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Alternative tools for modern agroecological research

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SUMMARY

Most researchers and scientists, including ourselves, encounter difficulties in finding data for building an extensive database, analysing, and summarizing information during the course of scientific research, which requires significant time investments. Therefore, our goal was to explore the possibilities of applying traditional methods of data collection and processing with interactive GIS mapping, created based on geomatics tools combined with artificial intelligence (AI) as a modern alternative tool for conducting scientific research.

Keywords: GIS technologies, agro-ecological monitoring, GIS-based geomatics tools, AI

Introduction

The yield of agricultural crops directly depends on many factors, with a foundation in the interdependence of agricultural sustainability under conditions of climate change, specifically the variability of climate factors. In addition to potential long-term risks, agriculture today suffers devastating losses caused by military actions, with catastrophic consequences such as the mining of territories allocated for agricultural activities, soil pollution, and the complete destruction of the irrigation system in southern Ukraine. As of 2023, the total direct damage inflicted on Ukraine's agro-industrial complex amounted to 49.0 billion USD. According to FAO estimates, the crop production sector alone has sustained damages of approximately 1.26 billion USD. (Recommendations of the committee hearings on the topic, 2024).

Today and during the post-war recovery phase, Ukraine will face the urgent need to restore agricultural production while ensuring high crop yields, taking into account potential natural and anthropogenic risks. This can be done more effectively by applying alternative approaches to the sustainable development of the crop production sector in accordance with European requirements.

Theory and Method

Analytical data sets are a key parameter for conducting many scientific studies. For ecological and agroecological research, it is particularly important to have the capability for multifactorial analysis of the widest possible range of parameters that directly or indirectly affect the ecosystem, causing corresponding changes; as well as the duration of the time series of observations, for example, when studying climate changes and the transformational (destructive) variations they cause.

An innovative solution in agricultural mapping is the combination of geomatic tools (based on GIS, RS, RPAS, and GNSS) with AI methods (Espinel, Herrera-Franco, Rivadeneira García, & Escandón-Panchana, 2024). Web-GIS combined with AI opens new possibilities for data processing and optimization of approaches in the field of agriculture. Unrestricted access to spatial maps enables scientists, farmers, and managers to integrate information, visualize scenarios, present powerful and motivating ideas about agriculture, and develop effective and practical solutions (Ayodele, 2024), achieving sustainable and efficient farming methods (Kumari, Pandey, & Tiwari, 2024).

The main areas of GIS application in crop production include assessing agricultural crop yields, evaluating soil fertility, monitoring crop patterns, assessing drought conditions, detecting and controlling pests, addressing agricultural crop diseases, implementing precision farming methods, managing fertilizers, and combating weeds. These areas encompass crop yield estimation and forecasting, assessment of soil fertility, analysis of cropping patterns and agricultural monitoring, evaluation of droughtconditions, detection and control of pests and crop diseases, implementation of precision agriculture techniques, and management of fertilizers andweeds. (Raihan, 2024).

In our view, two primary directions for the application of GIS technologies in agriculture can be distinguished:

1) practically-oriented towards local agricultural production needs and optimizing approaches to achieve a positive eco-economic effect in crop production. For example, field mapping using GPS and GIS technologies allows for detailed analysis of crop varieties, terrain, field boundaries, irrigation system efficiency, and more. Precision farming systems, based on remote sensing technologies, are increasingly popular each year and are gradually replacing traditional crop production technologies;

2) strategically-oriented towards overall comparative assessment and forecasting at the global and national levels. Scaling the assessment is capable of providing a strategic approach to optimizing the sector while considering the principles of sustainable development. This aspect is the primary focus of the current research.

Examples

In a previous study «Forecasting the adaptability of heat-loving crops to climate change in Ukraine» (Vozniuk, et all, 2023), we processed agrometeorological and climatic parameters with the primary task of forming and systematizing the corresponding data series for building regression models. In contrast, modern methods of interactive GIS mapping significantly optimize this complex process. For instance, the AgroStats platform (AI-based), which is part of the project "Climate-induced drought or flood and its impact on the environment and agriculture production in Ukraine and Texas," allows for the assessment of crop production dynamics in Ukraine, changes in the percentage of sown areas, yield trends, and fertilizer application. The platform provides statistical parameters, including crop yields, sown area, application of mineral and organic fertilizers, and irrigation of crops such as cereals, technical crops, forage crops, vegetables, fruits, and an additional row of crops (AgroStats).

For example, let's consider the yield dynamics of sunflower, one of Ukraine's most economically profitable crops. By analytically processing the data set for 2010-2020, we determined that sunflower yields are on average 3.5 and 1.4 times higher in the Forest-Steppe zone than in Polissia and the Steppe, respectively. Overall, during the period from 2010 to 2020, sunflower yields varied within the range of 2-13 c/ha in Polissia, 11-28 c/ha in the Forest-Steppe, and 13-19 c/ha in the Steppe (Figure 1; Vozniuk, et all 2023).

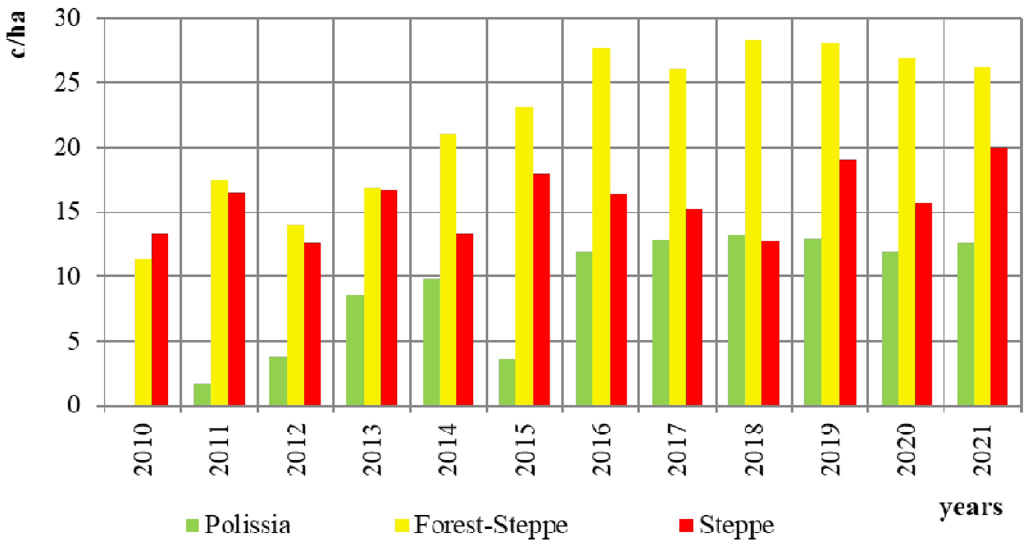

Figure 1. *Sunflower Yield Dynamics for 2010-2020, c/ha (Vozniuk, et all 2023)*

The AgroStats platform allows for the instant creation of cartographic and graphical representations of data, with the capability to download these in various formats (Figure 2). For example, using the case of Poltava Oblast (Forest-Steppe zone), we demonstrate information about the area under sunflower cultivation. A linear regression trend shows an increase in the area sown with this crop, from a minimum of 116.7 thousand hectares in 2001 to a maximum of 442.3 thousand hectares in 2022. The platform also allows for the visualization of other parameters, such as the application of mineral fertilizers (by group) and organic fertilizers for specific crops, among others.

In our forecasting, we applied the method of mathematical data analysis using the multiple correlation coefficient. For assessing and visualizing the resilience of Ukraine's agriculture both before and during the war, an alternative method can be utilized, which involves the capabilities of interactive mapping through EOS Data Analytics using satellite technologies.

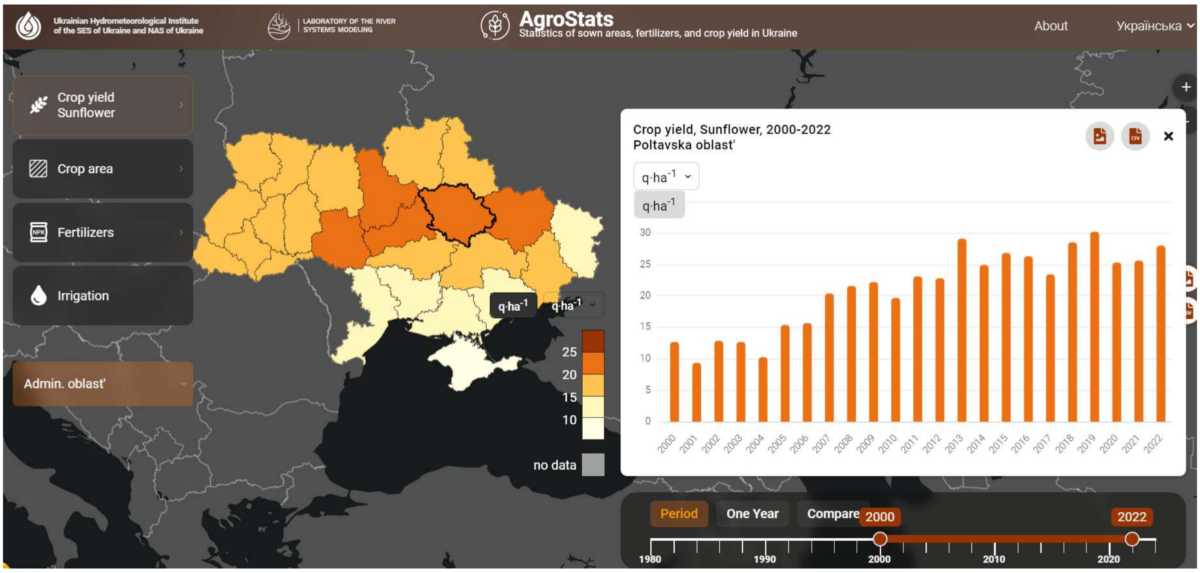

Figure 2. Map Diagram and Graphical Representation of Sunflower Yield Dynamics for 2000-2022, c/ha (AgroStats).

The interactive map visualizes data on sown areas, yield, and gross harvest of winter wheat, spring barley, corn, sunflower, and soybeans over the past three years, with an automatic forecast generation for 2024 (Figure 3-4, EOS Data Analytics). The forecast data is obtained based on a complex model that integrates scenario analysis, machine learning, retrospective yield data, and a combination of various weather forecasts.

Figure 3. Map Diagram of Yield Dynamics (EOS Data Analytics).

For example, according to EOS Data Analytics, the sunflower yield in Poltava Oblast in 2022 was 26.9 c/ha (compared to 28.1 c/ha according to AgroStats). The forecast for 2024 indicates a potential decrease in yield to 25 c/ha.

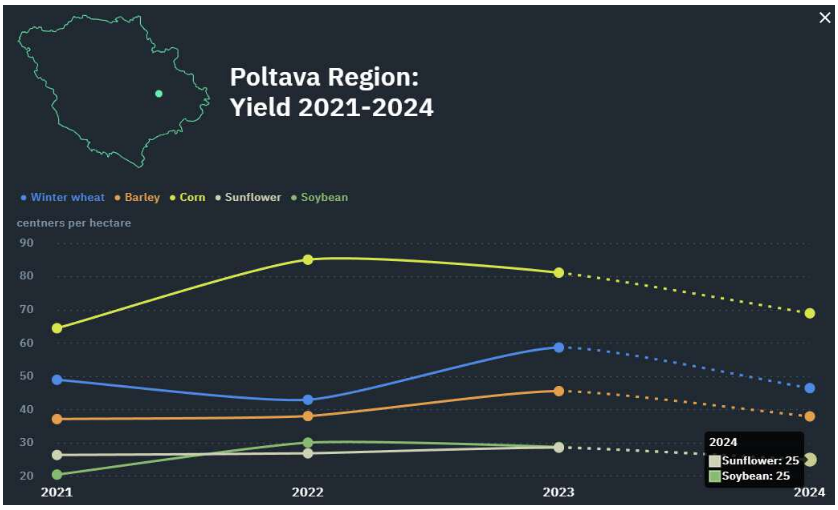

Figure 4. *Graphical Representation of Sunflower Yield Dynamics for 2021-2024, c/ha (EOS Data Analytics)*

Conclusions

Modern ecological and agroecological research is increasingly gaining more effective alternative tools through the extensive use of interactive GIS mapping, based on geomatic tools and the capabilities of artificial intelligence (AI). The application of these tools provides researchers and scientists with the ability to obtain a broader range of information, create databases for analyzing the current state of the studied ecosystems, and predict changes under the influence of various factors, both natural and anthropogenic. This facilitates effective management and informed decision-making.

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