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REMOTE IDENTIFICATION OF MICROSEDIMENTAL RELIEF FORMS AND SOIL SECTIONS OF AGROLANDSCAPES OF THE FORESTS OF UKRAINE WITH SIGNS OF HYDROMORPHISM

(Представлено членом редакційної колегії д-ром геол. наук, ст. дослідником О.І. Меньшовим)

B a c k g r o u n d . ***Agricultural lands play a key role in ensuring the food security of the population and the development of the country's economy. However, excessive wetting poses a significant threat to these lands, as a result of which the conditions for the formation of soils with signs of glaciation and low fertility are formed within the lower relief elements, which significantly reduces their potential. In order to highlight the problems of geospatial identification of micro-recessed landforms (MRLF) on agricultural lands, the article uses spectral indices based on the data of RSE.***

M e t h o d s . ***6 spectral indices were selected for the research. They were used to obtain data on areas of soil subsidence on arable lands, namely: NDWI, NWI, NDMI, NDVI, OSAVI, WRI. Solving research tasks involved the use of data from the Sentinel-2A satellite system. In order to visualize the spread of MRLF on the research territory, a high-resolution image (0.2 m per 1 pixel) obtained in the "Digitals Professional 5.0" software was used. Processing and geospatial visualization of the RSE data were performed in the Arc Map environment of the Arc GIS 10.8 program using the raster calculator tool.***

R e s u l t s . ***Within the reference fields, the dynamics of the values of water and vegetation indices were constructed and analyzed, and the identification ability for the geospatial separation of soil areas with signs of hydromorphism was evaluated. It is shown that the identification capacity of the indices depends not only on the level of soil moisture, but also on the biomass of vegetation (scales of crop damage), which is indicated by the high information capacity of the traditional vegetation index NDVI. The most informative index ranges were established: for NDVI, the range is from -0.117 to -0.024 with an identification percentage of 98.0 %; for OSAVI – 78.0 % with a range of 0.255–0.313; for NDMI with a range variation of -0.041 to -0.149 and an identification percentage of 56.0.***

C o n c l u s i o n s . ***The results of remote identification of the areas of the MRLF enabled to obtain information about the moisture content of the soils of the arable lands of the research area. The ability of the specified indices during the geospatial identification of micro-recessed landforms (MRLF) and soil areas within them with signs of hydromorphism was evaluated.***

It is demonstrated that the use of orthophotos with a resolution of 0.2 m per 1 pixel serves as important supporting aids of successful completion of the specified tasks. It was found that the identification ability of water indices on test fields without existing vegetation is too low. On the other hand, the shielding of the soil surface by vegetation with areas of damaged crops makes it possible to isolate MRLF.

The obtained information can be used during the development of the methodology of soil science surveying and planning of large-scale soil survey activities.

K e y w o r d s : ***micro-recessed landforms (MRLF), subsidence, remote sensing of the Earth (RSE), spectral indices of vegetation and moisture.***

Background

The study of the condition of the soils of agro-landscapes is one of the urgent problems related to important aspects of the modern functioning of any state. Agricultural lands play a key role in ensuring the food security of the population and the development of the country's economy. However, excessive moisture poses a great threat to these lands, as a result of which the conditions for the formation of soils with signs of glaciation and low fertility are formed within the lower relief elements, which significantly reduces their potential. To solve the problems of geospatial identification of defined areas of soil cover and areas of lowered relief elements on agricultural lands, methods of remote sensing of the Earth (RSE) are increasingly being used. The use of RSE tools makes it possible to obtain up-to-date and accurate information about the condition of individual plots of land, monitor, control and forecast the impact of various factors on their condition. The study of this issue is of great importance for preserving soil fertility, ensuring the sustainability of ecosystems and their stability. In addition, the development of algorithms for the automated identification of areas and areas of soil cover that are in a state of periodic and long-term waterlogging is important, because they provide for the possibility of isolating soil areas with signs of siltation and siltiness.

Micro-recessed landforms (MRLF) are known to be small hollows and depressions on the surface of the soil that arise under the influence of various processes (for example, erosion, landslides, waterlogging, and others). They can have a diameter from several tens of centimeters to several meters, a depth of several tens of centimeters and a shape of various complexity (Romanchuk, 2018). MRLF, as a rule, has a mostly negative impact on agriculture. However, in some cases, they can provide soils, especially the ones of light granulometric composition, with the characteristics of siltiness, which slows down unproductive infiltration along the profile and moisture loss and can be useful in dry regions or in conditions of reduced rainfall. At the same time, it should be borne in mind that the forms of relief mentioned above can be the cause of flooding of low-lying areas of the ground cover, which reduces the yield of cultivated plants or leads to their death.

As it was mentioned before, one of the key topics of research in the field of soil quality and condition research is the detection of subsidence or micro depressions that are formed in the fields. To study and monitor subsidence, scientists use data obtained from satellites, aircraft and other means of remote sensing. These data allow getting detailed information about changes in relief, soil moisture and plant parameters in the field. It is worth noting that the study of the formation of relief conditions at different levels of soil moisture can be carried out using two main approaches. The first one is based on the remote diagnosis of soil free from vegetation, when the value of the NDVI index does not exceed 0.1. The second one involves the use of RSE tools on areas of the ground cover covered with plants (shielded soil). The condition of the plant cover indirectly indicates the level of favorable conditions for their functioning under the influence of many factors, in particular, the availability of soil moisture (lack of moisture or its excessive amount) (I) and the level of their fertility (II), which largely depends on the presence of siltiness signs. The latter, as it is known, significantly reduces soil productivity due to the presence of toxic compounds in them.

Field research of MRLF is interdisciplinary in nature and it involves the work of scientists from various fields, such as geology, soil science, agronomy, hydrology, and others. It is aimed at understanding the causes of subsidence, determining their scale and developing effective strategies for managing soil and land resources. In particular, the problems of classification of MRLF that developed on agricultural lands of the reclamation system "Kuchynivka", located in the Shchor district of the Chernihiv region, were studied. In the work (Romanchuk, 2018) based on Sentinel-2 images and the NWI water index, soil moisture and MRLF were studied, as a result of which a map of soil surface layer moisture was constructed and the high efficiency of using the selected index for evaluating evapotranspiration was established . The use of the method of soil moisture research based on space images is described in the article of S.O. Dovhyy (Dovhyy et al., 2020). In the work (Slobodianyk, 2016), the methods of forecasting the yield of agricultural crops using remote vegetation indices PVI, SAVI, TSAVI, ARVI, GNDVI, NDVI were investigated, which made enabled to identify the problem areas of suppressed vegetation. In this case, it should be understood that crop yield data may indirectly indicate unfavorable moisture conditions that have arisen within the boundaries of the MRLF plots.

The causes of subsidence of the soil cover in the Central Valley, California were explored in the work (Stanko et al, 2019), where with the help of a model of the hydrological regime of the Central Valley created in GIS, the patterns of subsidence and their consequences were revealed in detail. The research investigated the features of using multispectral remote sensing from aboard an unmanned aerial vehicle (UAV) for mapping the state of water stress in corn in a farm which included the analysis of changes in the basic values of water stress and the corresponding values that are not associated with transpiration. The results demonstrated a high correlation between some vegetation indices and the water stress index. The specified demarcation made it possible to more clearly identify the regularities of the influence of various factors on the formation of water stress in plants, including the conditions of the MRLF.

Therefore, it should be stated that the study of formation, development of MRLF and territorial distribution of soils with signs of glaciation is an important scientific problem. Conducting an assessment of the structure of the soil cover should include remote identification of the above-mentioned areas, as well as provide for the development of algorithms for determining the danger of deterioration of their condition.

The article is devoted to the study of the features of the use of specialized indices of the state of vegetation and soil moisture obtained from the data of the RSE for the identification of MRLF with areas of soil cover that have signs of glaciation and calculation of their areas. The work solves the problem of developing an algorithm for the remote identification of defined problem areas of the soil cover based on the established ranges of water index values, characteristic of such areas. The geospatial separation of areas of the MRLF with areas of soil cover that have signs of glaciation involves a combination of spectrozonal images of the earth's surface and ultra-high resolution orthophotos.

The purpose of this study is to analyze areas of subsidence of agricultural land using remote sensing technologies, to substantiate the feasibility of their use to assess the condition of soils with signs of hydromorphism and to ensure the rational use of soil and land resources.

To achieve this goal, an analysis of literary sources is provided, data from field studies is collected and processed, and data from the RSE are used to obtain accurate maps of subsidence areas. The results of the research can become the basis for the development of effective methods of automated inventory of MRLF with soils with signs of siltiness located within them.

MRLF pose a problem for the use of agricultural land, because they concentrate excess moisture, which inhibits the formation of biomass of most plants. In addition, soils with gley genetic horizons are characterized by obstruction of vertical movement and horizontal redistribution of excess moisture, which creates anaerobic conditions for further gley formation. At the same time, oxides of iron and aluminum, which are toxic, are formed in the soil. Such soils have a low level of fertility, low productivity and quality of the crop. According to (Sherstyuk et al., 2021), an increase in production costs leads to a decrease in its profitability, environmental pollution and other related problems. In addition, MRLF can increase the risks of water erosion of soils and deflation, which in turn leads to physical losses of the soil, and as a result, to the development of practically non-renewable processes. That is why it is important to study MRLF in the fields of the research area. Boryspil district is located in the Kyiv region and is of great importance for the agriculture of Ukraine (fig. 1).

Characteristic elements of the relief in the research area are old rivers, lake depressions and dune formations (Martyn, Osypchuk, & Chumachenko, 2015). The background soils are: sod-podzolic soils on ancient alluvial and water-glacial deposits, moraine and loess rocks; podzolized soils mainly on loess-like rocks; meadow and chernozem-meadow soils on alluvial deposits; sod clay soils mainly on loess-like rocks. The research area is characterized by a high concentration of agricultural enterprises that specialize in the cultivation of plant products. Therefore, the efficiency of the use of agricultural land is an important component of achieving the maximum yield and ensuring the food security of the state. Micro-sags (subsidence) of soils in the research territory, which belongs to the Polissia zone of Ukraine, is one of the characteristic qualitative features of the soil cover of agricultural lands. Their presence negatively affects the growth and development of plants, reduces the yield of crops and the quality of products.

Therefore, when assessing the suitability of the soil cover for production tasks, it is advisable to take into account not only the presence of MRLF, but also the specifics of the impact on the soil in the short-term and long-term perspectives.

Micro-swelling (subsidence) of soils in the research area on the soil cover is differentiated by the nature of the manifestation of the negative impact of excessive moisture (fig. 2).

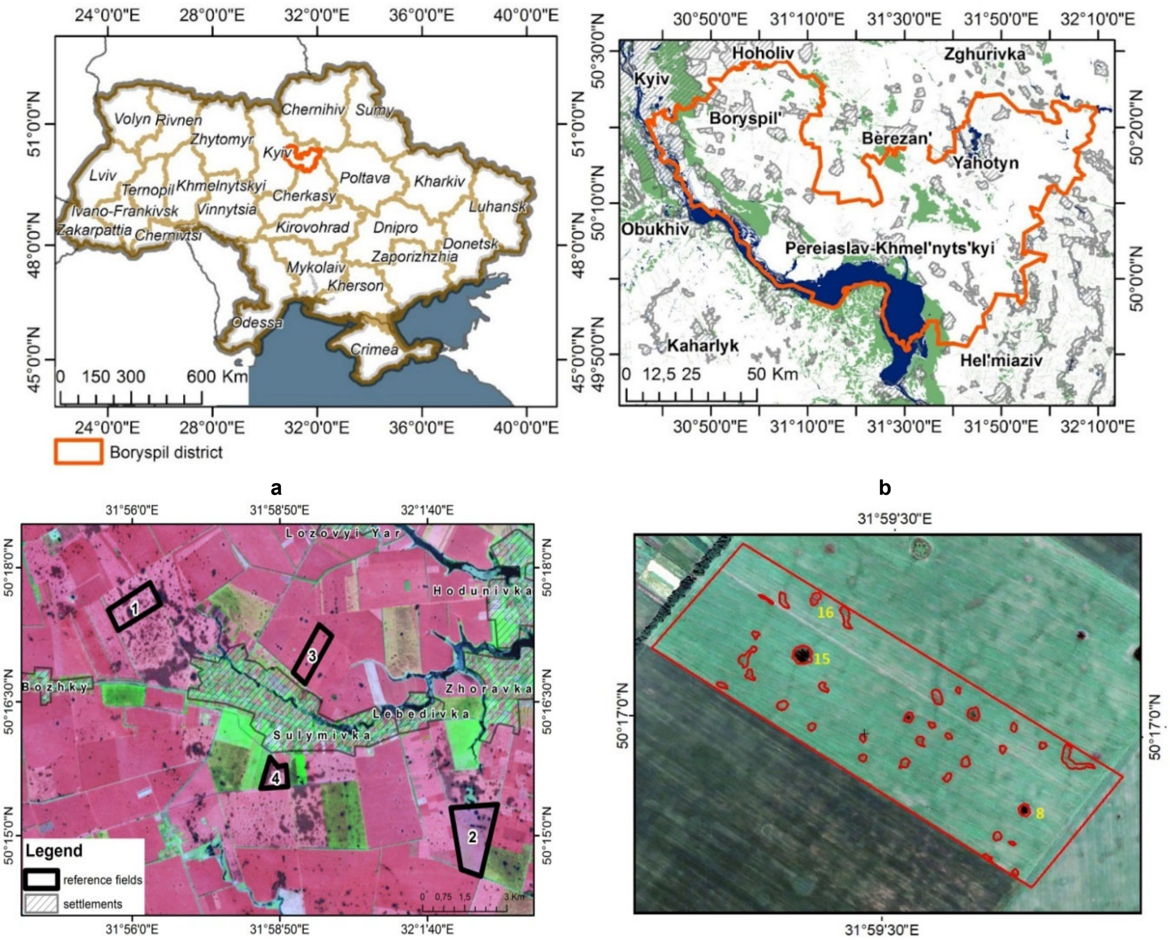


Fig. 1. General view of the research area and test fields:
a – a map of Ukraine with Boryspil district highlighted in red; b – Boryspil district in approximation;
c – test fields on the territory of the Sulymiv Territorial Community superimposed on the Sentinel-2 space image for April 18, 2018;
d – test field No. 3 with selected areas of MRLF (8,15,16) used for the identification ability of spectral indices superimposed on ultra-high resolution space images

Fig. 2. Micro-recessed landforms and their impact on soils and crops.
Ultra-high resolution composite images (0.2 m by 1 pixel) were obtained in Digitals Professional 5.0 software:
a, b – TRF No. 1 (arable land is overgrown with shrubs and young forest);
c – TRF No. 3 (figure shows the damaged areas of winter wheat sowing)

Their development leads to the transformation of arable land into forest plantations (see fig. 2a, b, c), cause irreversible changes in the soil, which reduces the yield of crops and the quality of products (see fig. 2a, b, c). The rest of the settlements, which are fixed remotely, belong to the elements of the nanorelief and are less harmful. However, the research program did not provide for the isolation of their habitats, because the processes of waterlogging and glaciation of soils can also occur within them, which is undoubtedly a negative phenomenon that requires an assessment and determination of the extent of the danger.

Methods

A characteristic feature of the state of vegetation, as one of the objects of the earth's surface, is its spectral reflectance, which is differentiated by differences in the reflection of radiation of different wavelengths. As it is known, to work with spectral information, RSE often resort to the creation of so-called "index" images. "Spectral indices", as indicators of the characteristics of the reflection of solar radiation from various objects on the earth's surface in different spectral ranges, are determined on the basis of mathematical operations with the spectral brightnesses of the imaging system obtained in different channels of the RSE (Kuchma et al., 2019).

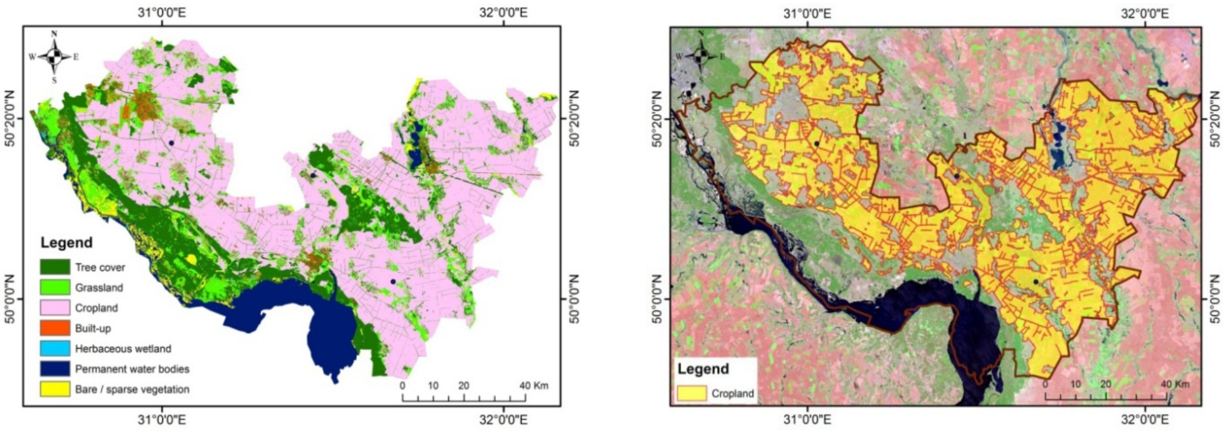
Earth remote sensing data from the Sentinel-2 satellite are publicly available at https://dataspace.copernicus.eu/browser and are part of the Copernicus program of the European Space Agency (ESA). In particular the use of Sentinel-2 data for soil research were studied.

Sentinel-2 satellite data with cloud cover <20 % were used to obtain maps of the territory's humidity and calculations of subsidence areas. Two scenes on the date: 04/18/2018 were selected for analysis. Calculations, execution of geoanalytical tasks and development of cartographic materials were performed in Arc GIS Arc Map 10x software.

In order to visualize the extent of the spread of MRLF on the research territory and their impact on the soil, a high-resolution image (0.2 m by 1 pixel) obtained in the "Digitals Professional 5.0" software, which was developed by the state research and production enterprise "Geosystem", Ukraine, was used.

The online resource EO Browser (https://www.sentinel-hub.com/explore/eobrowser/) was used to obtain graphs of changes in NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index) indices over the years. It should be noted that EO Browser combines many functions: data comparison, various automatic visualization parameters, channel synthesis, area measurement, obtaining statistical data in the form of graphs. Its application made it possible to obtain the dynamics of changes in the vegetation and water index and to export the received data in Microsoft Excel format for further analysis. The determined methodical approach made it possible to monitor and analyze the trends of changes in vegetation and water resources in the selected region during the research period.

During the calculation of the area of MRLF on agricultural land, all other classes of objects that are not agricultural land, but may be overmoistened, namely: urban agglomerations, hydrographic objects, forest massifs and other objects, are excluded. For this purpose, the classification map of surface types of Ukraine obtained from the ESA World Cover 2021 resource was used, which consists of 10 types of the earth's surface (Zanaga, Van De Kerchove, & Daems, 2021). One of which (cropland) was used to carve out an area of agricultural land. ESA World Cover is a map of land cover types with a spatial resolution of 10 meters created by the European Space Agency under the Copernicus Global Land Service (CGLS-LC) program. This map was built from annual Sentinel-1 and Sentinel-2 satellite images (fig. 3).



a b

Fig. 3. The input data of land surface types were used to create a mask of agricultural land within Boryspil district:
a – classification map of land surface types ESA World Cover 2021; b – the field mask superimposed on the Sentinel-2 space image for April 18, 2018 with a combination of channels 12,8A,4

The locations of the test reference fields (TRF) of the studies are shown in Fig. 1. According to the analyzed data, the main crops in the research area are corn and wheat.

Results

On the basis of spectral indices, the moisture content was estimated both in the vegetation cover and in the upper layer of the open soil (fig. 4).

The values of NWI, NDWI, WRI, NDSI, NDMI, OSAVI were calculated for each pixel based on the respective dependencies. In the resulting images, wetter areas appear darker, and in this case correspond to lowered relief elements with increased humidity or partially filled with water.

Territorial selection of research plots for the selection of a "working" index, which best identifies areas of the MRLF, completed this stage of conducting research.

After visual verification of the obtained index images of soil moisture by the geospatial distribution of NDVI values (see fig. 4), the index that best reflects the differentiation of overmoistened arable land areas (MRLF) was chosen. This is NDWI. The moisture scale contains seven segments (Dovgiy et al., 2020), which reflect the levels of soil moisture.

The wettest areas, shown in blue, where increased soil moisture is periodically observed and waterlogging processes may continue, while within dry zones (shown in green) with elevated relief elements, on the contrary, a lack of moisture may be felt. As a result, a map of the moisture of the surface layer of the soil was built, on which the vast majority of MRLF with increased humidity is clearly visualized (fig. 5).

According to the research results, it was found that the area of the MRLF in the territory of the research varies from 0.0034 to 0.9388 with an average value of 0.0637 m^2.

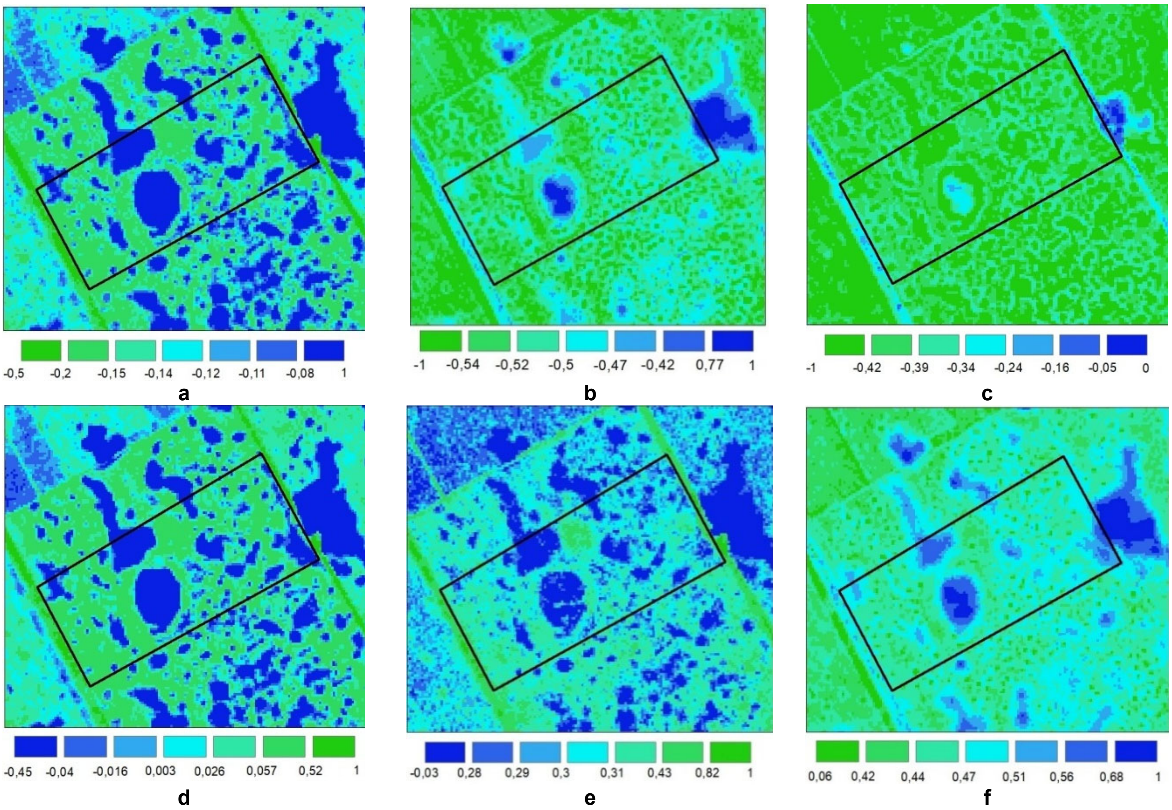


Fig. 4. Fragments of moisture maps of the territory on the example of the reference field No. 1 from the MRLF (contours are marked in black) obtained from remote spectral indices calculated on the basis of the Sentinel-2 image for April 18, 2018:
a – NDWI, b – NWI, c – NDMI, d – NDVI, e – OSAVI, f – WRI

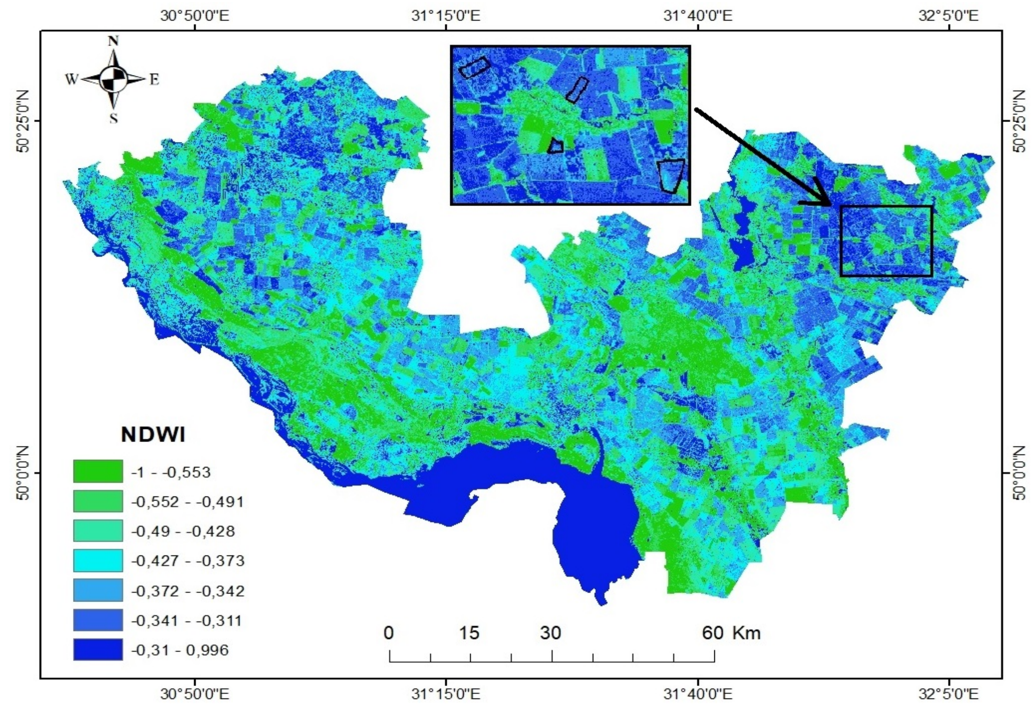


Fig. 5. The map of the distribution of moisture in the territory of Boryspil district was built according to the NDWI index for 04/18. 2018

The dynamics of index value changes and the state of the MRLF in the research area. Further, for a more visual display of changes in the moisture content of agricultural lands in the Boryspil district, graphs of changes in vegetation and water indices for 7 years were constructed for all TRFs from the MRLF (fig. 6–7).

NDVI measurement data from 2017 to 2023 on four reference fields varies from -1.0 to 1.0. From January 2018 until the end of April, all areas were excessively wet, which is a consequence of the melting of snow and ice in warm winter conditions. NDVI values indicate the absence of vegetation on the 1st and 4th test fields (see fig. 7), while on the 2nd and 3rd fields there are winter wheat crops (index values 0.20–0.25). Therefore, the earth's surface on the 1st and 4th test fields is free from vegetation and weakly shielded by vegetation areas of the soil cover.

The graph shows the dynamics of the NDWI index at four TEPs with measurements (fig. 7). The values of the NDWI index correspond to the following ranges: 1.0–0.2 – "water surface", 0.2–0.0 – "wet areas", 0.0 – -0.3 – "dry surfaces", -0,3 – -1.0 – "arid areas".

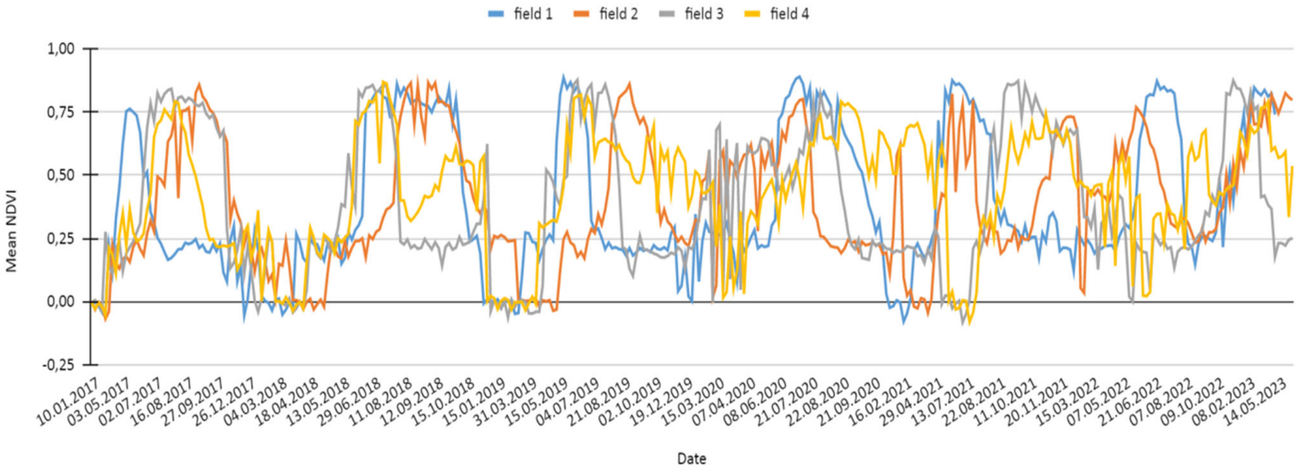


Fig. 6. The graph of changes in the vegetation index (NDVI) from 2017 to 2023 on reference fields

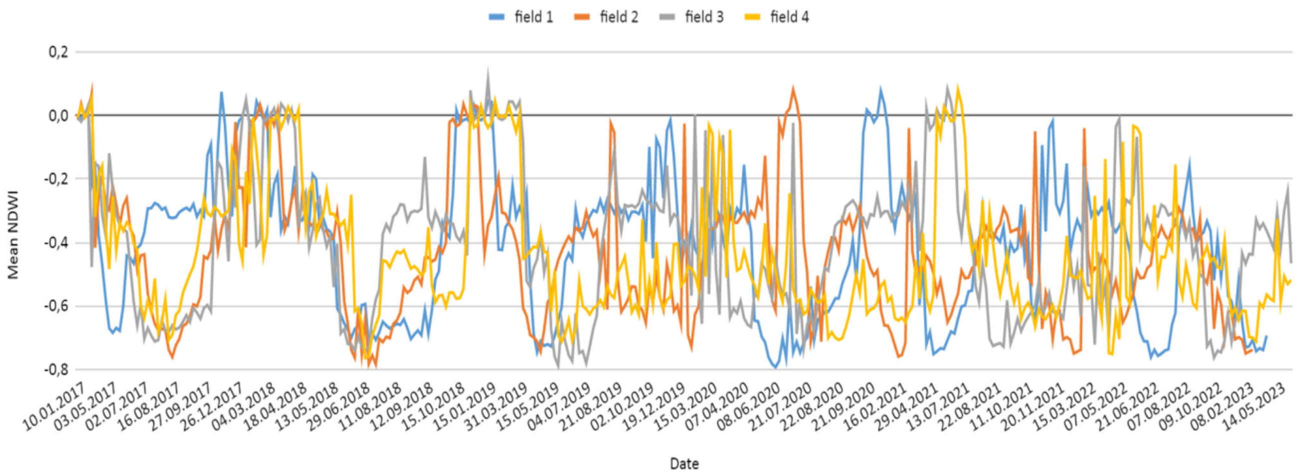


Fig. 7. The schedule of changes in the water index (NDWI) from 2017 to 2023, on reference fields

From the beginning of January 2017 to the end of February, the NDWI values at sites 2, 3 and 4 were in the range of 0.0–0.2, indicating high humidity, probably due to the presence of melting snow. From late 2017 to mid-April 2018, all sites except site 2 were overmoistened, while site 2 was only wet until late March. Since mid-October 2018, the NDWIs of the first and second sections have reached values of 0.0–0.2.

The high variation of the values of the indices on the test fields indicates significant differences in the level of soil moisture and the differentiation of the territory by the amount of biomass accumulation by vegetation at the time of removal.

The study of the identification ability of the indices was carried out by establishing the correspondence between the areas of the MRLF on the ground cover with soils with signs of silt, established on the basis of ultra-high resolution images and isolated areas that are formed by the geospatial concentration of high values of the indices: NDVI – 1, 2, 3, NDWI – 5, 6th, 7th grades; NDMI – grades 5, 6, 7; OSAVI – 1, 2, 3 (see fig. 4).

A graphic display of the geospatial identification of areas of soils with signs of siltiness by various indices is shown in figure 8. Red shows the limits of visual localization of soil areas with the consequences of hydromorphism based on ultra-high resolution orthophotos.

The identification ability of indices was determined on the basis of an expert classification scale with percentage intervals: 0–33 – "low ability", 34–66 – "average", 67–80 – "increased", 81–100 – "high".

Table 1 presents the identification ability of vegetation indices in relation to the localization of MRLF. As can be seen from the table, the high identification ability of the indices was found on the 3rd test field, almost all the indices showed a high percentage of detected MRLF. Satisfactory indicators were recorded on the 2nd test field. The lowest percentage was shown by 1 test field. In general, it should be stated that the identification capacity of vegetation indices depended on the level of soil moisture. Therefore, in the case of remote diagnosis of the MRLF, it is necessary to take into account the peculiarities of the moisture supply of the territory, which in practical terms indicates the need to choose a year with a sufficient amount of soil moisture in the period from March to August, which turned out to be the year 2018 (see fig. 8).

Fig. 9 presents the index ranges that proved to be the most informative.

Thus, for test field 3, plot 8, the most informative was the NDVI index with a range from -0.117 to -0.024, the percentage of identification is 98.0 %; for OSAVI – 78.0 % with a range of 0.255–0.313; for NDMI with a range variation of -0.041 – (-0.149) and an identification percentage of 56.0.

According to research results, the identification ability of indices depends not only on the level of soil moisture, but also on the geospatial differentiation of vegetation biomass (scales of crop damage), as indicated by the values of the traditional vegetation index NDVI.

As predicted, the identification ability of the vegetation indices NDVI, NDWI, OSAVI, NDMI, among which all but the first one are considered classical water indices, on test fields without existing vegetation is too low. This is due to the fact that the very fact of increased soil moisture is not a direct consequence of their becoming oleaginous. Instead, the presence of vegetation on the earth's surface allows us to indirectly fix the localization of the so-called "potholes" with clear signs of damaged crops. In addition, as is known, the lack of vegetation shielding of the soil of arable land is observed only for about 6 weeks, which significantly narrows the possibilities of using RSE tools due to time constraints. That is why, for the geospatial separation of soil areas with signs of hydromorphism, it is advisable to use an approach characterized as remote phytoindication (indirect remote soil research through vegetative plants).

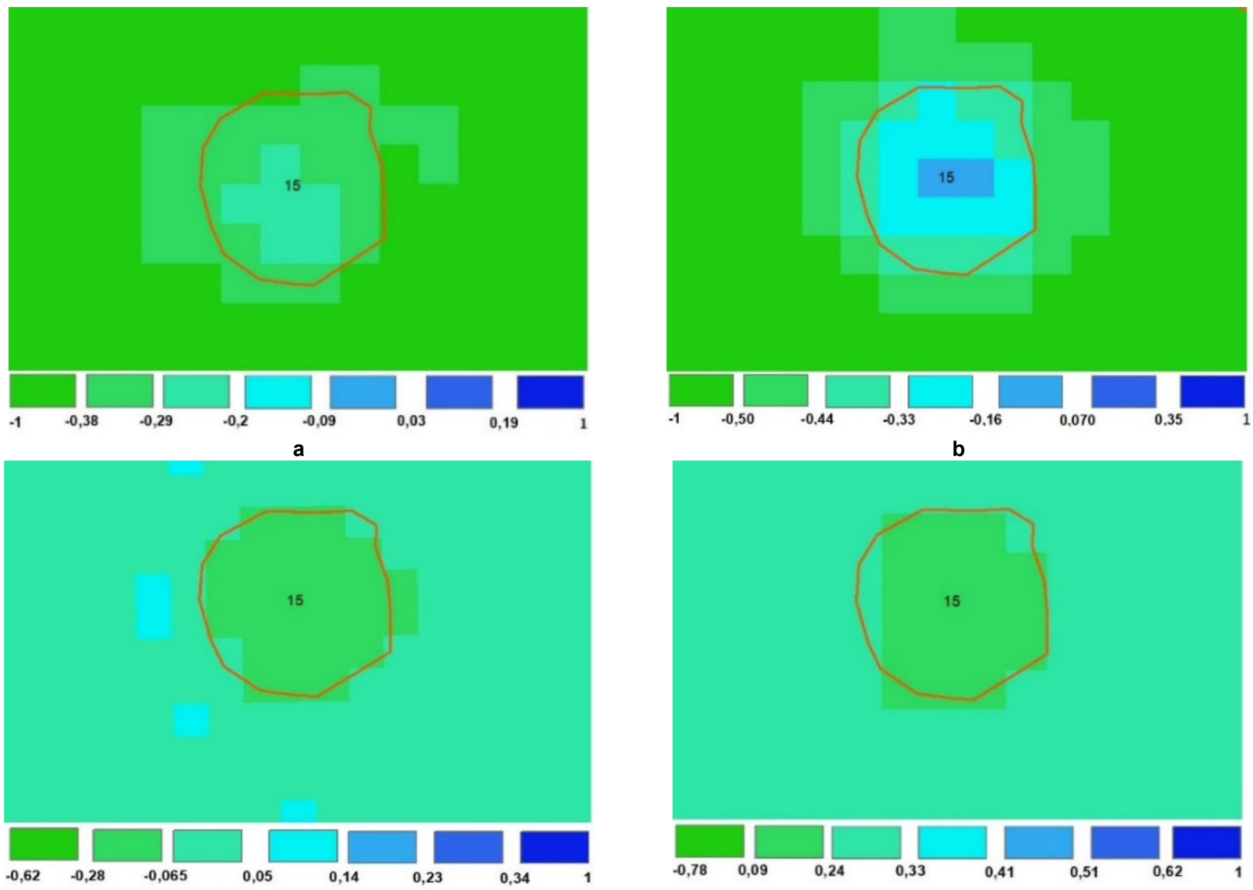


Fig. 8. Cases of range crossing in the photographs:
a – partial coincidence, field 3, plot 15, 44.0 %, NDMI index; b – full match field 3, plot 15, 98.0 %, NDSI index;
c – full match field 3, site 15, 98.0 %, NDWI index; d – full match field 3, plot 15, 88.0 %, OSAVI index

Table 1

Identification ability of indices

№	Name of the index	Test field number and index identification							
		Field 1		Field 2		Field 3		Field 4	
		%	ability	%	ability	%	ability	%	ability
1	NDVI	8 %	low	71 %	increased	83 %	high	83 %	high
2	NDWI	–	–	52 %	average	84 %	high	–	–
3	NDMI	–	–	80%	increased	44 %	average	–	–
4	OSAVI	–	–	84 %	high	83 %	high	98 %	high

Note: MRLF is not identified

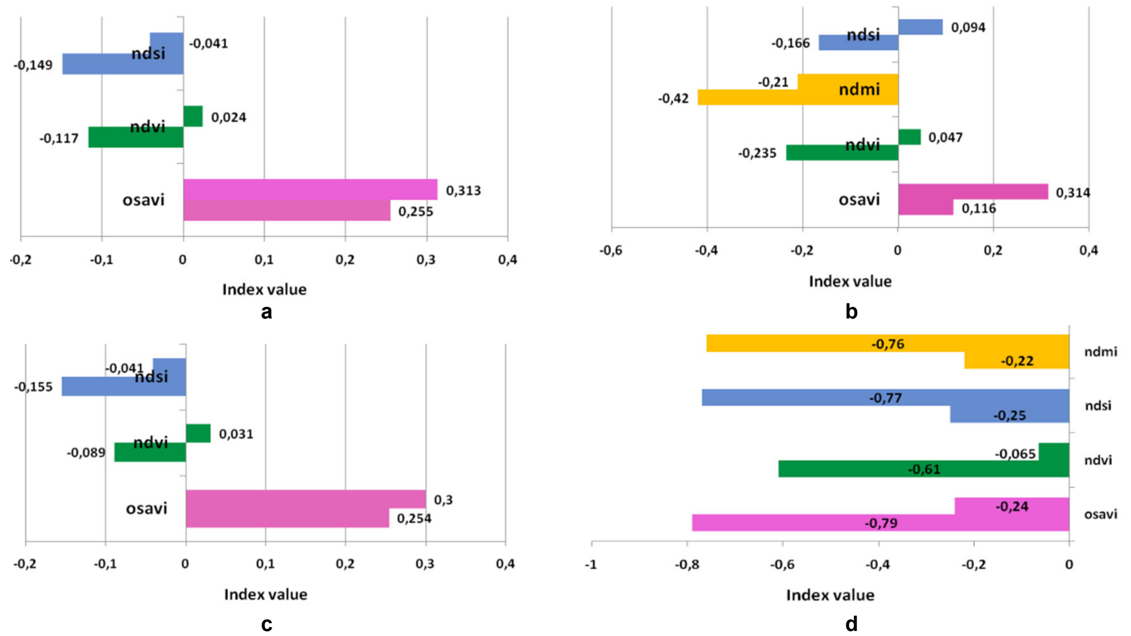


Fig. 9. Ranges of vegetation indices:
a – plot No. 8; b – site No. 15; c – plot No. 16; d – "identifying" ranges for field No. 3

Discussion and conclusions

The results of remote identification of the areas of MRLF, carried out on test fields using the NDWI, NDSI, NDMI, OSAVI indices based on the Sentinel 2A spectrozonal image, made it possible to obtain information on soil moisture of arable lands of Sulymiv territorial community of Boryspil district of Kyiv region. The ability of the specified indices during the geospatial identification of micro-recessed landforms (MRLF) and soil areas within them with signs of hydromorphism was evaluated.

It is shown that the use of orthophotos with a resolution of 0.2 m per 1 pixel is an important auxiliary means of successfully solving the specified tasks.

It was found that the identification ability of water indices on test fields without existing vegetation is too low. On the other hand, the shielding of the soil surface by vegetation with areas of damaged crops makes it possible to isolate MZFR (so-called "saucers").

The most informative ranges of vegetation indices were established: for NDVI, the range is from -0.117 to -0.024 with an identification percentage of 98.0 %; for OSAVI – 78.0 % with a range of 0.255 – 0.313; for NDMI with a range variation of -0.041 to -0.149 and an identification percentage of 56.0.

The obtained information can be used during the development of the methodology of soil science surveying and planning of large-scale soil survey activities.

Authors' contribution: Petro Trofymenko – conceptualization, formal analysis, methodology, review and editing; Olha Tomchenko – conceptualization, methodology; Rostyslav Poralo – formal analysis, data treating; Vitalii Zatserkovnyi – data validation, editing; Iryna Stakhiv – formal analysis, data treating.

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ДИСТАНЦІЙНА ІДЕНТИФІКАЦІЯ МІКРОЗАПАДИННИХ ФОРМ РЕЛЬЄФУ ТА ДІЛЯНОК ҐРУНТОВОГО ПОКРИВУ АГРОЛАНДШАФТІВ ПОЛІССЯ УКРАЇНИ З ОЗНАКАМИ ГІДРОМОРФНОСТІ

В с т у п . ***Сільськогосподарські угіддя відіграють ключову роль у забезпеченні продовольчої безпеки населення і розвитку економіки країни. Проте значну загрозу для цих земель становить надмірне зволоження, унаслідок чого в межах понижених елементів рельєфу формуються умови для утворення ґрунтів з ознаками оглеєння, низьким рівнем родючості, що значно знижує їхній потенціал. Для висвітлення проблем геопросторової ідентифікації мікрозападинних форм рельєфу (МЗФР) на сільськогосподарських угіддях у статті використано спектральні індекси за даними ДЗЗ.***

М е т о д и . ***Під час досліджень було відібрано 6 спектральних індексів, які використано для отримання даних про ареали просідань ґрунтів на орних землях, а саме: NDWI, NWI, NDMI, NDVI, OSAVI, WRI. Вирішення завдань досліджень передбачало застосування даних супутникової системи Sentinel-2A. Для візуалізації поширення МЗФР на території досліджень використано знімок надвисокої розрізненості (0,2 м на 1 піксель), отриманий у програмному забезпеченні "Digitals Professional 5,0". Обробку, геопросторову візуалізацію даних ДЗЗ виконано у середовищі Arc Map програми Arc GIS 10.8 із застосуванням інструмента raster calculator.***

Р е з у л ь т а т и . ***У межах еталонних полів побудовано і проаналізовано динаміку значень водних і вегетаційного індексів та оцінено ідентифікаційну здатність щодо геопросторового виокремлення ареалів ґрунтів з ознаками гідроморфності. Показано, що ідентифікаційна спроможність індексів залежить не лише від рівня зволоженості ґрунту, а також від біомаси рослинності (масштабів пошкодженості посівів), на що вказує висока інформаційна спроможність традиційного вегетаційного індексу NDVI. Встановлено найбільш інформаційні діапазони індексів: для NDVI діапазон в межах від -0,117 до -0,024 з відсотком ідентифікації 98,0 %; для OSAVI – 78,0 % з діапазоном 0,255–0,313; для NDMI з варіацією діапазону від -0,041 до -0,149 та відсотком ідентифікації 56,0.***

В и с н о в к и . ***Результати дистанційної ідентифікації ареалів МЗФР дали змогу отримати інформацію про зволоженість ґрунтів орних земель території досліджень. Оцінено здатність означених індексів під час геопросторової ідентифікації мікрозападинних форм рельєфу та ареалами ґрунтів в їх межах з ознаками гідроморфності. Показано, що важливим допоміжним засобом успішного вирішення означених завдань є використання ортофотознімків з розрізненням 0,2 м на 1 піксель.***

Виявлено, що ідентифікаційна здатність водних індексів на тестових полях без наявної рослинності є надто низькою. Натомість екранованість ґрунтової поверхні рослинністю з ділянками пошкоджених посівів дозволяє виокремлювати МЗФР.

Отримана інформація може бути використана під час розроблення методики проведення ґрунтознавчої зйомки та планування заходів з широкомасштабного обстеження ґрунтів.

К л ю ч о в і с л о в а : ***мікрозападинні форми рельєфу (МЗФР), просідання, дистанційне зондування Землі (ДЗЗ), спектральні індекси вегетації та зволоженості.***

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