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A DIGITAL WORKFLOW FOR LAND INVENTORY IN THE NATURAL RESERVE FUND: THE CASE OF THE CARPATHIAN NATIONAL NATURE PARK

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Abstract. *This article develops and tests a reproducible digital workflow for conducting a land inventory of the nature reserve fund, using the example of a single undeveloped state-owned land parcel within the Carpathian National Nature Park (CNNP). The scientific challenge lies in reconciling diverse cadastral, legal, cartographic, forest management, and geodetic sources, which differ in terms of when they were created, their purpose, and their spatial basis. The proposed approach involves classifying the sources and establishing their priority, spatial comparison of cadastral and forest management materials, field GNSS-RTK verification of key boundary points and regime-defining objects, verification of topology, areas, land uses, restrictions, and adjacent properties, as well as the creation of an electronic document and related technical documentation. The*

practical result was the formation of a land parcel with an area of 2035.1825 hectares, the preparation of technical documentation, and the entry of information about it into the State Land Cadastre. For fieldwork, a GNSS-RTK South S-82T with the System.NET network was used. At Digitals, XML files were generated, and a significant portion of the resulting text and graphic materials was automated. The scientific contribution lies in the methodology for multi-source reconciliation and the data quality control system, rather than in the regulatory sequence of the inventory itself or the standard functions of the software.

Keywords: *land inventory, nature reserve fund, Carpathian National Nature Park, land management, GNSS, Digitals, geoinformation technologies, XML file, technical documentation.*

Problem statement

Land inventory is a component of land management and one of the mechanisms for updating information on the location, boundaries, area, legal status, and actual condition of land. For areas within the nature reserve fund, its significance extends beyond ordinary cadastral registration, as spatial planning must take into account special protection regimes, functional zoning, land under permanent use, adjacent land uses, water bodies, and other regime-defining features [1–4].

The Carpathian National Nature Park is a representative site for research on digital inventory. According to the park's official data, its total area is 50,495 hectares, including 38,322 hectares of forest land under permanent use and 12,173 hectares of land belonging to other land users. The territory is functionally zoned into a nature reserve zone, a regulated recreation zone, a stationary recreation zone, and an economic zone [10].

For large forest areas, it is insufficient to simply copy the boundary from one source to another. The State Land Cadastre, title documents, forest management maps, open geospatial data, and modern GNSS measurements may differ in date, scale, purpose, and spatial accuracy. Therefore, a key scientific and applied task is

to develop a traceable digital workflow in which every spatial decision has a source, a prioritization criterion, and a verification procedure.

The current Procedure for Conducting Land Inventories defines the scope of inventory work, and the technical documentation is reviewed and approved in accordance with the procedure set forth in Article 186 of the Land Code of Ukraine [1]. Regulatory requirements form the necessary foundation of the procedure but do not, in and of themselves, define the methodology for reconciling geospatial sources from different time periods and of different types. This necessitates the improvement of methodological approaches to conducting land inventories and the implementation of digital technologies that ensure greater accuracy, efficiency, and reliability of the results obtained.

Analysis of recent studies and publications

The issue of land inventory and its role in the land resource management system is widely covered in the works of domestic and foreign scholars.

In their studies, E. Butenko, A. Danshova, I. Yurchenko, and M. Prykhodko view land inventory as one of the key tools for creating a reliable information base for effective land resource management, populating the State Land Cadastre, and improving the land management system. The researchers pay particular attention to identifying unaccounted-for land parcels, refining the boundaries of land-use categories, increasing the efficiency of land use, and ensuring the accuracy of cadastral data. In the current context of decentralization, scientific research focuses on the specifics of conducting land inventories for territorial communities. In particular, the need for a comprehensive approach is justified, one based on the integration of cadastral data, geographic information systems, remote sensing data, and the results of field surveys, which ensures the completeness and reliability of information on the land resource potential of territorial communities [5, 6].

A separate area of contemporary scientific research is related to the digitization of land management processes and the implementation of geoinformation technologies. In his work, A. Koshel demonstrates that the use of GIS technologies, remote sensing, satellite data, and digital platforms makes it possible to significantly

improve the efficiency and accuracy of land inventories, automate spatial data processing, and ensure effective monitoring of changes in land use [7].

V.P. Stanislavsky examines the legal aspects of the State Land Cadastre's operations, emphasizing the need to align Ukrainian legislation with EU standards. The author argues for the importance of automated geospatial data exchange and the creation of a unified information space to guarantee land rights [8].

In his work, G.B. Nesterenko analyzes current trends in the inventory of municipally owned land, proposing to modernize the process through the implementation of GIS technologies, 3D cadastres, and the integration of environmental monitoring [9].

In an international context, the Land Administration Domain Model (LADM) standards are important, as they provide a conceptual representation of the relationships between parties, rights, restrictions, and spatial units. Also relevant are the INSPIRE Protected Sites standards, under which protected areas are treated as distinct spatial objects linked to other thematic data. In this case, a land parcel and the boundary of a protected area should not be automatically equated [15–17].

Despite a significant body of scientific literature, there remains a need for further research aimed at improving land inventory methodologies and enhancing the effective use of modern digital technologies in land management activities. This paper addresses the issue of how to integrate heterogeneous sources and ensure the consistency of their geometric and attribute data prior to cadastral registration.

The purpose of the study

The purpose of this study is to develop and test a reproducible digital workflow for surveying a large forested area within the nature reserve fund, using the Carpathian National Nature Park as a case study, which combines multi-source spatial alignment, GNSS-RTK verification, and data quality control prior to the creation of an electronic document.

The relevance of this study stems from the need to ensure effective management of land resources within the nature reserve fund, improve cadastral registration, and establish legally defined boundaries for nature conservation areas.

Conducting a land inventory helps obtain reliable information about the land's legal status, spatial characteristics, and actual use, which is a necessary prerequisite for rational land use, the protection of natural complexes, and the prevention of land disputes.

Materials and methods of the study

The empirical basis consists of technical land management documentation regarding the inventory of state-owned lands within the nature reserve fund of the KNPP. The work was carried out pursuant to Order No. 281 of the Ivano-Frankivsk Regional Military Administration dated July 19, 2023; Order No. 2-IZ of the Main Directorate of the State Geocadastre in Ivano-Frankivsk Region dated July 21, 2023; the contract; and the technical specifications.

The legal basis was the state act granting the right of permanent use of land, Series I-IF No. 002770, dated December 29, 2001, issued pursuant to the decision of the Yaremcha City Council of People's Deputies dated December 27, 2001, and registered in the Register of State Acts under No. 000019. The total area specified in the act was 4133.3200 hectares. Within block No. 6 of this act, a land parcel with an area of 2035.1825 hectares was formed; the remaining area of 2098.1375 hectares, based on the source materials, is defined by other technical documentation.

Data from the State Land Cadastre, title documents, and information from the State Register of Real Rights were utilized, along with the client's graphic materials, the Voronenkiv Forest District's Forest Planting Plan, the 2001 forest management maps, the results of topographic and geodetic surveys, and open geospatial data.

The study employed methods of spatial analysis, GNSS surveying, office-based processing of geodetic data, digital mapping, and the creation of electronic land management documentation.

The digital workflow was implemented in Digitals and included classifying sources by legal status, date, scale, and spatial quality; aligning data to a harmonized coordinate system; alignment of cadastral and forest management boundaries; field GNSS verification of key points and features; verification of geometry, topology,

area, land use, restrictions, and adjacent properties; and the creation of an electronic document and technical documentation.

As a result, the following priority scheme for data sources was proposed: 1) title documents and current cadastral records serve as the foundation; 2) forest management materials are used as spatial context; 3) open data serves as a supplementary source; 4) GNSS-RTK serves as a means of field verification for ambiguous elements.

Research results and discussion

The subject of this study is an undeveloped state-owned land plot located within the Carpathian National Nature Park (CNNP), which is part of Ukraine's nature reserve fund and is situated in the western part of the country, within Ivano-Frankivsk Oblast [10].

The study area includes forested land not covered by forest vegetation, natural watercourses, land under roads, hayfields, and pastures. During fieldwork, power lines, water sources, and water bodies were surveyed.

The approximate boundaries of the land parcel to be registered in the State Land Cadastre were provided in the form of graphic material (Fig. 1).

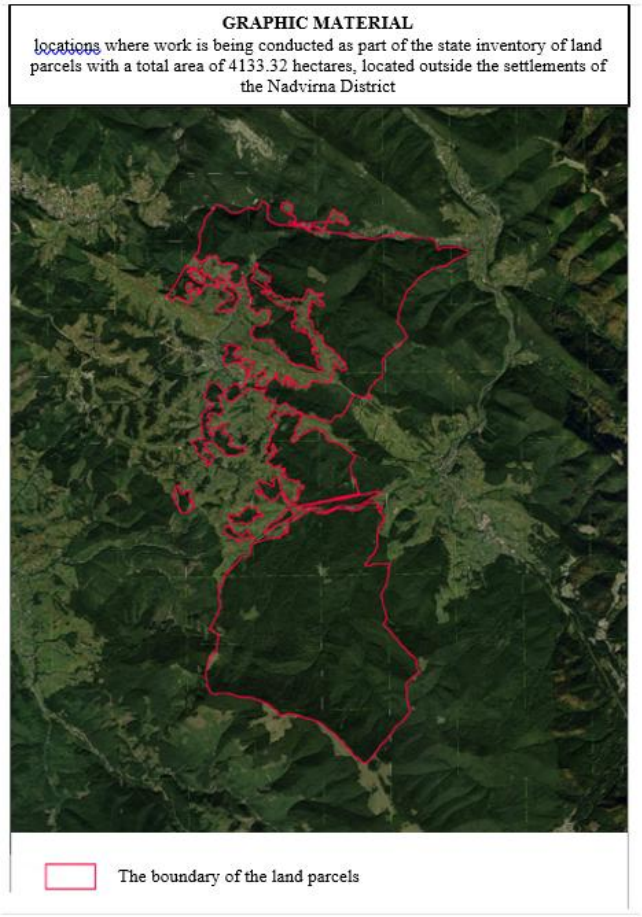

Fig. 1. Graphic representation of the site where the inventory of state-owned lands is being conducted

The provided graphic materials were used for spatial georeferencing using modern technology such as Digitals. The spatial georeferencing was performed based on topographic and geodetic surveys.

Using the Unified State Open Data Web Portal, information was obtained on the locations of nature reserve sites, cultural heritage sites, water bodies, and other environmental features [11].

The topographic and geodetic surveys conducted during the land inventory of the Carpathian National Nature Park were aimed at precisely determining the location of land management objects. They are a key component of subsequent land management measures and an integral part of this process [12].

Since the project area covers significant expanses of forested terrain, land parcel boundaries were created based on the source data and exported to KML format to improve navigation in the field.

A South S-82T GNSS-RTK receiver was used to perform topographic and geodetic measurements during the land inventory of the Carpathian National Nature Park.

Before work began, topographic and geodetic surveys were conducted to determine the spatial characteristics of the land parcels. A reconnaissance of the territory was carried out, and the boundaries of the zone within which the topographic and geodetic work would be performed were defined.

The coordinate system was based on the network of permanently operating System Solution GNSS reference stations. The positions of the base stations were determined in the SK63(3) coordinate system, and the conversion to the local coordinate system (MSK-26), which is linked to USK-2000, was performed using the coordinate conversion module of the Digitals software [13, 14].

The coordinates of the land parcel points were determined using an S82-T RTK GNSS receiver. Observations were performed in real-time (RTK) mode using reference GNSS stations from the System.NET network.

Access to the network server was provided via a mobile Internet connection using the GSM/GPRS standard. Data was transmitted in the RTCM v3.x format, and corrections were generated using the Master Auxiliary Corrections (MAX) network RTK technology.

RTK corrections were calculated using the Leica GNSS Spider v4.3 software suite installed on the network server. Field measurements were processed using Digitals software. Based on the results of the work, a diagram of GNSS observations was compiled (Fig. 2).

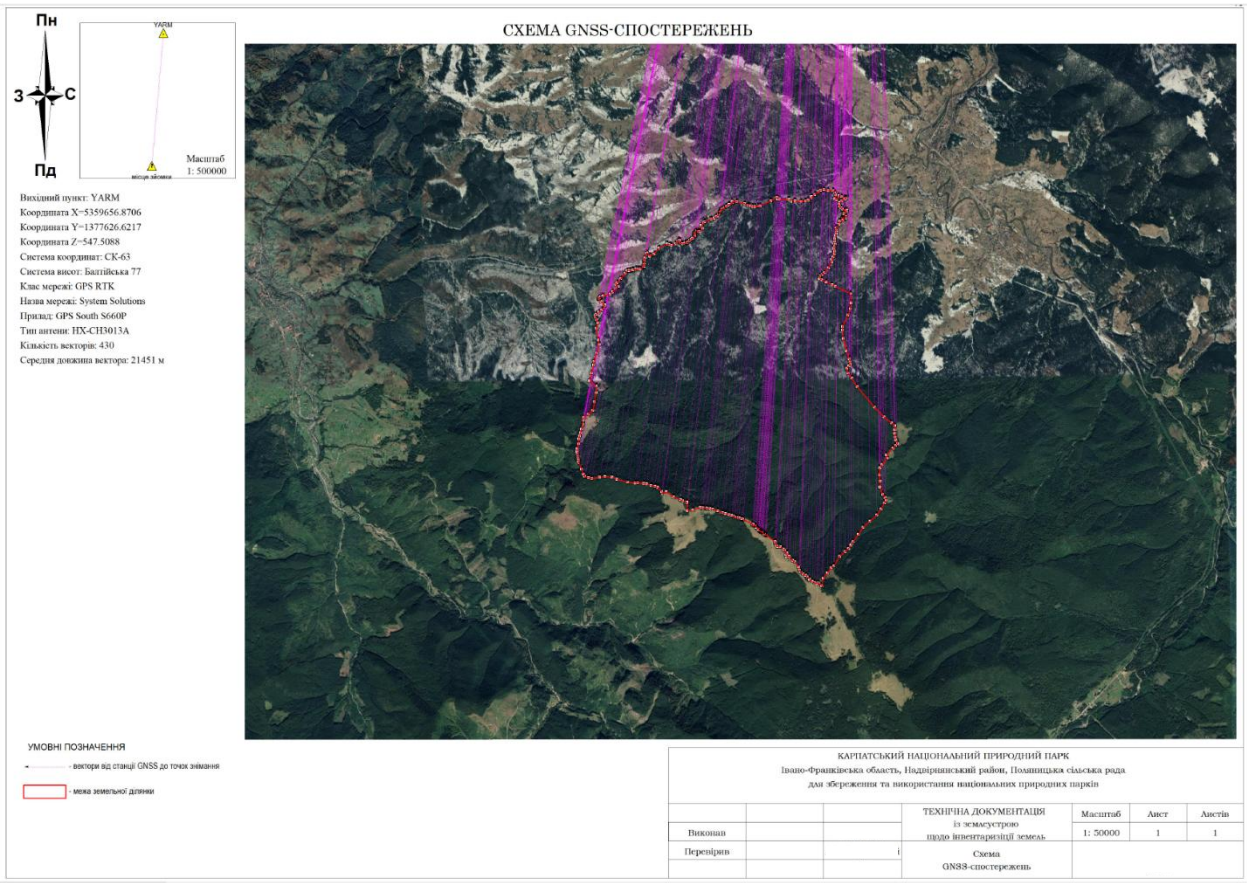

Fig. 2. Diagram of GNSS observations of the study site

As a result of topographic and geodetic surveys, the precise boundaries of the land plot were established and its area was determined to be 2035.1825 hectares. Land use categories and key features were identified, which made it possible to create a digital terrain model and produce a topographic map (Fig. 3).

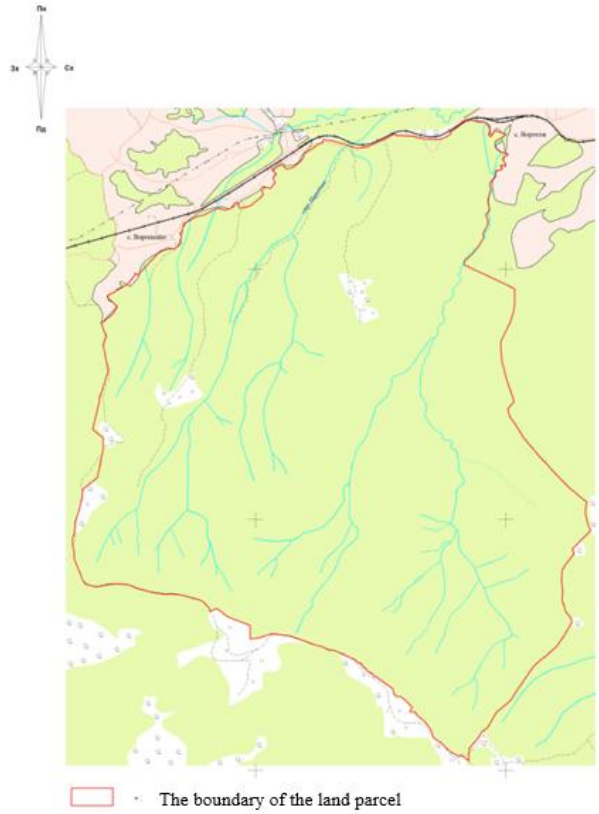

Fig. 2. Materials from topographic and geodetic surveys

During topographic, geodetic, and land-surveying work, regulatory factors were identified that affect the use of the land parcel. Based on these factors, restrictions and encumbrances have been established (Table 1).

Table 1. Restrictions (encumbrances) on the use of the KNP land parcel

Code and Description of Restrictions	Key Legislative Acts	Area of the restricted zone, hectares
10.01 National Nature Parks	Resolution No. 376 of June 3, 1980, of Kyiv on the Establishment of the Carpathian National Nature Park	2035,1825
10.08 Protected Zones of National Nature Parks	Law of Ukraine of June 16, 1992, “On the Nature Reserve Fund of Ukraine”	496,0637
10.09 Regulated Recreation Zones of National Nature Parks	Law of Ukraine of June 16, 1992, “On the Nature Reserve Fund of Ukraine”	1512,6780
10.11 Management Zones of National Nature Parks	Law of Ukraine of June 16, 1992, “On the Nature Reserve Fund of Ukraine”	26,4408

05.02 Riparian Protection Zone along Rivers, Around Water Bodies, and on Islands	Land Code of Ukraine, Water Code of Ukraine, Resolution of the Cabinet of Ministers of Ukraine No. 347 of April 14, 1997, “On Approval of the Procedure for Compiling River Profiles and the Procedure for Establishing and Using Riparian Zones of Waterways”	187,5313

The current Procedure for Maintaining the State Land Cadastre, approved by Resolution No. 1051 of the Cabinet of Ministers of Ukraine, sets forth the requirements for the information submitted for state registration of a land parcel. The Law of Ukraine “On the State Land Cadastre” provides for the submission of land management documentation in electronic form and as an electronic document.

Registration of a land plot in the State Land Cadastre was carried out on the basis of an electronic exchange file in XML format and technical land management documentation signed with an electronic digital signature (EDS) or qualified electronic signature (QES).

The exchange file must contain a set of attribute layers that ensure the technical characteristics of the data meet the requirements for successful registration of a land plot in the State Land Cadastre.

The XML file for a land parcel in the nature reserve fund with a total area of 2035.1825 hectares includes the following attribute layers:

- XML: Exchange File Details
- XML: Land Parcel
- XML: Cadastral Zone
- XML: Cadastral Block
- XML: Land Use
- XML: Restrictions
- XML: Related Entities

Based on an XML exchange file and using additional scripting functions of the Digitals software, most of the text and graphic materials for the technical documentation (TD) on land management related to the land inventory of the KNPP were created, namely the GNSS observation plan, topographic and geodetic survey materials, the cadastral plan of the land parcel, and the list of restrictions on land use. The methodological advantage lies in reducing the need for manual re-entry and the risk of discrepancies between interrelated materials.

Based on the technical land management documentation and the XML exchange file, a land parcel with an area of 2035.1825 hectares, designated for the conservation and use of national nature parks, was assigned a cadastral number, as confirmed by an extract from the State Land Cadastre.

The main challenge in conducting a land inventory of the Protected Natural Areas (PNA) lies in the interaction of several spatial units: the legally defined territory of a nature conservation area, the land parcel as a cadastral object, the forest management structure, and functional zoning. These objects may have different boundaries and should not automatically be merged into a single polygon. This approach can be adapted to other large nature conservation areas and requires further research.

Conclusions and prospects

Thus, this study developed and tested a digital workflow for inventorying land in the Protected Natural Areas Fund (PNAF), which combines the classification of source data, hierarchical spatial alignment, GNSS-RTK verification, and the validation of geometric and attribute data prior to the creation of an electronic document.

A single state-owned land parcel with an area of 2035.1825 hectares was formed for permanent use by the KNPP. The basis for the work was an order from the Ivano-Frankivsk Regional State Administration, an order from the Main Directorate of the State Geocadastre in Ivano-Frankivsk Oblast, a contract, and technical specifications.

GNSS-RTK surveying was performed using a South S-82T with System.NET. Within the plot, five types of restrictions were spatially accounted for: 10.01, 10.08, 10.09, 10.11, and 05.02. Their representation in a digital environment allows for the analysis of the relative positions of boundaries, functional zones, and regime-defining objects.

In Digitals, an XML exchange file and a significant portion of the derived text and graphic materials were generated. An advantage of this process is the coordinated use of a single set of geometric and attribute data, which reduces the risk of duplicate data entry.

The scientific contribution lies in the reproducible logic for harmonizing cadastral, legal, forest management, and geodetic sources. Applying this approach to other areas within the nature reserve system requires case-by-case consideration.

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ЦИФРОВИЙ РОБОЧИЙ ПРОЦЕС ІНВЕНТАРИЗАЦІЇ ЗЕМЕЛЬ ПРИРОДНО-ЗАПОВІДНОГО ФОНДУ НА ПРИКЛАДІ КАРПАТСЬКОГО НАЦІОНАЛЬНОГО ПРИРОДНОГО ПАРКУ

Анотація. *У статті розроблено та апробовано відтворюваний цифровий робочий процес інвентаризації земель природно-заповідного фонду на прикладі однієї несформованої земельної ділянки державної власності в межах Карпатського національного природного парку (КНПП). Наукова проблема полягає в узгодженні різнорідних кадастрових, правових, картографічних, лісовпорядних і геодезичних джерел, які відрізняються часом створення, призначенням та просторовою основою. Запропонований підхід передбачає класифікацію джерел і встановлення їх пріоритетності, просторове зіставлення кадастрових та лісовпорядних матеріалів, польову GNSS-RTK-верифікацію ключових точок меж і режимоутворюючих об'єктів, контроль топології, площ, угідь, обмежень і суміжників, а також формування електронного документа та пов'язаних матеріалів технічної документації. Практичним результатом стало формування земельної*

ділянки площею 2035,1825 га, підготовлення технічної документації та внесення відомостей про неї до Державного земельного кадастру. Для польових робіт застосовано GNSS-RTK South S-82T із мережею System.NET. У Digitals сформовано XML та автоматизовано значну частину похідних текстових і графічних матеріалів. Науковий внесок полягає у методиці багатоджерельного узгодження та системі контролю якості даних, а не у самій нормативній послідовності інвентаризації або стандартних функціях програмного забезпечення.

Ключові слова: *інвентаризація земель, природно-заповідний фонд, Карпатський національний природний парк, землеустрій, GNSS, Digitals, геоінформаційні технології, XML-файл, технічна документація.*