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Cartographic support of agricultural activities (case of rapeseed cultivation)

The purpose of this article is a systematic analysis of cartographic support introduction in rapeseed cultivation to increase the efficiency of agricultural production.

Main material. The use of modern cartographic methods is an integral part of the sustainable development of agricultural production. Introduction of these technologies contributes to increasing efficiency of land resource use, adaptation of the agricultural sector to climate change and environmental protection.

Comparison of average, minimum and maximum NDVI values showed a stable trend towards improving the state of vegetation in the studied period. Analysis of vegetation conditions in Cherkasy region based on average NDVI values allows us to assess deeper the agroecological conditions of the region and the potential of its territories for agricultural production. Analysis of the obtained NDVI data demonstrated significant variability in the level of vegetation cover, which indicates various natural and anthropogenic factors that affect the productivity of agricultural lands.

Conclusions. Analysis of the theoretical foundations of modern cartographic methods application in agriculture has confirmed that geoinformation technologies, remote sensing of the Earth and vegetation indices, in particular NDVI, are effective tools for cartographic support of management decisions regarding agricultural processes. Assessment of the NDVI index value confirmed its effectiveness in monitoring the condition of rapeseed at different stages of growth. Analysis of the obtained NDVI data demonstrated significant variability in the level of vegetation cover, which indicates various natural and anthropogenic factors affecting the productivity of agricultural lands. The work carried out on the analysis of vegetation conditions in Cherkasy region,, based on average NDVI values, allows for a deeper assessment of the regional agroecological conditions and the potential of its territories for agricultural production.

Keywords: *rapeseed, weather conditions, temperature regime, mapping, crop rotation, cultivation technologies, NDVI.*

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Introduction. In modern agriculture, ensuring effective management of land resources and productivity is one of the main prerequisites for sustainable development of the agricultural sector. Innovative approaches, in particular the use of cartographic methods, are becoming especially relevant in the context of rational use of natural resources and increasing the productivity of cultivated crops. The use of cartographic data allows agronomists to optimize resource management, contributing to increased productivity and crop quality, reduced costs and negative impact on the environment.

The relevance of the research topic is due to the growing demand for rapeseed, which is an important source of raw materials for production of foods, biofuels and animal feed. The use of modern cartographic methods in agricultural production, such as topographic maps, satellite data and vegetation indices, allows us to assess the condition of fields, plan crops more accurately, as well as monitor the the crop conditions throughout the growing season. This will allow you to solve key tasks of managing the sown areas and provide optimal conditions for growing rapeseed as well. This creates opportunities for accurate planning of agrotechnical measures, monitoring the condition of crops, controlling soil fertility and managing other important factors.

Agricultural production of rapeseed, as one of the most demanded products on the world market, requires maximizing productivity and minimizing resource costs, in particular, fertilizers, water resources as well as soil cultivation. The relevance of the study is increasing in the context of climate change as well, which causes unpredictable changes in the conditions for growing agricultural crops.

Background. History of humankind shows that the use of cartography in agriculture has always been important for ensuring sustainable development. With the development of modern technologies, maps have become even more detailed and accurate thanks to the use of geographic information systems (GIS) and satellite data. Modern farmers use these systems to create interactive maps of their fields, which allow them not only to see the relief and soils, but also to obtain data on the current condition of crops, moisture levels and nutrients in the soil. This mitigates making quick and accurate decisions about crop care and responding quickly to changing climatic conditions. For example, in Canada, farmers use satellite images to monitor the condition of fields, which allows them to reduce irrigation costs and optimize fertilizer application. Thanks to such innovations, the efficiency of growing crops, including rapeseed, increases, and the environmental load on the environment decreases.

Fertility analysis also allows for more efficient planning of fertilizer costs, as it is possible to determine the need for introduction of certain nutrients more accurately.

The use of topographic and land maps gives farmers the opportunity to integrate these data in creation of a comprehensive crop management system. Having analyzed the relief and soils, we can develop an agrotechnical plan, which includes land cultivation, fertilizer application, as well as selection of the best time for sowing and harvesting. In particular, rapeseed, which requires regular irrigation, can grow on flat areas with good drainage. However, it is better to grow crops that are less sensitive to moisture deficiency and can retain soi on slopes with a risk of erosion. This approach minimizes the risks of crop loss due to adverse natural conditions and allows for the most efficient use of available resources [8].

Maps are the foundation for developing such adaptation strategies, providing farmers with the information they need to make decisions about which crops to grow, how to space them, and when to harvest them [3]. In conclusion, the use of topographic and land maps in agriculture is critical to increasing production efficiency and resilience to natural challenges. Historical examples of maps show that they have always played a crucial role in the development of agriculture. Moreover, modern technologies further expand their potential, allowing farmers to plan their actions better and achieve high results [2].

The purpose of the article is a systematic analysis of the possibilities to introduce cartographic support in rapeseed cultivation in order to increase the efficiency of agricultural production.

To fulfill and achieve the goal, we have set the following tasks:

1. To analyze theoretical principles of mapping used in agriculture.
2. To analyze the specifics of rapeseed cultivation and determine geographical, agroclimatic and spatial factors that affect its productivity.
3. To investigate the possibilities of using satellite images, agronomic maps and other geospatial data to monitor the condition of rapeseed crops and improve management of agricultural processes.
4. To develop cartographic materials for monitoring rapeseed crops, to assess the value of the NDVI index to control the state of its vegetation.
5. To develop recommendations for minimizing the negative impact on the environment, as well as to assess the agroecological conditions of the region and the potential of its territories for agricultural production.

Presentation of the main material. The use of topographic and land maps for crop planning is a key aspect of effective agricultural production, as these maps provide accurate information about the terrain, water resources and soil conditions, helping farmers make informed decisions. Topographic maps depict physical characteristics of the territory, including elevations, slopes, water sources and drainage systems [5].

Agronomic maps are an extremely valuable tool for modern agriculture, as they provide detailed

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information about the condition of soils, the specifics of the relief, the level of fertility, moisture, prevalence of vegetation and even the impact of climatic conditions on specific areas. Due to such information, agronomists and farmers can effectively plan and control the processes of sowing, cultivation and harvesting. Creation of agronomic maps uses a wide range of data obtained through various sources, including satellite imagery, aerial photography, soil samples, climate sensors and data collected by drones.

To depict field conditions accurately, these maps are created using geographic information systems (GIS), which allows us to combine spatial data with information about the soil and agrotechnical condition of the fields. GIS technologies help analyze large volumes of geospatial data and display various field parameters with high accuracy, from changes in moisture levels to soil acidity and its mechanical composition [6]. In particular, agronomic maps allow you to identify areas with different levels of fertility and suitability for growing specific crops, such as rapeseed, which is important for increasing resource efficiency.

Agronomic maps play an important role in optimizing agronomic practices, such as fertilizer and pesticide application. They provide accurate information about the condition of each field, allowing for adaptation of agricultural practices to local conditions. For example, the use of agronomic maps for soil acidity management was introduced in the studies of G. Brady and R. Weil (2002), who emphasized the importance of liming to regulate soil pH in conditions of increased acidity.

Such maps are also becoming an important tool for reducing costs in crop cultivation. According to the works of K. Kuker (2011), proper optimization of fertilizer application rates based on cartographic data allows us not only to reduce costs for agrochemicals, but also to minimize the risk of excessive use of nitrogen, which contributes to the reduction of water pollution.

The use of cartographic tools for assessing environmental risks in agriculture is an important and powerful tool that allows farmers, ecologists and government organizations to obtain clear and structured information about the state of the environment and its interaction with agricultural practices. Thus, we can assess the spatial aspects of environmental risks, such as soil degradation, erosion, water pollution, climate change and the impact of agricultural activities on biodiversity. Modern technologies, such as satellite images, geographic information systems and drones, provide for detailed monitoring and creation of accurate maps that reflect changes in ecosystems and make it possible to predict their development [9].

Due to their high accuracy and detail, GIS can provide real-time monitoring of soil changes. Modern technologies allow for high-resolution images and data, which speeds up identification of problem areas and timely implementation of corrective measures. This is especially important for large agricultural enterprises, where manual monitoring of soil conditions throughout the territory is an extremely difficult task.

Therefore, geoinformation models for assessing soil degradation due to rapeseed cultivation are an indispensable tool in modern agriculture. The use of such models allows to monitor soil conditions effectively, analyzing the risks of erosion, loss of organic matter and pollution, as well as planning agricultural practices that reduce the environmental load on the land.

Summarizing the above, we can note that comparative analysis of satellite images allows farmers to identify problems in rapeseed fields timely, in particular, those associated with insufficient moisture, damage from pests or diseases, as well as violations in crop care. The use of vegetation indices, such as NDVI and EVI, allows you to effectively assess the condition of crops and promptly take the necessary measures to ensure stable yields. Using satellite technologies, we can reduce costs for agrotechnical measures, as well as negative impact on the environment and improve the crop quality.

The main advantage of precision farming is the ability to make decisions based on real-time data. Satellite images provide information that allows you to assess plant health and vegetation levels using indices such as NDVI (Normalized Difference Vegetation Index).

One important aspect of precision farming is optimizing fertilizer and pesticide application. Using satellite images, we can determine more accurately in which areas of the field you need to increase or decrease the application rates of substances. This not only helps reduce the cost of chemicals, but also reduces the risk of environmental pollution. For example, instead of evenly spraying fertilizer over the entire field, precision farming allows you to apply fertilizer only where the plants need it.

Precision farming also allows you to predict yields. Knowledge of plants condition and vegetation level allows you to create models that can predict the amount of harvest in a particular field with a fair degree of accuracy. Forecasts can take into account weather conditions, soil moisture, the amount of fertilizer applied, and the health of the plants. In this way, farmers can plan their resources and sell the harvest more economically profitably [4].

Precision agriculture based on satellite data is already an important stage in transformation of the agricultural sector and has every chance of becoming a key technology in the future of agriculture.

Rapeseed cultivation occupies a significant place in the modern agricultural sector and is of great importance for many countries, as it is a source of oil, animal feed, and biofuels. However, this crop has both positive and negative impacts on soils and ecosystems that are the basis of agriculture. Rapeseed, in particular, actively affects the soil, using nutrients, changing the structure and composition of the soil, affecting the surrounding biodiversity and water resources. Understanding of

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the rapeseed impact on the ecosystem is important for developing sustainable agricultural strategies that provide both high yields and minimal impact on the natural environment.

One of the advantages of growing rapeseed is the improvement of soil structure due to its extensive and deep root system. Rapeseed roots can penetrate into the lower soil horizons, loosening it and improving its water and air permeability. This creates favorable conditions for the root system of other crops, especially when using rapeseed in crop rotation. Such an improvement in soil structure preserves moisture, which is of particular importance in arid regions where water is a limited resource. In addition, rapeseed forms a dense plant cover that prevents soil erosion, protecting its surface from the destructive effects of wind and water, which is especially important on slopes and in regions with a high risk of erosion.

To reduce negative impact of rapeseed on the ecosystem, it is important to apply a sustainable approach to its cultivation. For example, alternating rapeseed with other crops within the crop rotation allows us to reduce the risk of pathogens and pests accumulation that can affect this crop, and to maintain natural fertility of the soil as well. Crop rotation helps to restore nutrients in the soil, reducing the need for large amounts of fertilizers.

Satellite monitoring of rapeseed crops is one of the most modern and effective tools for agricultural management, allowing farmers to receive accurate and up-to-date data on the condition of their fields in real time. Thanks to the development of satellite technologies, agronomists and farmers can carry out constant monitoring without having to be on site, which significantly reduces the cost of time and human resources.

The use of the Normalized Difference Vegetation Index (NDVI) to assess the condition of vegetation is an important part of modern agricultural field management and ecosystem monitoring. NDVI is a numerical indicator calculated from spectral data obtained with the help of satellites or drones. It allows you to assess the health of vegetation, its density, photosynthetic activity and general condition at different stages of development. This index plays a key role in agricultural management, as it allows farmers to receive accurate information about the condition of crops, identify problems in a timely manner and make informed decisions regarding further agrotechnical measures [13].

NDVI shows how vegetation reflects light in different parts of the spectrum. Green plants actively absorb visible red light for photosynthesis and reflect most of the near infrared (NIR) radiation. When plants are healthy, they have a high capacity for photosynthesis, which results in a significant difference between red absorption and infrared reflection. NDVI is calculated using a formula that includes red (Red) and near infrared (NIR) radiation reflectance

$$NDVI=((NIR-Red))/((NIR+Red))$$

This indicator varies from -1 to 1. Values close to 1 indicate dense and healthy vegetation, while values close to 0 or negative may indicate a lack of vegetation or plant stress caused by, for example, drought, disease or nutrient deficiency [12].

Considering all these factors, growing rapeseed can be quite productive and profitable, but it requires a responsible approach to resource use. The use of agrotechnology and sustainable farming approaches will reduce the negative impact of rapeseed on the soil and ecosystem, while ensuring high yields and minimal environmental risks. In the future, implementation of innovative solutions and sustainable practices will be a key to ensuring food security and preserving natural resources.

One of the key aspects of such optimization is the ability to accurately calculate the amount of seeds, fertilizers and other resources needed for a specific plot. GIS-based soil fertility maps show the levels of essential nutrients in each part of the field. This allows for more accurate fertilizer application planning, focusing on nutrient-deficient areas, helping to avoid unnecessary costs and improve productivity.

The authors have chosen Cherkasy region for the study for several reasons that emphasize its importance as one of the leading agricultural regions of Ukraine. Firstly, the region is located in the central part of the country, which provides stable soil and climatic conditions and convenient access to data analysis. This makes the region representative of the Forest-Steppe zone, which is important for agricultural production.

One of the main reasons for choosing Cherkasy region is its soil cover. Black soils dominate in the region, considered to be among the most fertile in the world. These soils have a high humus content (4–6%), which contributes to the cultivation of rapeseed as a highly productive crop. Fertile black soils provide stable yields even with minimal fertilizer application, which allows for efficient use of resources [10].

The climatic conditions of Cherkasy region are also favorable for cultivation of rapeseed. Moderately continental climate with an average annual temperature of +8°C, sufficient rainfall (500–600 mm per year) and a long growing season (approximately 200 days) create optimal conditions for the growth and development of this crop. Winter periods with mild frosts ensure good wintering of winter rapeseed, which is important for high yields.

In addition, Cherkasy region has a developed infrastructure for agriculture, which includes access to modern machinery, agrochemicals and possibility to implement innovative technologies such as precision agriculture. This allows us to conduct research based on geospatial data and satellite monitoring, which is especially important for assessing the conditions of rapeseed crops.

Another reason is the economic importance of Cherkasy region as an agricultural region. Agriculture plays a leading role in the economy of the region, and

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rapeseed is an important crop for export trade and biofuel production. Research in this region allows us not only to assess crop productivity, but also to provide practical recommendations for improving the efficiency of their cultivation.

Cherkasy region demonstrates certain challenges associated with the uneven distribution of precipitation and the impact of climate change, in particular, more frequent droughts. This makes the region ideal for testing innovative methods of crop monitoring and yield management [11]. The results of the study can become a valuable tool for adapting agriculture to new climatic conditions both in Cherkasy region and in other regions of Ukraine.

It is also worth noting that the duration of the growing season in Cherkasy region is approximately 200-210 days. This is enough for growing most crops, including rapeseed. In early spring, when the soil warms up, plants quickly resume vegetation, which allows them to effectively use the moisture accumulated over the winter.

Regarding the structure of soils (Table 1), in addition to black soils, there are meadow soils and gray forest soils in Cherkasy region which are less fertile, but also suitable for agricultural use, provided that organic and mineral fertilizers are applied [1]. Gray forest soils are usually located on elevations, while meadow soils are found in river valleys and are characterized by significant moisture. These soils require a special approach to cultivation and increasing their fertility.

Thus, the soil and climatic conditions of Cherkasy region are extremely favorable for growing rapeseed, although they require adaptation to new challenges associated with climate change. The combination of high soil fertility, temperate climate and sufficient rainfall creates all the prerequisites for the effective cultivation of this crop, especially under the conditions of rational use of resources and introduction of modern technologies [7].

Table 1

Soils characteristics in Cherkasy region

Parameter	2020	2021	2022
Humus (%)	2.5	2.7	2.9
pH	6.0	6.2	6.4
Nitrogen (mg/kg)	40	42	45
Phosphorus (mg/kg)	25	28	30
Potassium (mg/kg)	120	125	130

We used Sentinel Hub Playground as the main platform for obtaining and processing satellite images within the framework of the task. This online platform allows you to work quickly and conveniently with Sentinel-2 images, providing access to multispectral data, including the channels necessary for calculating the NDVI index (RED and NIR).

As part of the study of vegetation cover conditions in Cherkasy region, we have analysed the NDVI index (Normalized Difference Vegetation Index) for three years - 2020, 2021 and 2022 (Table 2). This analysis allows us to assess the dynamics of vegetation changes and identify areas with different levels of productivity, important for assessing the ecological state and the effectiveness of agrotechnical measures in the region.

The data indicate that the highest average NDVI was recorded in Zvenigorodskyi district (0.81), which may indicate the best condition of crops in this area. Cherkasy district also demonstrates a high NDVI (0.78), indicating generally favorable conditions for plant growth. Uman district has the lowest NDVI value (0.65), which may be due to less favorable climatic or soil conditions, insufficient moisture, or other factors. Zolotonosha and Smilan districts have average NDVI values (0.69 and 0.72, respectively), which indicate a satisfactory condition of vegetation.

Table 2

Comparison of average, minimum and maximum NDVI values

Parameter	2020	2021	2022
Average NDVI value	0.60	0.63	0.67
Minimum NDVI value	0.25	0.30	0.35
Maximum NDVI value	0.80	0.85	0.88
Area with high NDVI (>0.7)	40%	45%	50%
Area with low NDVI (<0.4)	25%	20%	15%

According to the created thematic map (Fig. 1), the highest NDVI values are observed in Zvenigorodskyi, Cherkasy, Kaniv, and Kamyansk districts. This indicates a high level of photosynthetic activity of plants, which may be the result of favorable soil and climatic conditions, sufficient moisture and effective management of agrotechnical measures. These areas have high potential for growing crops that require active growth and development under conditions of optimal resource availability. The average NDVI values recorded in areas such as Smila, Zolotonosha, Talnivsky and Horodyshchensky indicate a moderate level of vegetation cover. This may be due to the unevenness of natural resources, such as moisture supply, or to average soil fertility. Such areas require additional monitoring to identify factors that limit the potential of vegetation and plan appropriate agrotechnical measures.

Lower NDVI values were recorded in Uman, Khrystynivsky, Monastyryshchensky and Mankivsky districts. These areas are likely to face certain environmental or agrotechnical problems, such as soil erosion, insufficient rainfall or the impact of human activities, including irrational use of land resources. An action plan to improve the state of vegetation cover should be developed for these areas. This may include optimizing irrigation, implementing modern agricultural technologies, rational fertilizer application and monitoring soil conditions.

The results have also showed that areas with high NDVI values are characterized by significant biological

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productivity and ecological sustainability. This may become the basis for expanding crops cultivation with high commercial value.

For example, in the conditions of Cherkasy region, these may be cereals, oilseeds, as well as vegetables. A high level of NDVI may also be an indicator of the region's potential for the introduction of organic farming.

NDVI analysis has become an effective tool for studying the state of vegetation cover in the region, as it provides accurate information about the level of photosynthetic activity of plants over a large area. The methodology for analyzing satellite data allows you to obtain relevant data for decision-making quickly and economically. This is especially important for Cherkasy region, which has great agricultural potential.

In general, the results of the work demonstrate the significant potential of Cherkasy region for further development of agriculture, taking into account environmental features and the implementation of modern management methods. The use of NDVI analysis allows us not only to assess the current state of vegetation, but also to identify risk areas to increase the efficiency of land resource use. This, in turn, can contribute to the sustainable development of the region and increase the well-being of the local population.

Reducing the negative impact of agricultural activities on the environment is an important task that requires an integrated approach. Rapeseed cultivation, like many other crops, has both positive and negative consequences for the ecosystem and soils. In this

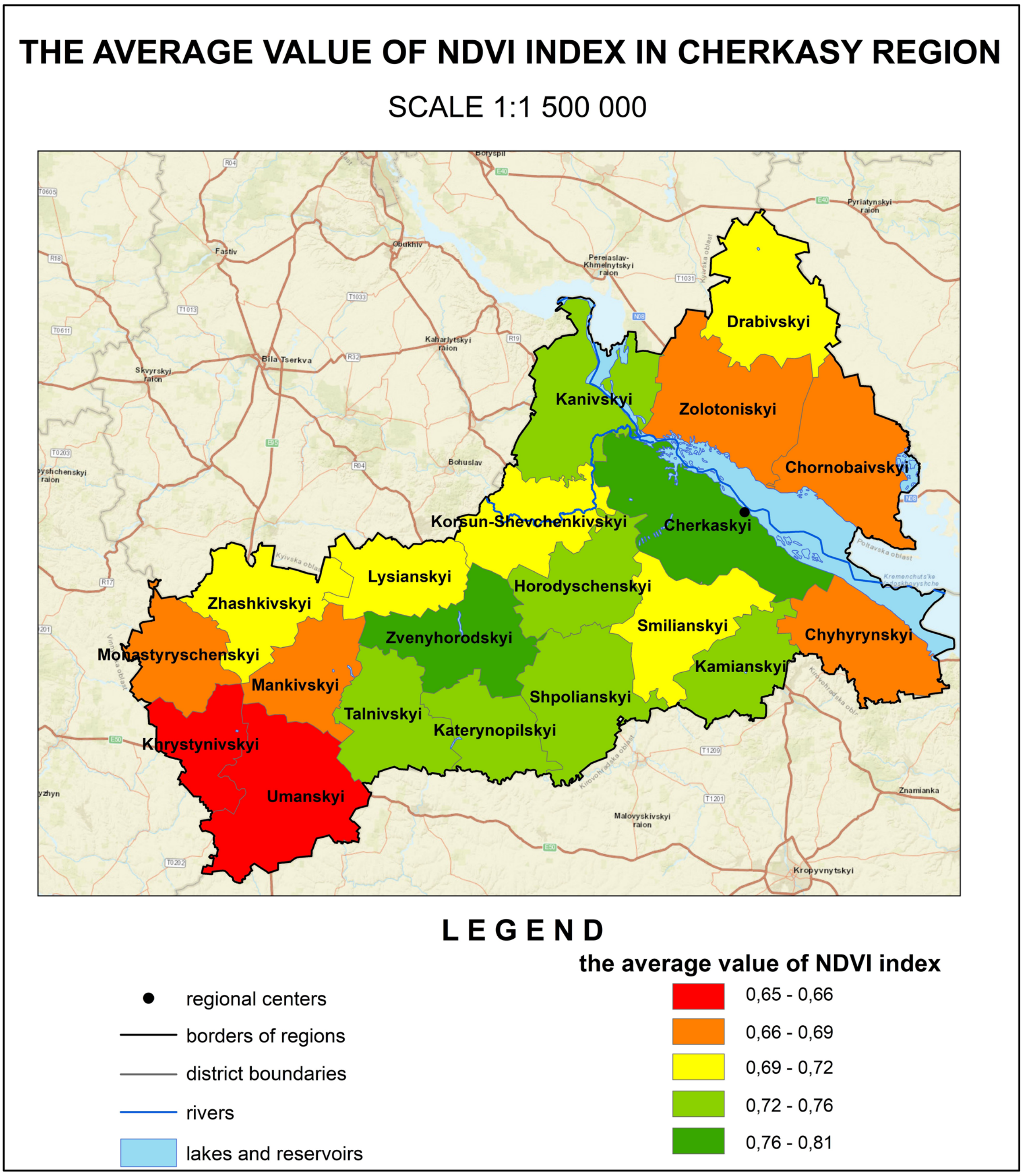

Fig. 1. Map of the average NDVI index value of Cherkasy region

regard, it is important to apply a sustainable approach to agricultural management, focusing on preserving natural fertility of the soil, reducing the use of chemical plant protection products and fertilizers, as well as optimizing the use of water resources. One of the most effective methods of maintaining sustainability of agricultural ecosystems is introduction of crop rotation, which allows you to avoid soil depletion and accumulation of pests, characteristic of monocultures. Alternating rapeseed with other crops, such as cereals or legumes, not only helps to reduce pest populations and the risk of plant diseases, but also maintains the natural structure of the soil, as the basis of its fertility.

Geoinformation technologies used for environmental risk assessment allow integrating various data on soils, water, vegetation and climatic conditions into a single system, creating multi-layered models of the state of agricultural landscapes. This contributes to effective monitoring and timely detection of degradation processes, such as erosion, reduction of organic matter or pollution, allowing farmers to respond in a timely manner and adjust agricultural measures. The use of drones for monitoring crops and soil conditions makes it possible to obtain data with high accuracy, which allows you to identify problem areas quickly and take the necessary measures to restore them. In addition, raising farmers' awareness of sustainable practices of ecological agriculture is important for reducing the negative impact on the environment.

Training programs and information campaigns aimed at spreading knowledge about the rational use of fertilizers, the benefits of biological plant protection methods, precision agriculture methods and efficient water management help farmers understand the possible consequences of their actions better and contribute to the implementation of sustainable practices in agriculture. Sustainable use of agricultural land, in particular rapeseed fields, requires an integrated approach to ecosystem management. It includes biodiversity conservation, rational use of resources, monitoring and control of the state of soils and ecosystems, as well as the implementation of environmentally responsible agricultural technologies.

Conclusions. 1. Analysis of the theoretical foundations of modern cartographic methods application in agriculture confirmed that geoinformation technologies, remote sensing of the Earth and vegetation indices, in particular NDVI, are effective tools for cartographic support of management decisions regarding agricultural processes. These methods provide fast and accurate monitoring of vegetation conditions , allowing us to optimize the use of natural resources.

2. Spatial features of rapeseed cultivation are determined by geographical, in particular, agroclimatic (moisture supply, temperature regime), soil (soil fertility level) factors, while yield largely depends on the proper organization of crop rotation. Analysis of data from Cherkasy region shows that rapeseed has high potential provided that agrotechnical measures are adapted to local natural conditions.

3. The use of Sentinel-2 and Landsat-8 satellite images to monitor the condition of rapeseed crops allows assessing the condition of vegetation at different stages, identifying problem areas and predicting yield. Agronomic maps take into account the heterogeneity of soils and climatic conditions, which contributes to increasing rapeseed yield through optimization of soil cultivation, crop rotation management and efficient use of resources. The authors compiled cartographic works of Cherkasy region based on the above sources of cartographic information, which agricultural producers can use to improve management of the sown areas.

4. Assessment of the NDVI index value confirmed its effectiveness for monitoring the condition of rapeseed at different stages of growth. Analysis of the obtained NDVI data for the districts of Cherkasy region demonstrated significant variability in the level of vegetation cover, which indicates various natural and anthropogenic factors that affect the productivity of agricultural lands. The highest NDVI values are in Zvenigorod, Cherkasy, Kaniv and Kamiansky districts of Cherkasy region, which indicates a high level of photosynthetic activity of plants, favorable soil and climatic conditions, as well as the effective management of agrotechnical measures. Lower NDVI values were calculated for Uman, Khrystynivka, Monastyryshchensky and Mankivsky districts of Cherkasy region. A high level of NDVI serves as an indicator of the region's potential for the introduction of agriculture.

5. The work carried out on the analysis of the state of vegetation in Cherkasy region based on average NDVI values allows for a deeper assessment of the agro-ecological conditions of the region and the potential of its territories for agricultural production. The results of the work demonstrate the significant potential of Cherkasy region for further development of agriculture, taking into account environmental features and introduction of modern management methods. We recommend that in Zvenyhorod, Cherkasy, Kaniv and Kamiansky districts of Cherkasy region, which are environmentally sustainable, consider the possibilities of expanding the volume of cultivation of agricultural crops with high commercial value, in particular grain crops, oilseeds, vegetables, and the introduction of organic farming. For Uman, Khrystyniv, Monastyryshchen, and Mankiv districts of Cherkasy region, we recommend to develop an action plan on improving conditions of the vegetation cover, including optimizing irrigation, implementing modern agricultural technologies, rational fertilizer application,as well as monitoring soil conditions.

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КАРТОГРАФІЧНЕ ЗАБЕЗПЕЧЕННЯ СІЛЬСЬКОГОСПОДАРСЬКОЇ ДІЯЛЬНОСТІ (НА ПРИКЛАДІ ВИРОЩУВАННЯ РІПАКУ)

Метою цієї статті є системний аналіз можливостей впровадження картографічного забезпечення у вирощування ріпаку задля підвищення ефективності аграрного виробництва.

Основний матеріал. Використання сучасних картографічних методів, є невід'ємною складовою сталого розвитку аграрного виробництва. Впровадження даних технологій сприяє підвищенню ефективності використання земельних ресурсів, адаптації аграрного сектору до кліматичних змін і збереженню довкілля.

Порівняння середніх, мінімальних та максимальних значень NDVI показало стабільну тенденцію до покращення стану рослинності у досліджуваному періоді. Аналіз стану рослинності в Черкаській області на основі середніх значень NDVI дозволяє глибше оцінити агроекологічні умови регіону та потенціал його територій для сільськогосподарського виробництва. Аналіз отриманих даних NDVI продемонстрував значну варіативність рівня рослинного покриву, що свідчить про різні природні та антропогенні фактори, які впливають на продуктивність сільськогосподарських земель.

Висновки. Аналіз теоретичних засад використання сучасних картографічних методів у сільському господарстві підтвердив, що геоінформаційні технології, дистанційне зондування Землі та індекси рослинності, зокрема NDVI, є ефективними інструментами для картографічного забезпечення прийняття управлінських рішень щодо сільськогосподарських процесів. Проведена оцінка значення індексу NDVI підтвердила його ефективність для контролю стану ріпаку на різних стадіях росту. Аналіз отриманих даних NDVI продемонстрував значну варіативність рівня рослинного покриву, що свідчить про різні природні та антропогенні фактори, які впливають на продуктивність сільськогосподарських земель. Виконана робота щодо аналізу стану рослинності в Черкаській області на основі середніх значень NDVI дозволяє глибше оцінити агроекологічні умови регіону та потенціал його територій для сільськогосподарського виробництва.

Ключові слова: *ріпак, погодні умови, температурний режим, картографування, сівозміна, технології вирощування, NDVI.*

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