

The technology of artificial intelligence in land monitoring

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Abstract. This study explores the application of neural network processing and geoportals technologies in analysing changes in agricultural land near the city of Tyumen. The utilisation of satellite imagery and remote sensing technologies has become integral to land monitoring processes, particularly in agriculture. By integrating satellite data with artificial intelligence, the study identifies field boundaries, tracks land usage, and monitors crop development. Key findings underscore the effectiveness of geoportals in providing real-time monitoring of crop status, growth stages, and pest infestations. The study highlights the role of advanced vegetation indices as NDVI and EVI in assessing land dynamics and soil conditions. The results show the potential of these technologies to support sustainable agriculture and land management practices. Continued research and technological advancements are recommended to fully harness the benefits of remote sensing in promoting sustainable land use and agricultural development.

1 Introduction

Remote sensing data processing technologies are rapidly developing in terms of information analysis for land management [1-2]. Important data for assessing the state of resources include water and soil cover. Changes in soil and vegetation cover are influenced by the process of anthropogenic impact, which affects the ecological state of the planet, and also indirectly affects the economic and social well-being of the Earth's population. The intensive use of natural resources causes global changes, leading to serious consequences for their potential impact on the global environment, raising questions about the need to predict changes based on the analysis of the dynamics of the transformation of water and soil cover in terms of quantitative and qualitative indicators in space.

Tracking and studying changes in the actual state of an area plays a critical role in maintaining the ecological balance, combating natural disasters, detecting fires, monitoring urban development, managing resources, organising transport logistics, providing food, solving climate change problems, assessing the state of ecosystems, and other issues [2-4]. It is important to consider that the basis of the land monitoring system is the assessment of the dynamics of changes in their condition. Analysis of satellite images using multispectral processing methods and automated interpretation enables the obtainment of data on changes

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in the land's state [5]. Introducing artificial intelligence technologies improves this process and allows the generation of reports with long-term data covering vast territories in a short time. When integrated with geoportal technologies, a wide range of people can independently receive reports on the state of land.

Using artificial intelligence technology in land monitoring using remote sensing data offers several key positive aspects [1-5], including:

- Land cover monitoring provides an opportunity to assess the health and sustainability of natural ecosystems, crucial for maintaining biodiversity, reducing deforestation, managing wetland degradation, combating desertification, and maintaining the health of aquatic ecosystems.
- Monitoring the impact of climate change and land cover allows establishing a close relationship between spatial changes in vegetation and atmospheric phenomena.
- Considering the dynamics of urbanization and establishing vectors for the development of urban areas enables the forecasting of changes in agricultural, forest, and water areas, including optimizing city construction to account for changes in urban infrastructure design.
- Identifying the potential of land resources and opportunities for enhancing them for agricultural development not only aids in making informed decisions in agricultural resource management but also is essential for ensuring food security and sustainable agricultural sector development.

Using satellite remote sensing and artificial intelligence data processing techniques is the starting point for the development of an effective system for detecting land cover changes. The main goal of the study is to study land monitoring from the point of view of presentation as an effective system for detecting land cover changes, integrating satellite remote sensing data and artificial intelligence technologies [6-7]. New approaches in land monitoring using remote sensing of the earth in scientific research [1-11] most fully reflect the specifics of the development of methods for analyzing satellite data and the use of artificial intelligence in detecting changes in land cover. For a more complete characterization of the issue under consideration, the works of S. Y. Miroshnichenko, V. S. Titov, A. A. Yashchenko, and T. I. Mikheeva [10-11] were studied, which also make a significant contribution to the understanding of methods for processing and analyzing satellite data in detecting changes in the land cover. In terms of the study, it is important to focus on the use of geoportal technologies in the presentation of land monitoring data [12-13].

These studies have significantly contributed to developing methods for detecting land cover changes, yet the challenge of developing effective data processing and analysis methods to enhance the detection of land cover changes remains. The study of land monitoring methods presents promising research areas aimed at improving the efficiency of environmental impact detection using artificial intelligence methods and remote sensing image analysis. Therefore, it is important for future research to focus on improving data processing methods, integrating various sources of information, promoting machine learning methods, increasing the spatial resolution of images, and creating automated monitoring systems. A key point is to emphasize the importance of integrating data with other research areas to gain a comprehensive view of environmental impacts.

2 Materials and methods

2.1 Aerial Imagery as Input

At present, aerial photographs provide primary data for the process of land-use mapping. It is important to note that aerial photography serves as the basis for subsequent analysis and interpretation of data aimed at creating maps covering various aspects of land use and environmental conditions.

Some researchers [14-16] cite that the mode and quality of the terrain representation primarily depend on the spatial resolution of the elevation matrix and orthorectified images. Satellite imagery from remote sensing is a crucial source of spatial data for establishing the foundation for the extraction of geospatial information. Through the processing of geospatial information, it is possible to determine the exact boundaries of real estate and land holdings. By comparing changes in spatial data over time, it is workable to forecast changes in spatial objects in the future (Figure 1).

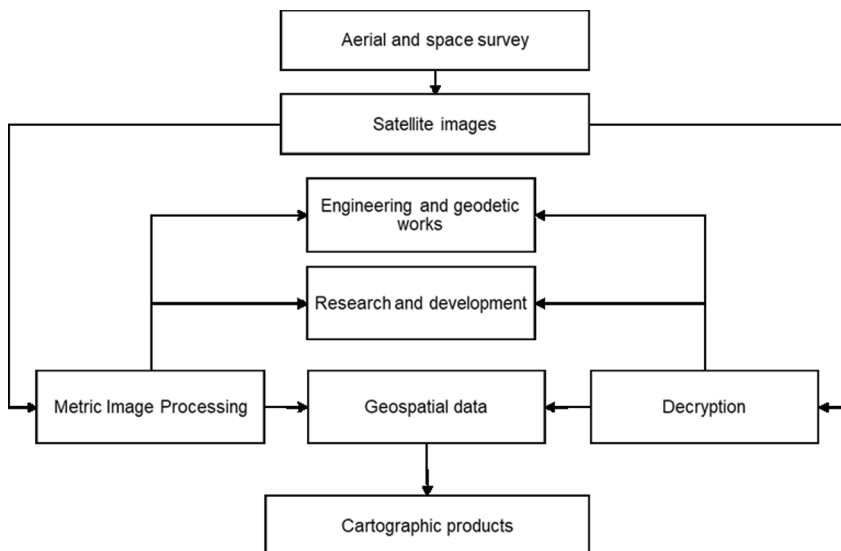


Fig. 1. Relationship between the use of aerial imagery data (author).

Using satellite images has become widespread in human activity, so it is important to study the processes and methods of image processing and their further use.

2.2 Remote Sensing Data Processing Technologies

Remote sensing data archives are constantly expanding, which leads to an increase in the requirements for the speed and quality of their processing.

Methods of processing images of remote sensing data can be classified into preliminary (image correction), with the help of interpretation, metric processing. Common pre-treatment includes contrast enhancement, orthorectification, radiometric correction, and the removal of background, noise, and other undesirable elements. Metric processing involves determining the geometric parameters of terrain objects in Space. Interpretation makes it possible to determine the types and types of terrain objects and geometrical characteristics of boundaries by various methods, including automated methods.

A scientific study [17-19] shows that the use of these methods with artificial intelligence technologies makes it possible to expand the range of functions and expand the range of tasks. The use of trained neural network models for searching, analysing changes, and recognizing objects based on training in classical processing methods makes it possible to obtain high-performance computing.

Neural network training technologies make it possible to train them to solve specific problems. For example, the analysis of changes in land use boundaries will make it possible to optimize the management system of a particular territory. And considering the use of modern telecommunication technologies (the Internet), the visualization of the results got is possible with the help of geoportals. A big advantage of geoportal allows the user to independently set the territories for research and, with the connection of data analysis functions using various methods, allows you to generate reports to predict the use of territories over time with various tasks for land monitoring.

The use of remote sensing data processing methods to monitor the dynamics of changes in city boundaries and their impact on the development of agricultural land is justified by the need to identify and analyse the processes of land cover transformation associated with urbanization and expansion of urban areas.

It has been established that neural network models are able to detect and classify agricultural objects with a high degree of accuracy and efficiency. Monitoring through the calculation of the Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI) [20] plays an important role in scientific research, in particular for assessing the dynamics of land change, assessing biological diversity, analysing crop yields and assessing the state of ecosystems.

NDVI and EVI are key tools for the quantitative assessment of phytomass and photosynthetic activity of vegetation cover on the Earth's surface based on data obtained from satellite surveys of the Earth.

NDVI is calculated as the normalized difference between the infrared and visible portions of the electromagnetic radiation spectrum, which can be obtained using optical spectrometers on satellites. The NDVI index has a range of values from -1 to +1, where higher values indicate more active and healthy vegetation.

EVI, on the other hand, is an improved version of NDVI that takes into account the effects of atmospheric aerosols and ozone on vegetation measurements. It can also be calculated from satellite data and generally provides more sensitive and reliable estimates of vegetation conditions, especially in conditions of severe atmospheric distortion.

Land monitoring, which aims to assess the impact of urban development processes on agricultural land, makes it possible to identify areas of land that have been altered by urban development, as well as to develop strategies for optimizing the use of agricultural resources in the context of a changing urban environment. Forecasting based on the received reports will give a clear picture of the necessary measures to make effective management decisions on land management and promote sustainable development of both urban and rural areas.

But based on the studied methods, we will single out a certain algorithm for data assignment using neural network data processing (Figure 2).

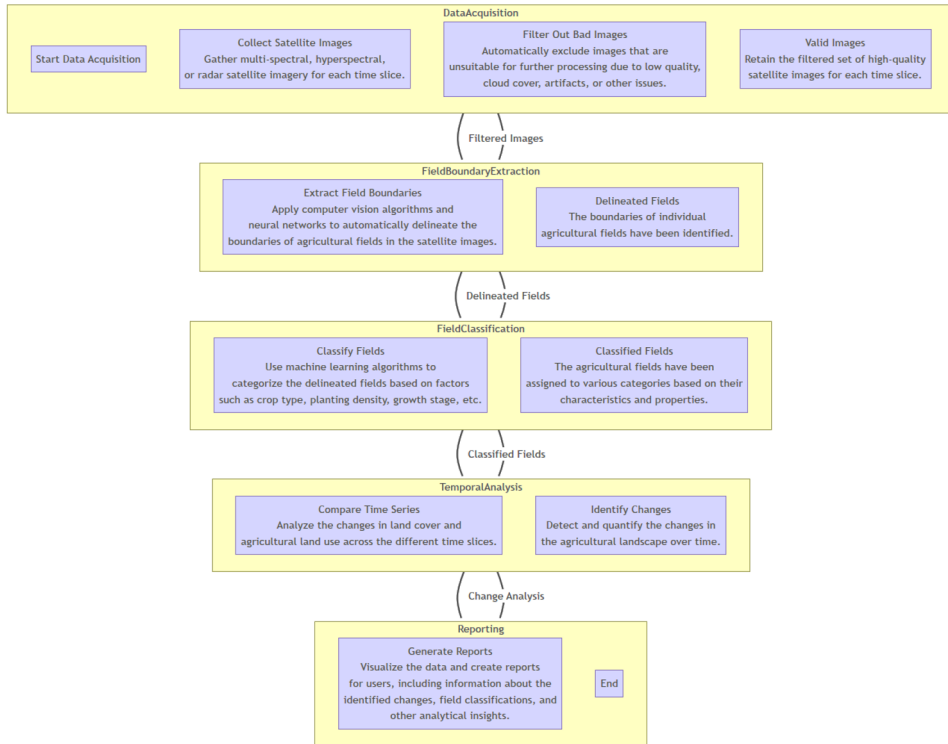


Fig. 2. Stages of Processing Technology for Remote Sensing Data Processing Using Neural Networks (author).

As a result of the application of remote sensing data processing methods for monitoring agricultural land, it has been found that the optimal approach includes the selection of multiple data layers for each time slice, the rejection of unusable images, the identification of field boundaries using artificial intelligence, the classification of fields and the comparison of data on different time slices. Based on the study of the data obtained, it is possible to assess changes in soil and vegetation cover and analyze the dynamics of agricultural land. The use of geoportals as a tool for obtaining reports on various types of monitoring provides convenience for users in perceiving and analyzing data.

2.3 Object of research

The object of the study is the territory located near the border of the city of Tyumen and intended for the placement of agricultural land. This area covers the plots of land adjacent to the urban zone allocated for agricultural use, including fields, vegetable gardens and horticultural plots. The object of the study also includes adjacent urban areas, as their development and changes can have an impact on agricultural land.

The study examines the dynamics of changes in the boundaries of urban development and its impact on the structure and use of agricultural land within a given territory. The Tyumen arable field is characterized by shallow contours and scattering of separately cultivated massifs over the territory. The average size of a separate contour does not exceed 40 hectares. If in the forest-steppe zone there are large arable areas, then in the northern part of the region the arable land resembles a patchwork quilt. The average size of the contour here does not exceed 15-20 hectares, and the contours themselves have an extremely inconvenient configuration for processing.

Due to the flat nature of the terrain, the water drains slowly, often large areas are swamped, which makes it difficult to involve them in agricultural turnover. Figure 3 shows the layout of the study object.



Fig. 3. Boundaries of inventory objects (12.07.2022).

3 Results and Discussion

Neural networks can be effective tools for processing such data because of their ability to train on large amounts of data and automatically extract features from images. With the use of geoportal technologies, the object of study was studied using the automated neural network system for processing and interpretation of satellite images "PIXEL. AI" TERRA TECH JSC.

Table 1. Property information.

Inventory Object	Agricultural fields
Constituent entity of the Russian Federation	-
Raion, Republic of Bashkortostan	-
Area of the customer's area of interest	3776.1 ha
Total area of agricultural land	3479.4 ha
Share of agricultural land in the total area	92.1%
Number of agricultural fields	1.0 state.
Centre Point Coordinates	57.1880 65.7917

This report is based on the following Sentinel-2 satellite images. Based on the results, the field boundaries were identified based on the Sentinel-2 image, the cloudiness was 26%.

In the selected area, the land is fully used (Table 2).

Table 2. Field usage statuses in the study area.

Field Usage Type		Area, ha	Quantity, pcs.
By Purpose	It is registered that the field has been sown	3479.4	1.0
	It is registered that the field has been ploughed	0.0	0.0
	It is registered that the field is fallow	0.0	0.0
Off-label	It is registered that the field is overgrown	0.0	0.0
Total:		3479.4	1.0

Let us highlight the major consequences: changing the boundaries of the city of Tyumen and changing the intended use of land next to the Tyumen District:

- The expansion of the city boundaries will lead to an increase in urban land and the transformation of rural areas into urban development, which will contribute to the development of new infrastructure such as roads, schools, hospitals and public services,

stimulating economic growth and improving the performance of a comfortable urban environment.

- The conversion of agricultural land into industrial or residential areas can affect the ecological state, reducing the share of agriculture and increasing industry and housing construction.
- Increased urban development can have a negative impact on the environment, causing environmental degradation because of more traffic, emissions, and resource consumption.

Thus, the change in the boundaries of the city of Tyumen can have a significant impact on the development of the Tyumen region, both from an economic, social and environmental point of view. It is important to conduct a comprehensive analysis of the consequences of such changes and develop strategies for managing the development of the region, considering the interests of all stakeholders.

Research and experience in using geo portals and data monitoring platforms shows the importance of these tools in the study and protection of the environment (Figure 4).

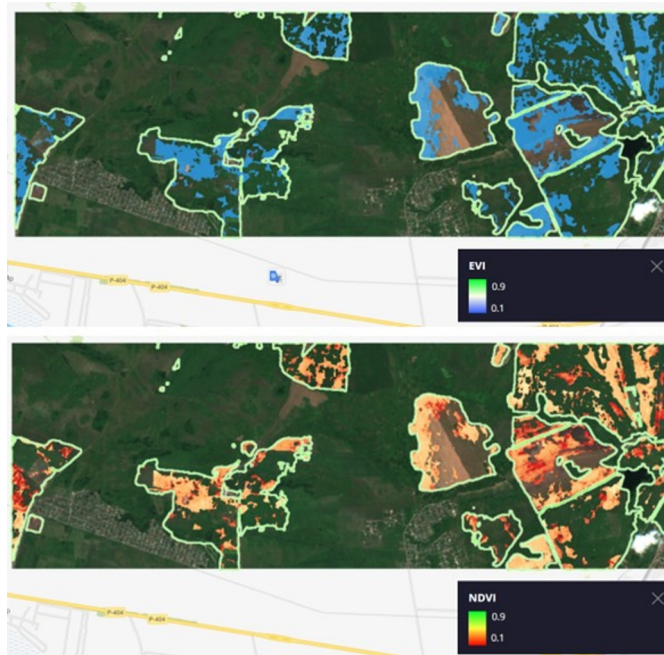


Fig. 4. Indicators of NDVI and EVI indices.

Because of the study, material was got, the analysis of which made it possible to conclude that almost all agricultural fields are used for their intended purpose. However, it is worth noting forest cover and the heterogeneity of the borders in shape, but it is also worth considering the time of year when the images were taken.

Because of the study, material was got, the analysis of which made it possible to conclude that almost all agricultural fields are used for their intended purpose. It is also important to note the significant amount of forest cover and the heterogeneity of field boundaries in shape. But evaluating the indices, it can be concluded that the territories are subject to water logging and more than half of the territory intended for growing plants is not quite favourable for growth and development. Of course, climatic conditions and soil features in the Tyumen region have an impact. Therefore, it is important to conduct not only analysis based on image data but also actual field surveys of the soil cover. In order to

make a more objective assessment, it is worth using further improved NDVI indices, such as the Soil-Adjusted Vegetation Index (SAVI) to analyse soil conditions [21-22].

4 Conclusion

Land monitoring is an important process in agriculture, especially given the seasonality and transience of processes in this area. Using satellite imagery makes it possible to continuously monitor the large-scale and diverse changes that occur during the season, which is a key aspect of the management of agricultural resources.

Important tasks of land monitoring are the determination of field boundaries, the tracking of land overgrowth, the monitoring of crop development, as well as the classification of crop types.

The introduction of artificial intelligence technology as an element of geospatial analysis makes it possible to establish trends in the development of crops and changes in the boundaries of land. Geoportals allow real-time monitoring of crop status, growth stages and pest infestations by combining satellite imagery and ground-based field data. As a result, it can be concluded that geoportal technologies contribute to the development of a land monitoring system.

Geoportals were also found to be an effective tool for accessing spatial data and implementing monitoring of farmland, providing a user-friendly interface for visualizing and analyzing information.

Definitely, the technology under study allows agricultural enterprises to plan field work, monitor the condition of land, identify areas with the death of crops, select the most productive areas for further work, as well as identify signs of land degradation and record the results obtained. In the future, there is a need to continue research in this area and improve existing technologies and methods for monitoring land resources in order to fully realize their potential in supporting sustainable agriculture and sustainable land use.

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