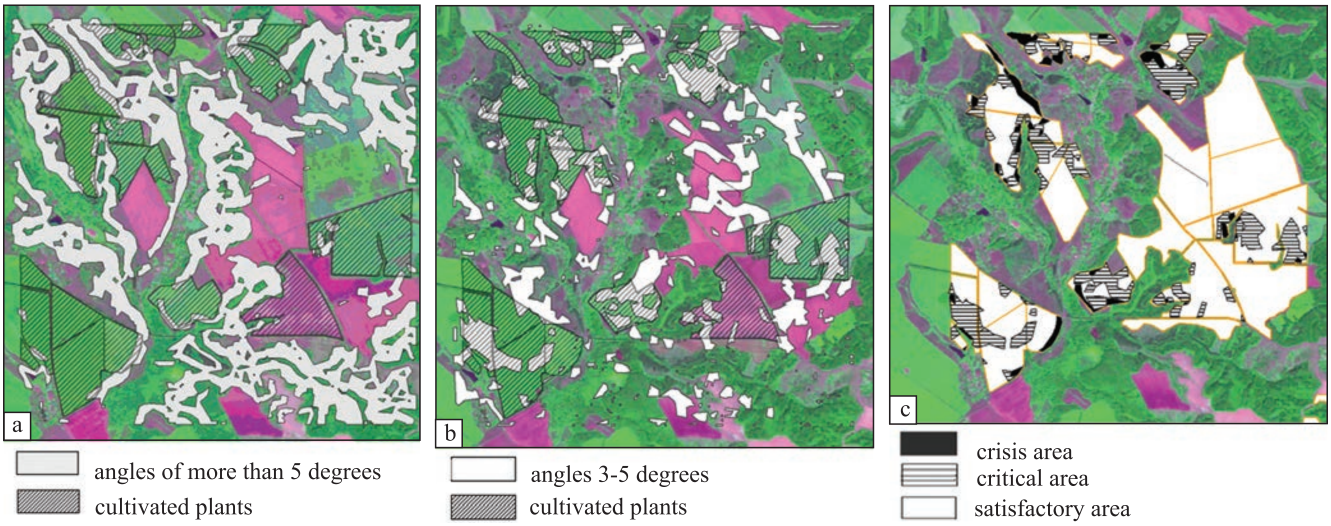


Fig. 4. Determination: (a) cultivated plants at slopes >5° (crisis area – 4.93 % of plowed lands); (b) cultivated plants at slopes 3–5° (critical area – 17.24 % of plowed lands); (c) risk estimation of erosive processes development at the plowed lands

development of linear erosive processes is the characteristic feature of the photographs of gully network in general. The gully network is especially clearly manifested with the natural grassy vegetation in spring and autumn against the general background of maximum plowed fields, though not yet covered with sprouts (Fig. 3, *a*).

As a result of linear erosion objects deciphering based on materials of the prompt space survey the integrated map of the cultivated land's gully rate is generated. Basing on it, the intensity of linear erosion both for separate farms and administrative units is evaluated. An example of the gullies and their density decoding within the limits of test area on the data of the space survey of high spatial resolution from Aster, are given on Fig. 3, *b*.

For the cultivated area specification on the risk degree of the erosive processes development, the arable soils are divided into three ecological-technological groups (ETG) according to the soil protection system of the area and its outline-reclamation organization [19]. In particular, the 1st ETG includes the soil with the full-profiled and slightly-eroded soils located on the plateaus and slopes up to 3°, where it is permitted to place all cultures together with the field ones. The 2nd ETG includes the lands with slightly- and medium-eroded soils located on the slopes of 3−5°, where grain-grass and grass-grain crop rotations without field crops are introduced. The 3rd ETG includes slopes of more than 5° with middle- and heavy-eroded soils, which must be derived from the category of the arable lands for conservation with the subsequent natural and artificial meadows or foresting.

Thus, the estimation of the arable land area as for the risk degree of the erosive processes development by virtue of the sowing classification within the arable land mask by grouping into continuous sowing cultures, field crops and perennial grass according to the space survey data is important in this respect. Basing on combined analysis of obtained data joined to the map of slope angles, the area chart is compiled for the estimation of the area as for the risk degree of the erosive processes development and determination of share of the soils in critical and crisis state, which must be derived for conservation.

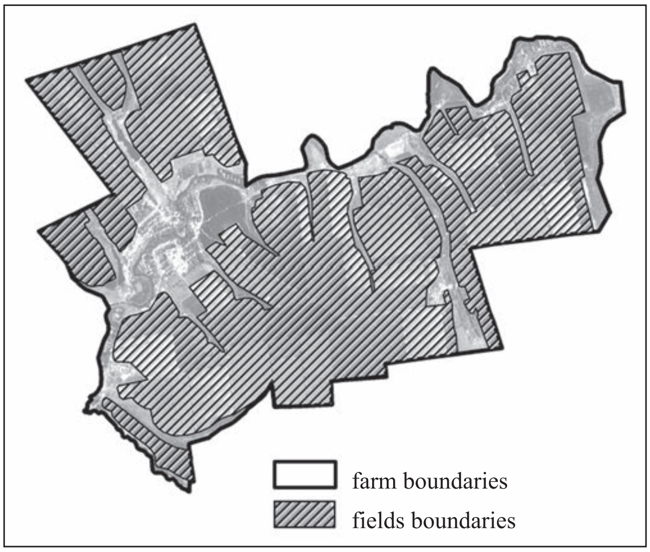


Fig 5. The "plowed soils" mask classified within the testing farm of Kirovohrad Agrarian Testing Area

The determination of the crisis (field crops at the territories with the slope angle > 5°) and critical state territories (field crops at the territories with the slope angle > 3−5°) according to the space survey data of high spatial resolution combined to the geographical three-dimensional data concerning the quantity indicators (morphological measures) of relief (in particular, slope

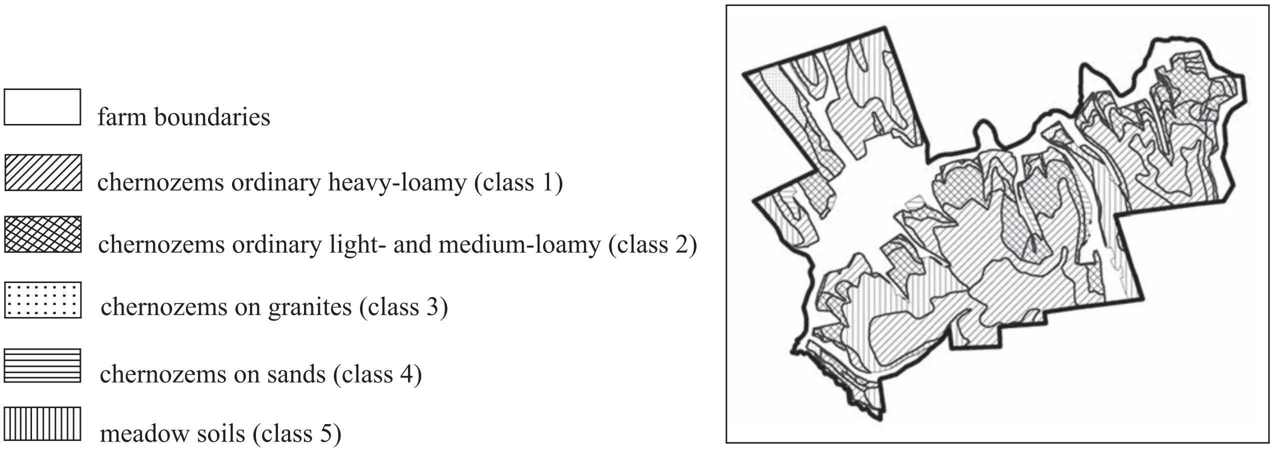


Fig. 6. Optically-uniform soil classes chart within the plowed lands of the Kirovohrad ATA testing farm

angles) allows to establish promptly the norms of the ecologically substantiated structure of planted areas and crop rotations as per the risks of the erosive processes manifestation [21]. The results of processing the space survey materials from the RapidEye satellite regarding the crisis and critical territories are represented in Fig. 4.

Sheet erosion classification and determination of the erosiveness degree of the arable lands. For the classification of sheet erosion materials of spatial resolution up to 30 m were used. The data obtained from Landsat meet these requirements. The sheet erosion classification is carried out on the basis on materials of the survey dated on April 17, 2013

According to logical model (Fig. 1), within the test farm of the Kirovohrad agrarian test area the “plowed soil” mask is classified (Fig. 5), also classes of uniform soils are isolated according to their optical characteristics on the basis of the data on physical clay content.

Within the “plowed land” mask five soil classes were isolated (Fig. 6). The analysis of the uniform soil classes areas states that the basic (background) classes are: chernozems ordinary heavy-loamy (class 1) and chernozems ordinary light- and medium-loamy (class 2), their combined rate is 80 per cent of the total area. The area of the fifth class is equal to only 2 per cent of the total area, but after joining to the fourth class, which spectral properties are very similar, they occupy together about 5 per cent. Therefore, these two classes were united for the development of the multiple regression models.

The radiometric characteristics in the separate channels of the shot were determined, samples for the uniform classes were formed and the correlation matrix of the radiometric characteristics together with humus content were calculated for each point of the training samples within the uniform soils classes (Table 1).

The negative values of the correlation between the spectral values and humus content were observed. Furthermore, it turned out that for each soil class high correlation coefficient has different combination of

Table 1. Landsat Spectral and Spatial Parameters and Pair Correlation Coefficients for Humus Content and Radiometry*

Spectral channel	Wave length, µm	Spatial resolution, m	Chernozems ordinary heavy-loamy (class 1)	Chernozems ordinary light- and medium-loamy (class 2)
R 1	0.433–0.453	30	−0.08616424	0.17508811
R 2	0.450–0.515	30	−0.18671322	−0.13465445
R 3	0.525–0.600	30	−0.38384836	−0.14096474
R 4	0.630–0.680	30	−0.32709449	−0.43665725
R 5	0.845–0.885	30	−0.31383183	−0.00590255
R 6	1.560–1.660	30	−0.27921164	−0.29464546
R 7	2.100–2.300	30	−0.16285069	0.0224444
R 8	0.500–0.680	15	0.14082281	−0.16322813
R 9	1.360–1.390	30	0.44868727	−0.1352743
R 10	10.30–11.30	100	0.48759112	0.17323846
R 11	11.50–12.50	100	−0.08616424	0.21780346

* The training sample for the 3rd and 4th classes was too negligible for two classes formation.

spectral channels. This confirms the expediency of soils subdivision.

The multiple regression equations were calculated and validated by the method of multiple regression for each sample. For the first soil class the total value of regression for the dependent variable composed 0.85391, for the second class – 0.799607. According to the results of validation absolute error for the first class was equal to 0.32 per cent, for the second one – 0.28 per cent, relative error – 9.0 per cent and 7.4 per cent respectively. At the following stage the humus content was estimated with the application of a scanning calculator basing on the output photograph within the separate uniform class and corresponding plural linear regression equation (Fig. 7).

For the differentiation of the erosiveness (washout) degree the data on the humus content in various genetic horizons of the soil profiles are used, which were allowed for various soil classes, and also for various sections of the researched area from the point of view of morphometry (slope angles). Thus, the appropriate gradations of the erosiveness classes are obtained for each uniform region (Fig. 8, a). The automated generalization (post-classification) of image is carried out after decoding, which consists in the removal of small outlines.

The determination of erosiveness on the plant cover. The erosiveness degree was estimated using the data of high spatial resolution from the RapidEye satellite dated on April 11, 2009. Within the agrarian test area located in the Myronivka district of Kiev region, one uniform soil region – deep low-humus chernozems – is determined, and also the distribution of the mask of the arable land into three classes is carried out: the plowed soil, the soil cropped with winter cultures and the unplowed soil. The selection points of the training samples were within the plowed land and winter cultures sowing.

Within the selected class of winter cultures sowing the brightness index (*BI*) proposed by Mathieu [11] is used for the classification of sheet erosion as the mediate indicator. The index is calculated with the following formula:

$$BI\,(x) = \sqrt{\frac{(R_{green}(x))^2 + (R_{red}(x))^2}{2}},$$

where *R* is the spectral brightness coefficient for the correspondent channel. For the RapidEye data it has the following shape:

$$BI = \sqrt{\frac{R2^2 + R3^2}{2}},$$

while for the spectral range “red edge” –

$$BIRE = \sqrt{\frac{R2^2 + R4^2}{2}}.$$

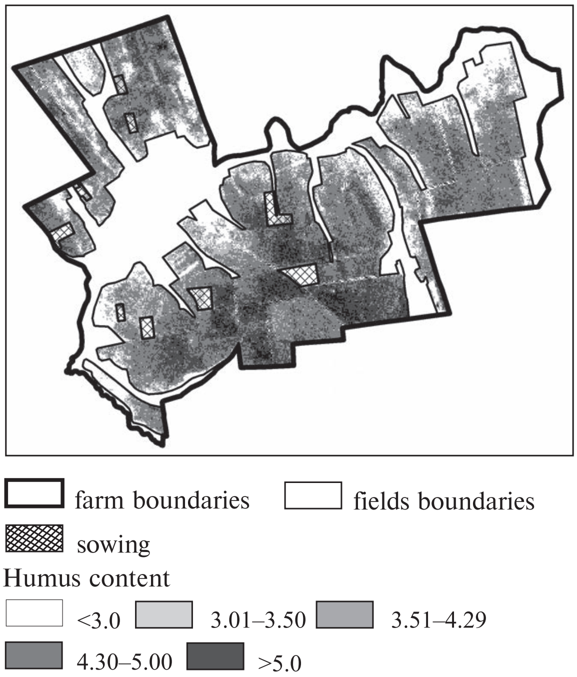


Fig. 7. Humus content distribution chart generated on the basis of the space survey data

The following vegetation coefficients were estimated:

$$NDVI = (R5 - R3)/(R5 + R3)$$
$$\text{and } NDVIRE = (R4 - R3)/(R4 + R3),$$

where *Ri* is i^{th} spectral channel of the RapidEye satellite.

The generated correlation matrix (Table 2) allowed to calculate the multiple regression equation for the plowed soils:

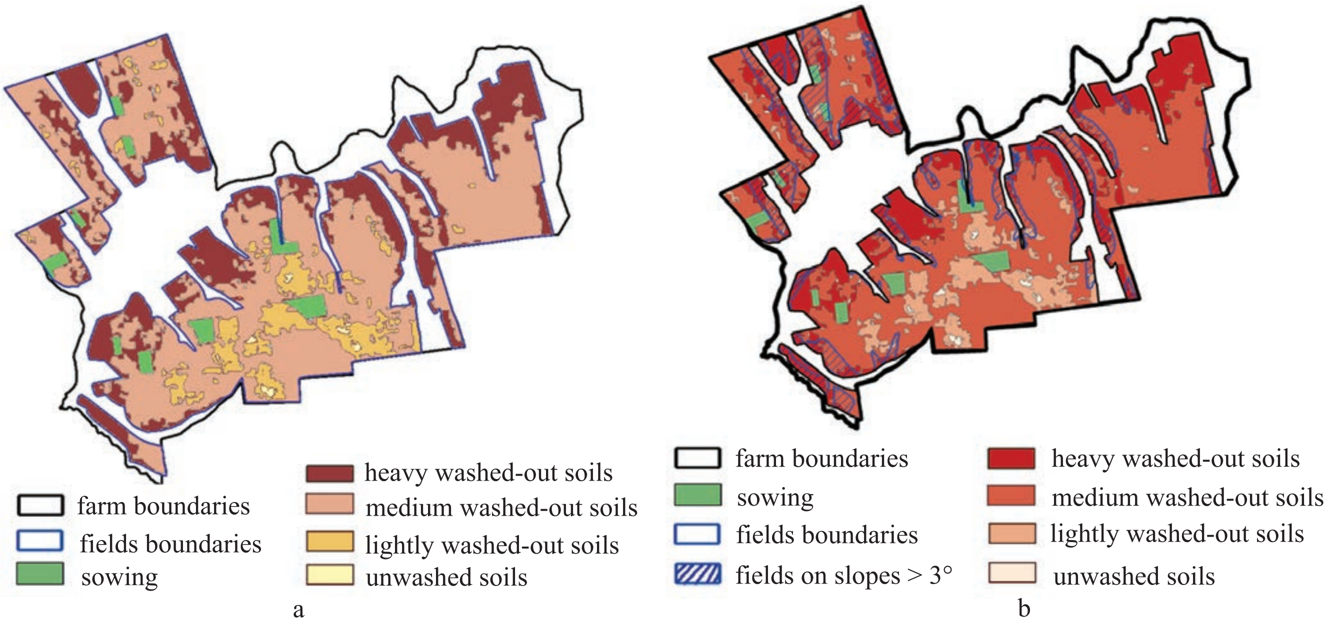
$$H = 9.902789 – 0.062484 \cdot R2 + 0.014422 \cdot R3 – \\ – 0.006204 \cdot R4 + 0.013109 \cdot R5,$$

where *H* is the humus content, also for the soil planted with winter cultures,

$$H = 5.5626 + 2.0184 \cdot NDVIRE43 – 0.0187 \cdot BI.$$

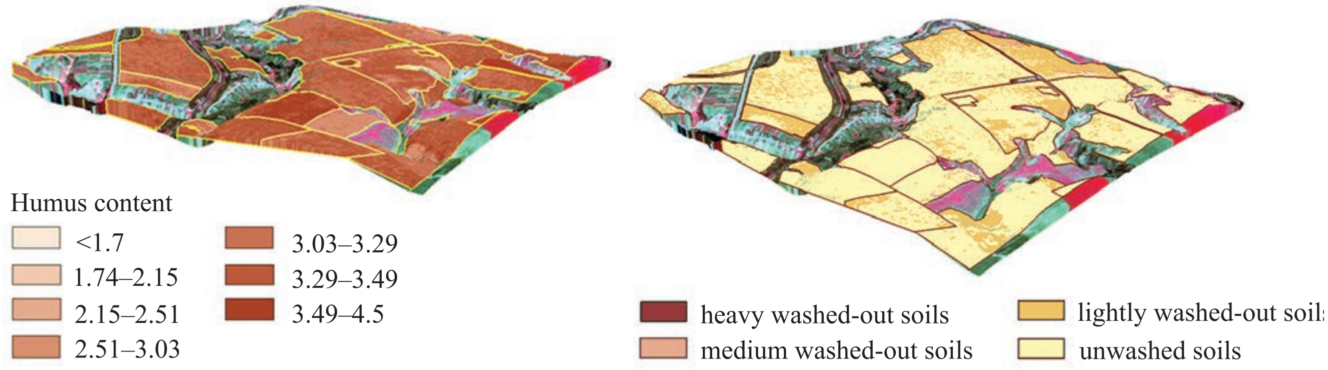
Table 2. Pair Correlation Coefficients for Humus Content, Radiometry and Vegetation Indexes as Reported by Rapid Eye for Uniform Soil Class on ATA Myronivka District, Kyiv Region

Vegetation Index, Channel, nm	“Winter Cultures” Class	“Plowed Soils” Class
R2 (green), 520−590	−0.632	−0.690
R3 (red), 630−685	−0.553	−0.319
R4 (red edge), 690−730	−0.242	−0.301
R5 (near-infrared), 760−850	0.438	−0.368
NDVI	0.519	
NDVIRE43	0.578	
BI	0.593	
BIRE	0.479	



a b

Рис. 8. Soils erosion chart (a) joined to slopes angles chart (b) classified on the Landsat 8 data



a b

Fig. 9. Humus content (a) and soils erosiveness (b) estimation within ATA at plowed lands and planted with winter crops on the RapidEye data

The total value of regression for the dependent variable composed 0.78198 for the class "plowed soils", while 0.78566 for the class "winter cultures". According to the results of validation, the absolute error for the plowed soil was equal to 0.27 per cent, and for the soils planted with winter cultures – 0.29 per cent, while the relative error was 9.0 per cent and 8.1 per cent respectively.

Further technological steps in data processing are identical to the classification of the sheet erosion as for the plowed soil and are completed with mapping of the eroded soils (Fig. 9).

Risk estimation of the erosive processes development. The rate of fields on the slopes of more than 3° was used as the indicator for the risk estimations of the erosive processes development within either the separate agrarian farm, or administrative unit. If it comprises less than 10 per cent of the arable territory, the area has the weak level of the erosion manifestation risk; from 10-20 per cent – the average level of erosive risk, more than 20 per cent – the critical level of erosive risk. These data are used for substantiation and developing the anti-erosion measures, among which is the contour-reclamation management, soil management system and planted areas structure correction.

So, for example, the total area of agricultural land in the Kirovohrad ATA testing farm composes 47.67 km^2, while the area of fields on the slope of more than 3° is 14.7 km^2, according to the ERS data, which corresponds to 31 per cent of the total area (Fig. 8, *b*). Thus, the farm has the critical level of erosiveness risk and requires implementation of the soil protection contour-reclamation system.

CONCLUSIONS

Application of contemporary information technologies of the Earth remote sensing, together with geo-

information and global positioning technologies provides the opportunity of prompt obtaining information about the propagation of soil erosive deterioration in the agrolandscapes over the large territories and carrying out the reliable updating of information about the state of soil cover, in particular, the three-dimensional propagation of water erosion both within the limits of separate agrarian farms and administrative units.

The ability of the soil water erosion degree classification according to the data of the up-to-date ERS multiarea systems of high spatial resolution is proven. The logical models of determination and identification of soil water erosion and automated classification models of this process according to the ERS data are proposed.

The materials of the remote determination of the erosive processes risk is the fundamental base for planning of development and implementation of measures for the optimization of the agricultural landscapes structure and soil management systems, also for the creation of the soil economical utilization and protection programs, introduction of soil- and water-guarding measures in the agrolandscapes.

Космічні технології в системі агроекологічного моніторингу

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Сучасний розвиток систем дистанційного космічного знімання та елементів геоінформаційних технологій відкриває принципово нові можливості контролю, прогнозування та інтерпретації даних агроекологічного моніторингу. **Мета**. Охарактеризувати зональні природно-кліматичні умови території України, її сільськогосподарську освоєність та ризики проявів ерозійна деградація ґрунтів у контексті кліматичних змін. Визначити фактори, що впливають на спектральні характеристики еродованих ґрунтів, для їхньої ідентифікації дешифрування та моніторингу деградації агроландшафтів і систем землекористування за супутниковими даними. **Методи**. Розроблено логічну модель визначення та ідентифікації водної ерозії за даними дистанційне зондування Землі (ДЗЗ) високого просторового розрізнення на основі класифікації за основними дешифрувальними ознаками та процедури формування навчальної вибірки. Для ідентифікації процесів площинної і лінійної ерозії використано матеріали космічного знімання Landsat 8, SPOT, ASTER і RapidEye, картографічні матеріали та дані натурних наземних спостережень на тестових об'єктах. Застосовано два під-ходи щодо визначення ерозії ґрунтів. Перший – ґрунту стані розораності і другий – ґрунт під рослинним покривом. Ступінь еродованості ґрунту визначали за спектральними характеристиками та вмістом гумусу, яружності − за площею і протяжністю ярів. **Результати**. Запропоновано визначати вміст гумусу в ґрунті за просторовим розподілом спектральних характеристик у межах однорідних районів та відповідними математико-статистичними моделями. Показано можливості класифікації лінійної і площинної ерозії за даними ДЗЗ, а також їхнє використання в системі моніторингу та оцінки екологічного стану агроландшафтів і систем землекористування. **Висновки**. Дані космічного моніторингу ерозійної деградації ґрунтів і в цілому агроландшафтів дають можливість більш ефективно використовувати земельні ресурси за рахунок оперативного визначення деградаційних процесів з наступним плануванням і розробкою заходів з оптимізації структури ерозійно небезпечних агроландшафтів, а також впровадження ґрунтоводоохоронних систем землекористування.

Ключові слова: земельні ресурси, ерозійна деградація, дистанційне зондування, моніторинг, клімат.

Космические технологии в системе агроэкологического мониторинга

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Современное развитие систем дистанционной космической съемки и элементов геоинформационных технологий открывает принципиально новые возможности контроля, прогнозирования и интерпретации данных агроэкологического мониторинга. **Цель.** Охарактеризовать зональные природно-климатические условия территории Украины, ее сельскохозяйственную освоенность и риски проявлений эрозионной деградации почв в контексте климатических изменений. Определить факторы, влияющие на спектральные характеристики эродированных почв, для их идентификации, дешифрирования и мониторинга деградации агроландшафтов и систем землепользования по спутниковым данным. **Методы.** Разработана логическая модель определения и идентификации водной эрозии по данным дистанционного зондирования Земли (ДЗЗ) высокого пространственного разрешения на основе классификации по основным дешифрующим признаками и процедуры формирования обучающей выборки. Для идентификации процессов плоскостной и линейной эрозии использовали материалы космической съемки Landsat 8, SPOT, ASTER и RapidEye, картографические материалы и данные натурных наземных наблюдений на тестовых объектах. Использованы два подхода для определения эрозии почв. Первый – распаханная почва и второй – почва под растительным покровом. Степень эродированности почвы определяли по спектральным характеристикам и содержанию гумуса, яружность − по площади и протяженности яров. **Результаты.** Предложено определять содержание гумуса в почве по пространственному распределению спектральных характеристик в пределах однородных районов и соответствующим математико-статистическим моделям. Показаны возможности классификации линейной и плоскостной эрозии по данным ДЗЗ, а также их использование в системе мониторинга и оценки экологического состояния агроландшафтов и систем землепользования. **Выводы**. Данные космического мониторинга эрозионной деградации почв и в целом агроландшафтов дают возможность более эффективно использовать земельные ресурсы за счет оперативного определения деградационных процессов с последующим планированием и разработкой мероприятий по оптимизации структуры эрозионно опасных агроландшафтов, а также внедрения грунтовых водоохранных систем землепользования.

Ключевые слова: земельные ресурсы, эрозионная деградация, дистанционное зондирование, мониторинг, климат.

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