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PECULIARITIES OF THE CREATION OF GIS FOR MONITORING THE ACTIVITIES OF AGRICULTURAL ENTERPRISES IN POLTAVA REGION

Modern trends in the development of the agricultural sector in Ukraine require the widespread implementation of information technologies to ensure effective management of land and production resources. First of all, the use of geographic information systems in agriculture is an effective tool for monitoring and accounting for land assets of agricultural enterprises.

This article proposes a method and peculiarities for creating a geographic information system for monitoring the activities of agricultural enterprises (hereinafter – MAAE GIS) in the Poltava region. A functional model of the MAAE GIS and a conceptual model of the geospatial database (hereinafter – GDB) of the MAAE GIS have been developed. The authors of the article conducted a pilot implementation of the MAAE GIS, and based on its materials, thematic maps were created that reflect crops in the territories of the Sergiyivska, Serednyakivska, Petrivsko-Romenska, Berezovolutska, Ruchkivska and Kharkivska village councils of the Poltava region for the period of 2022-2025. During the analysis of cartograms, conclusions were drawn more specifically regarding the activities of agricultural enterprises in the area of interest and trends observed in agricultural commodity production than research on the cultivated crops.

The developed methodology allows to create a GIS designed to track the inappropriate use of land resources of Ukraine. Its implementation contributes to achieving sustainable development goals, directly affecting the possibility of exporting agricultural products to EU countries and European integration in general.

Keywords: geospatial data; GIS; monitoring; agriculture; geospatial database; geospatial analysis.

Problem formulation. On June 9, 2023, the EU Deforestation Regulation (EUDR, Regulation (EU) 2023/1115) [1] was approved. Although this regulation is not integrated into Ukraine's legislation, its compliance is necessary not only due to the country's specific geopolitical vector of development, but also for economic reasons.

The regulation aims to combat deforestation by setting clear requirements for export products:

– export products must be grown on land that has not been subject to deforestation after December 31, 2020;

– the process of growing/manufacturing export products must not violate the legislation of the supplier country;

– the possibility of full traceability of the logistics chain;

– the presence of a Due Diligence Statement (DDS) – an official legal statement confirming the legality of export products and compliance with the requirements listed above.

In addition, a clear list of products covered by the EUDR requirements has been defined:

– cattle (including derivatives such as beef and leather);

– cocoa (including related products such as chocolate and cocoa butter);

– coffee;

– palm oil (including derivatives used in hygiene products, cosmetics, industry, etc.);

– rubber (and related products such as tyres);

– soy (including derivatives used in soy-based foods and animal feed);

– wood (including wood, pulp, paper and furniture).

From the above, it becomes clear that by establishing the conformity of land use with its intended purpose, one of the requirements of the EU regulation is fulfilled - the conformity of sources and production of goods with local standards. In the context of the Ukrainian agricultural sector, such a product is soybeans.

Thus, the creation of the MAAE GIS will ensure control over the implementation of EUDR requirements, which, in turn, guarantees stable profits from the export of agricultural products to EU countries. Maintaining access to the European market, as a result, becomes especially important in conditions of martial law. In addition, the creation of the MAAE GIS will contribute to the achievement of two sustainable development goals at once: overcoming hunger and preserving the terrestrial ecosystem. Compliance with sustainable development goals, in contrast to the requirements of the EUDR, is legally enshrined in Ukraine by the Decree of the President of Ukraine dated 09/30/2019 No. 722/2019 “On the Sustainable Development Goals of Ukraine for the period up to 2030” [2].

Analysis of recent research. To understand the functionality and creation of geographic information systems for monitoring agricultural activities, it is necessary to analyse the existing experience of using relevant systems in the farm sector using specific examples.

A Ukrainian example of a geographic information system for monitoring agricultural activities is the IoT platform "Agrocontrol" – in essence, a GIS, which allows for optimising costs and automating production processes in agriculture [3]. The developers offer access to GIS in the form of 24 modules, depending on the user's needs. In general, access to the modules involves installing appropriate measuring devices that will record the requested indicators for further analysis: meteorological stations, GPS trackers for agricultural machinery, video cameras and various sensors. In addition, the functionality includes classic tools for web mapping and geospatial analysis.

It should be noted that it is much more common to use established GIS such as QGIS and ArcGIS than to create customised ones for specific needs. One such example is the nitrogen management in sugar beets using remote sensing and GIS, which is one of the most successful early applications of remote sensing and geographic information systems in agriculture [4].

Sugar beet is a crop that leaves much of the nitrogen it takes up during the growing season in the field at harvest. A portion of that nitrogen can be credited against the supplemental fertiliser nitrogen required by the following crop. Satellite imagery can be used to delineate areas within sugar beet fields where higher or lower nitrogen credits can be applied to the subsequent crop. The amount of nitrogen credits for subsequent crops is directly related to the green reflectance of the sugar beet's canopy [4].

The colour of leaves at harvest is related to the amount of nitrogen contained within the plant. Yellow sugar beet tops at harvest suggest that the leaves contain low levels of nitrogen, while green tops suggest that the plants contain a substantial amount of nitrogen. Leaf colour can be used as a basis for nitrogen credits from sugar beet. For yellow leaves, nitrogen residues are absent, whereas for dark green leaves, a specific residue has been identified [4].

In this specific example, the methodology for monitoring residual nitrogen levels consists of the following stages [4]:

1) Acquisition of input data – obtaining LANDSAT imagery for the area of interest with a spatial resolution of no worse than 30 meters. The images most useful for assessing residual nitrogen are acquired between August and October.
2) Image processing and NDVI calculation.
3) Researching the area of interest.
4) Classification of the area of interest into several zones based on the color of the sugar beet canopy.
5) Creation of thematic maps of residual nitrogen.

6) Soil sampling for residual nitrogen according to the thematic maps throughout the entire crop rotation.

American Crystal Sugar Cooperative reported that about 30% of their grower acreage used sugar beet canopy tops in 2005 to reduce fertiliser nitrogen levels to subsequent crops [4]. The lack of such practice among domestic agricultural enterprises once again highlights the gap in the application of GIS between Western countries and Ukraine.

This study aims to define the peculiarities of developing GIS for monitoring the activities of agricultural enterprises in the Poltava Region as a case study.

Results. The method for developing the MAAE GIS includes the development of its functional model and the conceptual model of the GDB of MAAE GIS.

The functional model represents a generalised view of the system through its functions. In other words, the functional model describes the activities or processes that occur within the system without detailing the technical implementation (fig. 1).

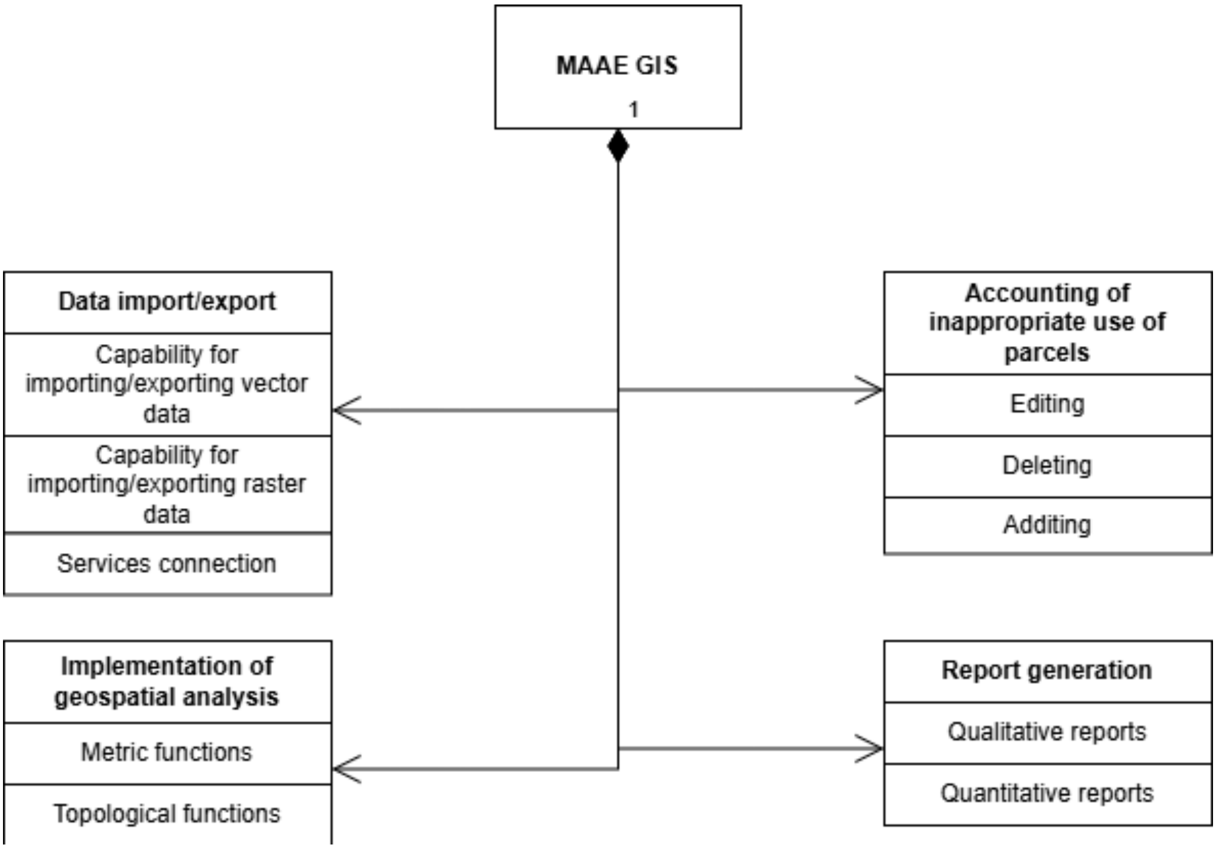

Fig. 1. UML diagram of the functional model of MAAE GIS

Data import/export. This block provides the user with the following functionalities:

– import and export of vector data. For example, field boundaries of a specific agricultural enterprise can be uploaded, and land parcels within its area can be analyzed;

– import and export of raster data. If necessary, up-to-date remote sensing data or aerial imagery of the study area can be loaded;

– integration of external services. API-based connections to the Public Cadastral Map of Ukraine and the State Register of Real Property Rights enable access to all information required for a comprehensive analysis of agricultural enterprise activities.

Implementation of geospatial analysis. This block includes such geospatial analysis functions as metric and topological analysis. The metric function enables the precise measurement of the area of inappropriate land use. The topological function enables the performance of overlay analysis, specifically the selection of land parcels that fall within the boundaries of cultivated fields of a particular agricultural enterprise.

Accounting for the inappropriate use of parcels. This module allows adding, deleting, and editing attribute information and land parcels whose use does not comply with their designated purpose.

Report generation. This module enables the user to generate reports, which are conventionally divided into quantitative and qualitative. Quantitative reports allow generating a table containing information on:

– the total number of land parcels used not in accordance with their designated purpose;

– the total area of such parcels;

– the total area of inappropriate use within the parcels;

– the total percentage of such parcels relative to the total number of parcels.

Qualitative reports allow generating a table with information on all land parcels used not in accordance with their designated purpose, including:

– cadastral number;

– designated purpose of the parcel;

– type of land use (land category);

–area, ha;

– actual use of the land parcel;

–land parcel lessee.

The conceptual model consists of the main types of objects: the territory of administrative-territorial units and territorial communities, parcels, and contours of agricultural enterprise fields. The relationships between the object types, associations, are shown, as well as their attributes, without technical details (such as data types, attribute field lengths, etc.).

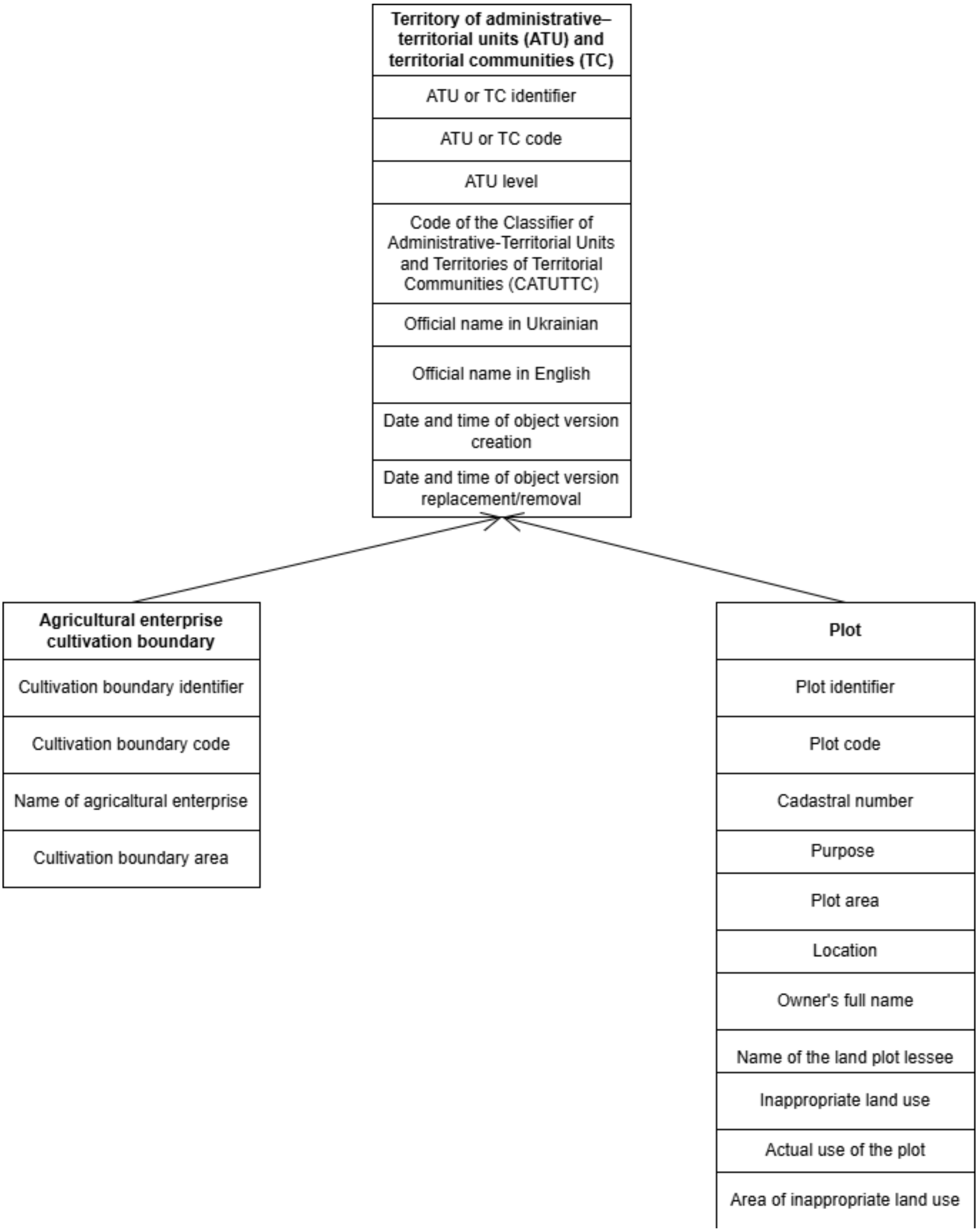

Fig. 2. UML diagram of the conceptual model of the GDB of MAAE GIS

In addition, based on the materials of the geographic information system, cartograms were created to illustrate crop patterns within the territories of the Serhiivska, Seredniakivska, Petrivsko-Romenska, Berezovolutska, Ruchkivska, and Kharkovetska village councils of Poltava Region for the period 2022–2025 (fig. 3.a – 3.d).

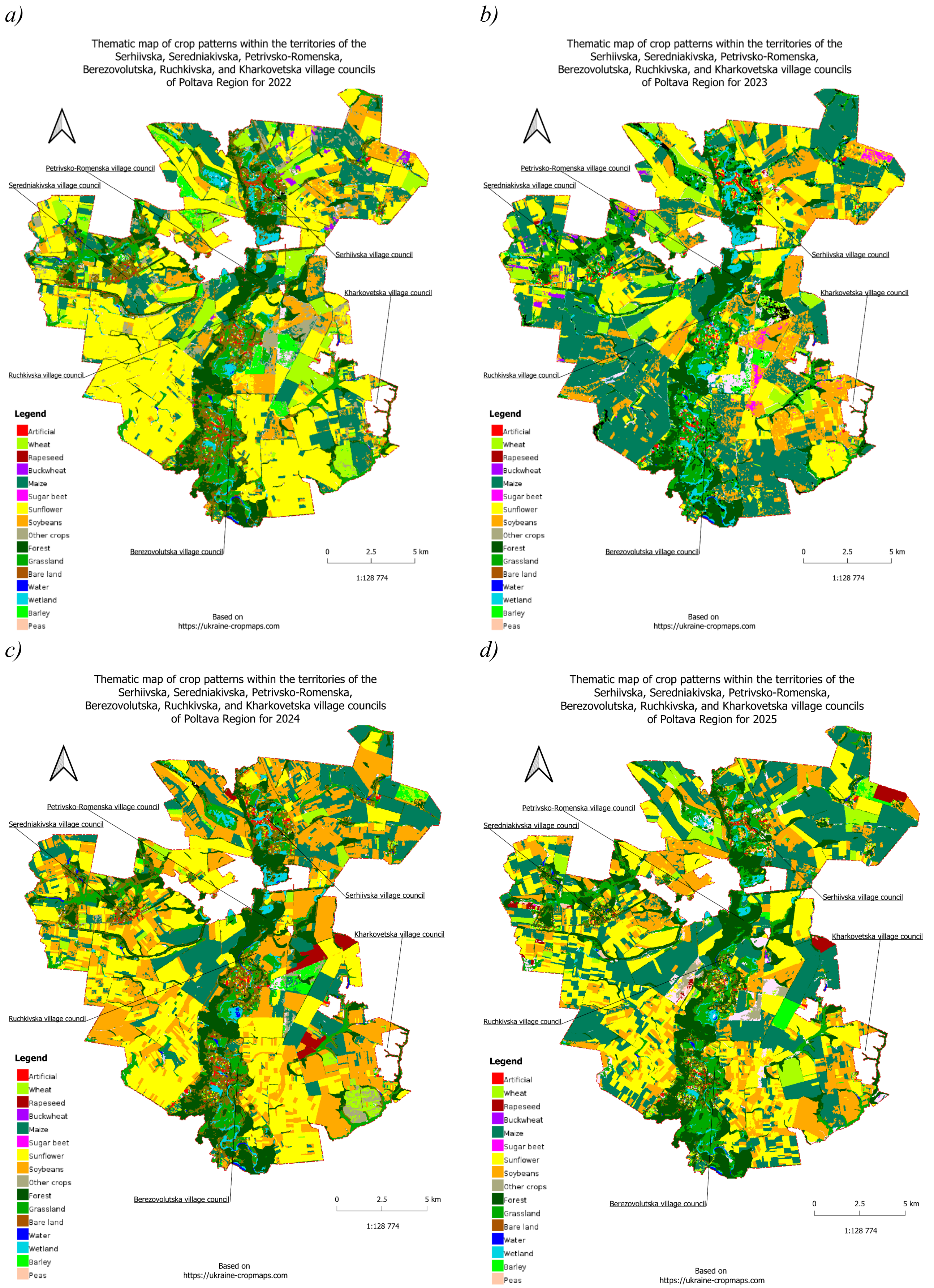

Fig.3. Thematic maps of crop patterns based on selected rural councils of Poltava Region for 2022-2025

After analysing the thematic crop maps for the territories of the Serhiivska, Petrivsko-Romenska, Berezovolutska, Ruchkivska, and Kharkovetska rural councils for the period 2022–2025, the following conclusions can be drawn:

– within the area of interest, agricultural activities are carried out by both large agroholdings and small agricultural enterprises and individual farmers;

– the type of agricultural land lessee can be identified by the scale of cultivated areas under a single crop and the degree of their consolidation: the larger the field and the higher its level of consolidation, the greater the probability that the land is cultivated by an agroholding. This relationship is explained not only by financial capacity but also by a higher level of operational planning, which is characteristic of agroholdings;

– within the analysed rural councils, the set of cultivated crops is typical and consistent with standard crop rotation practices;

A trend toward an increasing number of individual parcels and small land blocks within previously consolidated areas has been observed. The crops cultivated on these parcels differ from those grown in the formerly consolidated land masses. This indicates a withdrawal of landowners from agroholdings and a transition either to individual land cultivation or to leasing land to small farming enterprises.

Conclusions. The GIS for Monitoring the Activities of Agricultural Enterprises (MAAE GIS), whose development process has been presented and substantiated in this article, can become a successful technological solution for the inventory and monitoring of land banks of agricultural enterprises in Ukraine.

Based on the MAAE GIS data, crop cartograms for the territories of rural councils in the Poltava Region were created and analysed. To a large extent, these cartograms were used to track the activities of agricultural land lessees and to identify emerging trends in the agrarian sector.

The research results contribute to achieving two Sustainable Development Goals simultaneously: Zero Hunger and Life on Land. By ensuring compliance between land use and its designated purpose, one of the requirements of the EU Regulation on Deforestation-free Products (EUDR) – namely, the conformity of product sources and production processes with local regulations – is fulfilled. Compliance with EUDR requirements, in turn, opens access for Ukrainian agricultural products to the European market and confirms that their producers adhere to environmental commitments.

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ОСОБЛИВОСТІ СТВОРЕННЯ ГІС ДЛЯ МОНІТОРИНГУ ДІЯЛЬНОСТІ СІЛЬСЬКОГОСПОДАРСЬКИХ ПІДПРИЄМСТВ НА ПРИКЛАДІ ПОЛТАВСЬКОЇ ОБЛАСТІ

Сучасні тенденції розвитку аграрного сектору в Україні вимагають широкого впровадження інформаційних технологій для забезпечення ефективного управління земельними та виробничими ресурсами. В першу чергу, використання геоінформаційних систем в сільському господарстві є ідеальним інструментом для моніторингу та обліку земельних активів аграрних підприємств.

У цій статті запропоновано методику створення геоінформаційної системи для моніторингу діяльності сільськогосподарських підприємств на прикладі Полтавської області (далі – ГІС МДСГП), а також визначено її особливості розроблення. Створено функціональну модель ГІС МДСГП та концептуальну модель бази геопросторових даних (далі – БГД) ГІС МДСГП. Авторами статті проведено дослідну реалізацію ГІС МДСГП, а за її матеріалами створено та проаналізовано тематичні карти, що відображають посіви на територіях Сергіївської, Середняківської, Петрівсько-Роменської, Березоволуцької, Ручківської та Харковецької сільських рад Полтавської області за період 2022-2025 рр. В ході аналізу картограм більшою мірою було зроблено висновки саме щодо діяльності аграрних підприємств в зоні інтересу та тенденції, що прослідковуються в сільськогосподарському товарному виробництві, аніж про перелік вирощуваних культур.

Розроблена методика дозволяє створити ГІС, що призначена для відслідковування нецільового використання земельних ресурсів України. Її імплементація сприяє досягненню цілей сталого розвитку, напряму впливає на можливість експорту сільськогосподарської продукції в країни ЄС та євроінтеграцію загалом.

Отримані в ході дослідження практичні матеріали, тобто тематичні карти посівів, мають практичне значення для вирішення як аналітичних та статистичних типів задач, так і моніторингових. Використання таких тематичних карт дає розуміння не тільки про розміщення та масштаби вирощуваних за заданий часовий діапазон культур, а й дозволяє відслідковувати діяльність сільськогосподарських підприємств та тенденції в аграрній сфері.

Ключові слова: геопросторові дані; ГІС; моніторинг; сільське господарство; база геопросторових даних; геопросторовий аналіз.

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