Forest Policy Report SFI/2025

Guidance on the design of the NFI data gathering and processing software in Ukraine (DGP)

(based on experiences of German Bundeswaldinventur)

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About the Project “Sustainable Forestry Implementation” (SFI)

The project “Technical Support to Forest Policy Development and National Forest Inventory Implementation” (SFI) is a project established in the framework of the Bilateral Cooperation Program (BCP) of the Federal Ministry of Food and Agriculture of Germany (BMEL) with the Ministry of Environment and Natural Resources of Ukraine (MENR). It is a continuation of activities started in the forest sector within the German-Ukrainian Agriculture Policy Dialogue (APD) forestry component.

The Project is implemented based on an agreement between GFA Group, the general authorized executor of BMEL, and the State Forest Resources Agency of Ukraine (SFRA) since October 2021. On behalf of GFA Group, the executing agencies - Unique land use GmbH and IAK Agrar Consulting GmbH - are in charge of the implementation jointly with SFRA.

The project aims to support sustainable forest management planning in Ukraine and has a working focus on the results in the Forest Policy and National Forest Inventory.

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Disclaimer

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ABSTRACT

General description of the concept

This document defines the conceptual basis for the development and implementation of an innovative system for collecting and processing data for the National Forest Inventory (NFI) of Ukraine, based on modern digital technologies and methods harmonized with international standards of UNECE (United Nations Economic Commission for Europe), FAO (Food and Agriculture Organization of the United Nations), as well as best practices, in particular the experience of Bundeswaldinventur (BWI — German National Forest Inventory).

The concept was developed taking into account a detailed analysis of existing problems in the NFI data collection system, a comprehensive study of the requirements of the current NFI Methodological Guidelines, and an in-depth review of international best practices, in particular the German BWI system, which has proven itself over several inventory cycles and is currently being modernized.

Justification of the need for technological transition

The document provides a detailed justification of the strategic need to transition to open-source architecture as a key element in ensuring Ukraine's long-term institutional independence in the field of forest monitoring. This approach guarantees the possibility of adapting the system to national needs without dependence on external software suppliers, which is critical for national security and sovereignty in the field of forest resource management.

The concept provides for a comprehensive improvement in data quality through the implementation of automated validation algorithms, a multi-level verification system, and integration with external geospatial databases. Operational efficiency is achieved through the optimization of work processes, reduction of data processing time, and minimization of human error in data entry.

System architecture and technological components

The proposed system has a three-layer architecture that ensures scalability, reliability, and flexibility of the solution:

Mobile application for field data collection – a cross-platform solution for Android and iOS with offline mode support, integrated GPS functions, photo capture capabilities, and automatic data synchronization when the network connection is restored. The application includes an intuitive interface with controlled input forms that minimize operator errors.

Server system with a centralized database – a backend solution based on modern cloud computing technologies with a distributed architecture that provides horizontal scaling and fault tolerance. The system includes PostgreSQL

with PostGIS spatial extensions for efficient storage and processing of geospatial data.

Web interface for administration and analytics – a progressive web application (PWA) with adaptive design that provides full-featured access to the system from any device. Includes interactive dashboards, data visualization tools, export to standard formats, and advanced reporting capabilities.

Innovative quality control system

A key innovation of the concept is the adaptation and development of advanced BWI quality control principles based on a multi-level system of automated checks with an optimal balance between strict quality control and operational flexibility. The system includes:

- **Initial validation at the mobile application level** with instant alerts about potential errors and logical inconsistencies in the data.
- **Server validation with complex algorithms for checking** inter-parameter relationships, comparing with historical data, and detecting statistical anomalies.
- **Expert verification with visual control tools** and the ability to return data for revision with detailed comments.

Methodological basis and standards

The concept fully complies with the requirements of the current Methodological Guidelines of the NFI of Ukraine and integrates the best practices of international forest inventory standards, including recommendations from the FAO (https://www.fao.org/forest-monitoring/how-we-collaborate/national-forest-inventories/en), UNECE (https://unece.org/forests), and other international organizations. The system ensures full compatibility with existing national classifiers and the ability to export data in internationally recognized formats.

Implementation plan and stages of implementation

The concept includes a detailed phased implementation plan for the project, designed for 18 months with the possibility of parallel execution of individual tasks to optimize deadlines:

- **Phase 1 (months 1-3): Architectural design and development of a minimum viable product version** with basic data collection and initial validation functionality.
- **Phase 2 (months 4-9): Expansion of functionality** and integration of all components of the quality control system.

- **Phase 3 (months 10-12): Pilot testing** with parallel data collection using traditional methods to validate results.

- **Phase 4 (months 13-18): Full-scale implementation** with staff training and transition to the new system in all regions of Ukraine.

Risk analysis and risk mitigation strategies

The concept includes a comprehensive risk analysis with categorization by impact and probability of occurrence:

- **Technical risks** - development delays, compatibility issues, integration difficulties with existing systems.

- **Organizational risks** - resistance to change from staff, insufficient training, coordination problems between departments.

- **Financial risks** - budget overruns, funding delays, exchange rate fluctuations.

- **External risks** - changes in legislation, geopolitical factors, equipment supply issues.

Specific mitigation strategies and response plans have been developed for each risk, including backup solutions, alternative approaches, and rapid recovery mechanisms.

Success criteria and performance indicators

The document defines measurable project success criteria with specific target values:

- **Quantitative indicators:** reduction in data collection time, reduction in input errors, increase in data processing speed.

- **Qualitative indicators:** improvement in data quality, increased user satisfaction, strengthening of institutional capacity.

- **Strategic goals:** ensuring technological independence, creating a basis for integration with international forest monitoring systems.

Long-term perspective and development

The concept lays the foundation for the long-term development of the system with the possibility of future integration with satellite monitoring systems, artificial intelligence for automatic image analysis, IoT sensors for continuous monitoring of forest ecosystems, and blockchain technologies to ensure data immutability. The planned modular architecture will allow for the gradual expansion of the system's functionality without fundamental changes to the basic platform.

The implementation of this concept will provide Ukraine with a modern, efficient, and technologically independent national forest inventory system that meets the highest international standards and creates a solid foundation for sustainable management of the country's forest resources in the 21st century.

CONTENTS

1. INTRO

1.1. Context and relevance

The National Forest Inventory is a system of selective statistical surveys of Ukraine's forest resources aimed at obtaining reliable, generalized information on forests for planning purposes, including strategic planning, forest management, the state forest cadastre, and forest monitoring. The forest inventory will provide statistically sound information on the quantitative and qualitative indicators of the state of and dynamics of the country's forests, their resource potential for the needs of public administration, strategic planning of forest management, the state forest cadastre, environmental monitoring, scientific research, and international reporting on forests.

The inventory of Ukraine's forests is based on a mathematical and statistical method of observation in a network of permanent plots that are representative of all the country's forests. The object of selective surveys of the national forest inventory is all plots of the forest fund of Ukraine, regardless of the categories of land on which they are located according to their main purpose and regardless of ownership rights to them. The procedure for conducting the national forest inventory provides for the use of a combined approach that uses remote sensing methods to stratify inventory plots and conduct field surveys on forest inventory plots.

The national forest inventory is one of the key components of the overall forest and land use monitoring system in Ukraine. It provides representative, statistically sound, and institutionally independent data on the condition, stocks, structure, and changes in forest ecosystems, which cannot be fully replaced by any separate departmental records or exclusively remote methods. NFI data are the basis for:

- the formation and adjustment of state forest policy;
- assessing sustainable forest management and the effectiveness of measures to conserve, restore, and protect forests;
- the implementation of Ukraine's international commitments under the UN Framework Convention on Climate Change, the Paris Agreement, sectoral LULUCF requirements, participation in FAO FRA and other global processes;
- ensuring transparency for international partners, investors, and society, including in the context of European integration and compliance with European regulatory frameworks in the field of environment and climate.

In the context of large-scale aggression against Ukraine, the role of the NFI is further enhanced. A significant part of Ukraine's forests are located in areas that are dangerous or completely inaccessible for field work due to mining, the consequences of hostilities, damaged infrastructure, or temporary occupation. Some of these areas are expected to remain restricted for many years or even decades. This poses a systemic challenge for NFI: the need to maintain the quality and completeness of information in conditions where the traditional model of full field accessibility is no longer realistic.

In this reality, NFI must perform a dual function:

1. A ground-based observation network – providing high-quality field data where access is possible, with strict measurement and quality control standards.
2. A basic calibration and validation system for Earth observation – providing reference data for satellite and aerial images, remote monitoring products (changes in forest cover, damage, fires, logging, degradation, restoration), carbon balance models, etc.

Combining NFI with Earth remote sensing data (Copernicus, Landsat, Sentinel, commercial satellites, UAVs, LiDAR, etc.) is not an option but a necessity. Without an integrated digital system that allows:

- consistently collect ground data using a unified methodology;
- quickly upload it to a centralized database;
- automatically compare it with spatial and spectral indicators;
- generate reliable assessments for accessible and inaccessible areas.

The state forest monitoring system loses its ability to provide a complete, verified, and tamper-proof picture.

Closed source code, dependence on a commercial developer, limited scalability, lack of flexible implementation of complex quality control rules and spatial checks, as well as technical failures, which in fact forced a partial return to paper forms in 2025, demonstrated the incompatibility of the current tools with modern and military challenges. Such risks are unacceptable for the state statistical and scientific infrastructure, which forms the basis for international reporting and strategic decisions.

That is why the development of a new system for collecting and processing NFI data based on the principles of openness (open-source), modularity, transparent algorithms, and reproducible procedures is not just a technical upgrade, but a necessary condition for:

- institutional independence of the NFI center and the state from individual suppliers;
- building trust on the part of international organizations, donors, and expert communities;
- reliable integration of ground-based and remote data into a single forest monitoring system;
- adaptation of NFI to the long-term consequences of war, including the inability to fully physically access all forests.

The system proposed in the Concept, which includes a mobile application for field collection, a server platform with a centralized database, and a web interface for administration and analytics, is designed to ensure the sustainable operation of Ukraine's NFI in these difficult conditions, compliance with best European practices (in particular, the experience of BWI), and readiness for further integration with national and international platforms for monitoring forests, climate, and land use.

1.2. Purpose of the document

This document defines the conceptual framework for the design and implementation of an integrated system for the collection, processing, storage, quality control, and use of NFI Ukraine data (Data Gathering and Processing system, DGP) as a key element of the modern digital infrastructure of the national forest inventory. The concept was developed by a national expert in collaboration with international experts from Germany as part of the Sustainable Forestry Implementation (SFI) project, taking into account the experience of the Bundeswaldinventur (BWI) and the practices of several cycles of the German NFI.

The purpose of the document is to:

1. To form a comprehensive architectural vision of the DGP system, which provides a complete cycle of work with NFI data: from field measurements at inventory plots to the formation of aggregated indicators, official statistics, analytical products, and international reporting.
2. To establish principles of openness and institutional control, under which the source code, database structure, validation and processing algorithms are transparent, documented, and accessible for independent audit, and the key components of the system are under the management of Ukrainian state institutions and authorized scientific institutions.

3. Integrate the field module (mobile application) and server infrastructure into a single system, where the mobile application acts as the official data collection tool and the DGP acts as the single center for receiving, verifying, storing, analyzing, and further using information.
4. Adapt the BWI multi-level quality control system to the conditions of the NFI of Ukraine, including:
    a. "input" validations (logical, range, and structural checks at the mobile application level);
    b. automated server checks (cross-analysis between indicators, comparison with previous cycles, spatial checks, anomaly analysis);
    c. expert review and documentation of decisions on problematic data.
5. Ensure the readiness of the NFI to operate in conditions of limited territorial accessibility and military risks by:
    a. built-in offline mode support;
    b. the ability to statistically correctly combine field measurements with remote sensing data for hard-to-reach and dangerous (mined) areas;
    c. maintaining the representativeness and reproducibility of assessments at the national level.
6. Define requirements for interoperability and integration with:
    a. national geoinformation resources and registers (land cadastre, state forest cadastre, environmental registers);
    b. satellite services for monitoring forests, fires, degradation, and restoration;
    c. international reporting platforms on forests, land use, and greenhouse gases.
7. Create a basis for further technical tasks, tender documentation, and regulatory decisions, in particular:
    a. developing specifications for software components;
    b. regulation of procedures for working with NFI data;
    c. coordination of methodological documents with the DGP architecture.

Thus, the purpose of the document is not only to describe a specific software solution, but to form a coordinated conceptual framework for building a sustainable, transparent, and state-controlled digital ecosystem for Ukraine's NFI, compatible with best European practices and suitable for long-term operation in both peacetime and the prolonged aftermath of military action.

2. ANALYSIS OF THE CURRENT SITUATION

2.1. The National Forest Inventory of Ukraine

The NFI of Ukraine is based on a systematic sampling network with a cell size of 5×5 km, covering the entire territory of the country. Data collection is carried out by field teams with a target frequency of 5 years, which allows tracking the dynamics of changes in forest cover and forest condition at the national level.

The NFI provides representative, statistically sound estimates of key indicators: wood stock, species composition, age structure, spatial distribution of forests, condition of plantations, natural regeneration, dead wood, biodiversity indicators, and other parameters necessary for the formation of state forest policy, strategic planning, adaptation to climate change, and assessment of the sustainability of forest use. Unlike forest management, which is a detailed and tactical tool for individual forest users, NFI performs a macro-level function — it provides an independent information basis for decisions at the state level and international reporting.

A key methodological feature of NFI is a spatially uniform grid of inventory plots, independent of administrative boundaries, forest users, or forms of ownership. This ensures the impartiality of the sample, enables integrated analysis across the entire country, and eliminates selectivity associated with departmental interests. Inventory plots are georeferenced and discreetly marked in the field and have a standardized design (geometry, radii, approaches to accounting for trees, undergrowth, regeneration, dead wood, etc.), which allows for repeatable measurements with comparable results over time.

The NFI of Ukraine is designed to be integrated into international methodological frameworks: its data structure and classifications are aligned with the requirements of FAO FRA and with the UNFCCC reporting framework for the LULUCF sector, as well as with approaches used in national forest inventories of EU countries. This allows NFI results to serve as a consistent basis for national indicators, including changes in carbon stocks, forest area, degradation processes and restoration effects.

In post-war and war conditions, NFI takes on additional significance as a systemic basis for assessing forest losses and damage due to hostilities, fires, pollution, and mining. At the same time, some of the test sites are located in areas with limited or no access. This reinforces the need for a methodologically sound combination of NFI data with remote sensing of the Earth (optical and radar satellite series, aerial photography, LiDAR), the use of statistical methods to fill gaps, the calibration of satellite products based on available ground measurements, and the transparent documentation of these procedures.

Thus, the NFI of Ukraine serves as a cornerstone of the national forest monitoring system (see: Comprehensive overview of Ukraine's National Forest Inventory):

- provides independent, verified ground-based information;
- serves as a basis for calibrating and validating remote sensing data and thematic geoinformation layers;
- supports integrated assessments of the condition, change, and sustainability of forest ecosystems;
- creates a foundation for long-term, traceable forest monitoring in a country that is simultaneously moving towards European integration and overcoming the consequences of armed aggression.

2.2. Problems with the existing NFI data collection system

An analysis of the functioning of the current digital NFI data collection system has revealed a number of critical shortcomings that make it unsuitable as a long-term solution and contradict the principles of transparency, sustainability, and institutional independence of the state monitoring system.

- Lack of control over the source code (closed system).

  The current system is based on closed software, without access to the source code, complete technical documentation, and internal data processing logic. This makes it impossible to conduct independent audits and systematic reviews of algorithms, verify compliance with NFI methodological requirements, and quickly adapt to changes in legislation, international standards, and methodological approaches. Ukrderzhlisproekt, whose structural unit is the NFI Center, does not have full control over the key tool for generating official statistical data.

- Limited quality control functionality (lack of multi-level validation). The existing data verification mechanisms are fragmented and mainly limited to basic format and range checks. There is no integrated multi-level validation system, which increases the risk of undetected errors, systematic distortions, and reduced confidence in the results.

- Dependence on a single supplier. The update and technical support model creates technological dependence on a single developer with no realistic alternatives. Any refinements, bug fixes, or adaptations to new requirements require separate agreements, additional costs, and time. At the same time, the customer does not have the appropriate tools to influence the priorities of the system's development.

- Limited modification and integration capabilities. The lack of open specifications, full access to configurations, database structure, and stable APIs limits:
  - the prompt updating of reference books, classifications, and forms in accordance with the NFI Methodological Guidelines;
  - integration with state geoinformation systems, cadastres, and remote sensing platforms;
  - the consideration of conditions specific to Ukraine, in particular military risks, inaccessible/mined territories, and specialized damage and restoration indicators.

- Lack of transparency in processes and limited trust in results. The closed nature of the software and limited opportunities for independent verification of the algorithms and procedures implemented create methodological and reputational risks.

All these factors show that keeping the current closed system for collecting NFI data is not in Ukraine's strategic interests. To ensure reliability, stability, transparency, integration with the Earth Observation System, and compliance with international requirements, it is necessary to transition to an integrated open data collection and processing system (DGP) with a mobile field module, full control by Ukrainian institutions, and the possibility of flexible development taking into account the conditions of the war and post-war period.

2.3. Legal principles of open architecture and software ownership

To ensure the institutional independence of Ukraine's NFI, the long-term sustainability of the system, and the elimination of critical dependence on a single software supplier, the new DGP system must be based not only on technical but also on clearly defined legal principles.

Key principles:

1. State ownership of source code and technical documentation

- All software components developed as part of the DGP creation project and related modules (mobile application, server platform, web interface, quality control modules, database schemas, API configurations, data processing tools) must be created with the transfer of intellectual property rights to an authorized state institution (the NFI Center or another designated structure).
- Contracts with developers must include provisions for the transfer of all exclusive property rights to the software product, including the right to modify, distribute, create derivative products, and involve third parties in further development.

2. Open architecture and documented interfaces

- The database structure, processing logic, quality control algorithms, exchange formats, and APIs must be fully documented and accessible to authorized bodies and auditors.
- The ability to connect alternative modules and services without the need to change the base system or resort to a single "monopoly" supplier is ensured.

3. Use of open licenses and components

- When developing DGP, the use of open-source technologies with licenses compatible with state ownership of the integrated product and the possibility of its further free use by state institutions is permitted and encouraged.

- In the case of publishing individual components as open source code (e.g., validation modules or data processing libraries), licenses are applied that encourage transparency and cooperation but do not jeopardize state control over critical infrastructure.

4. Prohibition of technological "vendor lock-in"

- Technical solutions, the choice of technology stack, and system architecture must not create artificial dependence on a single private supplier, closed protocols, or undocumented components.
- Procurement conditions and tender documentation must explicitly provide for:
  - the possibility of involving any qualified developer in the refinement of the system;
  - full access by the state to code repositories, build, testing, and deployment systems;
  - the transfer of all technical documentation together with the software.

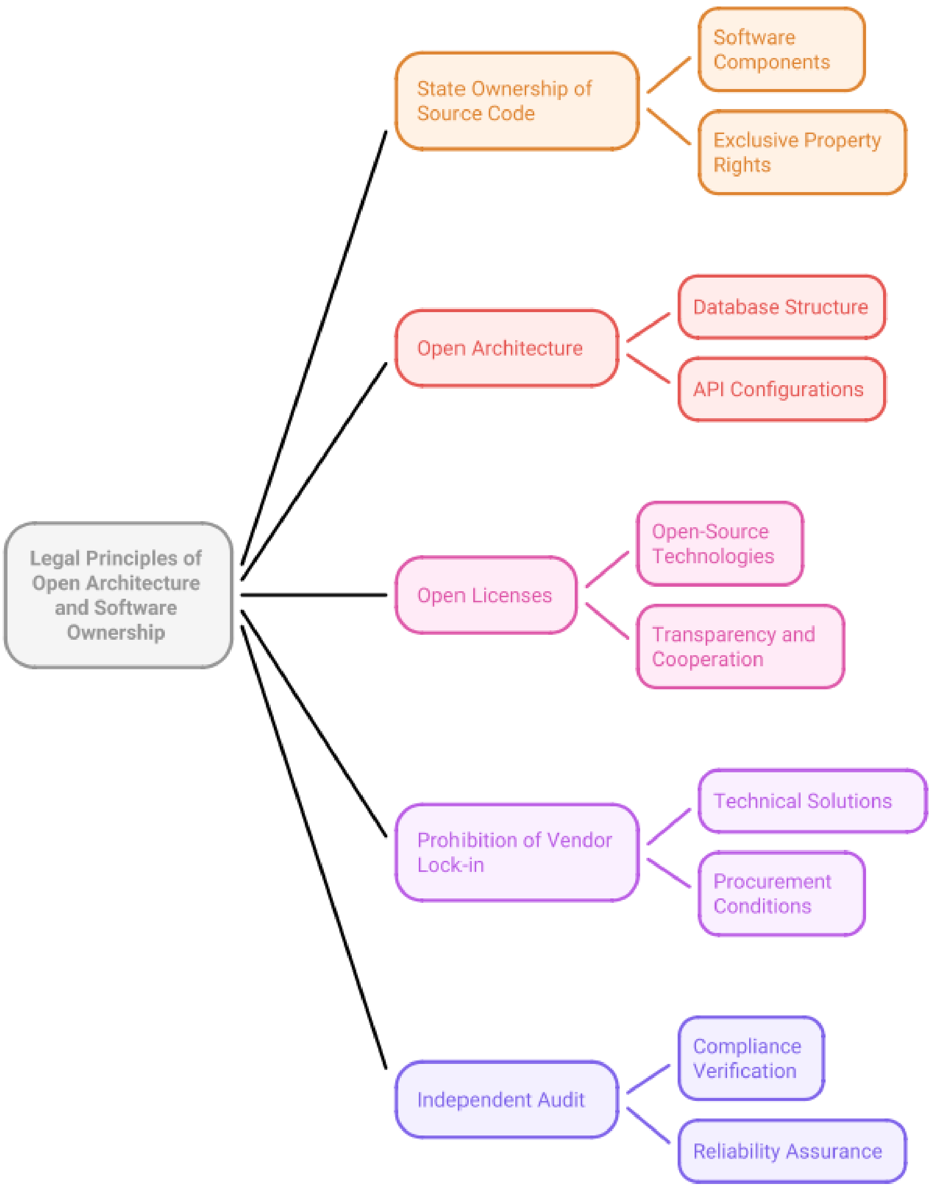
5. Possibility of independent audit

- The openness of the architecture and the availability of technical documentation to authorized persons, scientific institutions, and international partners ensures the possibility of independent verification of:
  - compliance of implementation with the official NFI methodology;
  - the correctness of calculations and quality control procedures;
  - the absence of hidden data manipulation.

- his creates an additional level of assurance for the government, society, and donors regarding the reliability of official NFI results.

The enshrinement of these principles in regulatory documents (NFI methodologies, regulations on the NFI Center, terms of tenders and grant agreements) is a prerequisite for the successful implementation of an open, sustainable, and state-controlled DGP system. (See: Legal Principles of Open Architecture and Software Ownership).

Legal Principles of Open Architecture and Software Ownership



3. EXPERIENCE OF BUNDESWALDINVENTUR (BWI) IN GERMANY

3.1. Overview of the BWI system

Germany's Bundeswaldinventur (BWI) is one of the most developed and methodologically transparent national forest inventory systems in Europe. Since 1986, BWI has implemented several full-scale inventory cycles, during which the sampling scheme, set of indicators, quality control procedures, and technical means of data collection and processing have been gradually improved. This has resulted in a mature, stable, and flexible system.

Key features of the BWI system relevant to Ukraine's NFI:

- Statistically sound sampling scheme. The inventory is based on the principles of systematic placement of sample plots in accordance with scientifically proven approaches, which ensures the representativeness of results, traceability of changes over time, and minimizes the influence of the human factor on the selection of measurement sites.
- Open architecture and use of open-source components. BWI uses an architecture in which key software components are based on open technologies. This involves:
  - control over source code and data structures by the inventory administration, which is accountable to the supervising ministry;
  - dependence on a single private supplier has been overcome in the new version; long-term support is provided through the open-source concept and in-house staff.
  - the possibility of independent auditing of algorithms;
  - flexible updating and adaptation to new requirements;

Open architecture does not mean full public disclosure of all code, but it does guarantee that the state and authorized experts have full technical control.

- Integrated data collection, validation, and processing system The following are closely linked in BWI:

  1. mobile tools for field data collection;
  2. centralized database;
  3. server modules for processing and quality control;
  4. analytical and reporting tools.

All stages - from data entry in the field to the formation of official indicators - are described, documented, and technically implemented as a single process chain.

- Multi-level quality control system. One of BWI's strongest points is the development of a formalized quality assurance system, which includes:
  - automated checks during field entry (completeness, ranges, logic within the site);
  - server checks after uploading;
  - independent field checks and repeat measurements;
  - expert analysis of anomalous values and documentation of all data correction decisions. This approach ensures high confidence in the results and their reproducibility.
  - Full traceability and documentation of processes. For each stage of data processing (collection, transfer, modification, aggregation), the following are provided:
    - action logging;
    - version control;
    - clear instructions for field teams, analysts, and administrators. This makes it possible to reproduce any processing step, which is especially important for official statistics and international reporting.
- Flexibility in setting indicators and scaling. BWI demonstrates the ability to systematically update the list of indicators in line with new political, environmental, and climate priorities (e.g., carbon stocks, biodiversity, climate change resilience, damage). The system architecture allows new variables to be added without disrupting the underlying structure.

For Ukraine, the BWI experience is particularly valuable in view of the following aspects:

- building NFI as a state infrastructure system with full institutional control over data and technologies;
- the introduction of open architecture and transparent algorithms;
- creation of a multi-level quality control system that ensures high confidence in the results;

These BWI principles form the basis of the proposed Data Gathering and Processing (DGP) system concept for Ukraine's NFI as a modern, sustainable, and verifiable solution.

3.2. Principles of data quality control in BWI

The quality control system in Bundeswaldinventur is designed as a sequential, multi-level process. For the purposes of this description, the main QA/QC tasks can be grouped into three interrelated types of activities:

1. Direct validation in the field (on-site validation) .At the first level, quality control is built directly into the field data collection tools. As a general rule, as many plausibility checks as possible should be implemented in the field software. Only errors that are detected immediately in the field can be corrected properly. Key elements:

   - Online/offline field validation during data entry:
     - range checks (e.g., diameter, height, age within acceptable limits);
     - mandatory fields (incomplete records will trigger an alert);
     - formal restrictions (coordinate format, codes for species, categories, age classes, types of damage).
     - Cross-checks between cycles and over time:
       - comparison of current measurements with previous ones for the same site;
       - detection of unrealistic changes (e.g., jumps in stock, height, species composition, area).
   - Logical checks within the plot:
     - consistency of coverage/area percentages;
     - relationship between land use categories, forest formations, and taxation indicators;
     - combination control (e.g., diameter and height do not contradict each other).

Warning messages instead of "blocking" errors in disputed cases:

   - The interface allows you to continue entering atypical but potentially real values, recording them for further verification at subsequent levels. This provides a balance between quality and operational flexibility.
   - Support for geospatial accuracy:
     - control of proximity to the target coordinates of the test site;
     - recording of GPS signal quality, measurement time, and team identifiers.

The goal of this level is to minimize elementary errors in the field, reduce the need for manual corrections, and ensure a high baseline quality of raw data.

- Automated marking rules:
  - each record or section can be assigned a status (accepted, needs verification, rejected, corrected);
  - all actions are recorded in an audit trail.

2. Post-processing and centralized verification (server-side validation) The second level occurs after the data is uploaded to the central database. All tests already performed by the field software are repeated again to ensure that all notifications have been processed. In addition, some advanced verification algorithms are implemented that are impossible or impractical to perform at the level of an individual device. However, checks outside of field measurements have the disadvantage that field teams cannot be held responsible. Retroactive corrections can also cause bias if they only recognise deviations in one direction (e.g. trees that are too high but not those that are too low). Spatial checks:

- compliance of coordinates with the official network of inventory plots;
- checking for "shifted/mixed up" plots;
- analysis of the distribution of indicators in space to identify systematic deviations of certain teams.

Statistical analysis of anomalies:

- detection of suspiciously homogeneous or, conversely, overly variable data for individual measurements/team reports;
- identification of systematic errors (e.g., rounding, systematic under-/over-measurement).

This level provides a systematic, formalized consistency check that goes beyond the capabilities of field control and prepares the data for expert review.

3. Expert analysis and targeted rechecks. The third level focuses on the professional interpretation of the results of automated checks:

Manual review of flagged anomalies:

- Experts analyze areas and indicators that have been flagged as suspicious (atypical changes, non-standard combinations of values, logic violations, etc.).

Decision-making on adjustments:

- confirmation that the values are real (e.g., due to damage, logging, fires);
- making corrections based on additional materials;
- marking data as unusable with reasons recorded.

Targeted re-measurements:
For at least 5% of the plots, a repeat field trip (control measurements) is mandatory to check the quality of the work of specific teams or to clarify questionable results.

Documentation of decisions:

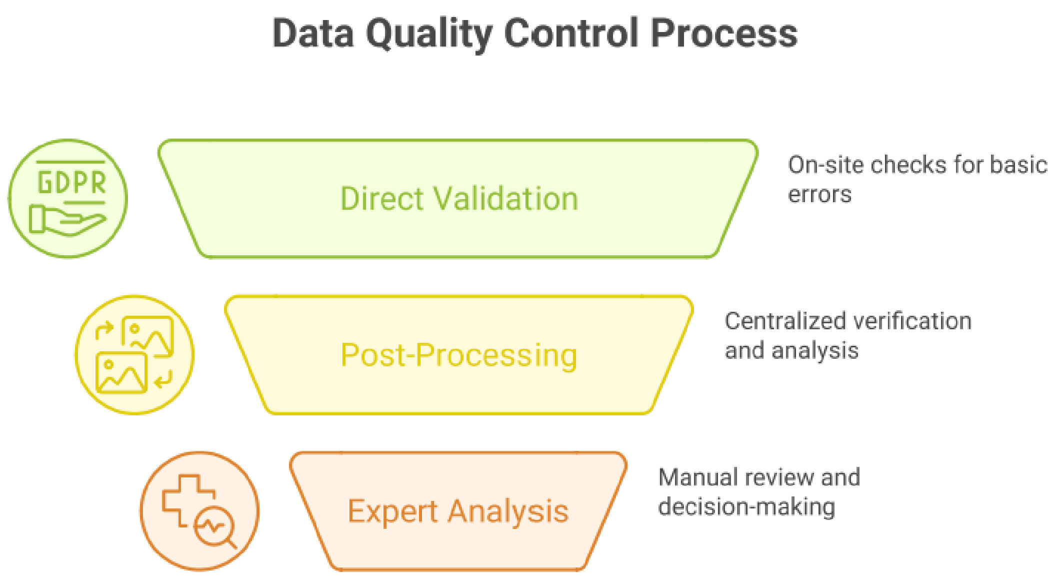
- All exceptions, corrections, and expert conclusions are formalized and stored together with the data, ensuring full traceability of the process.

It is the combination of automated algorithms and professional assessment that creates a system in which each suspicious case is not simply "corrected" but reasonably classified and documented.

Conclusion for adaptation in Ukraine. The BWI model demonstrates that effective quality control must be:

- multi-level (field → server → expert);
- formalized (clear rules, protocols, change logs);
- transparent (possibility of independent audit);
- flexible (allows for real extreme values, but requires explanations).

The proposed DGP system for Ukraine's NFI is directly based on these principles, taking into account Ukrainian conditions, military risks, and the need for integration with remote sensing data. (See: Data Quality Control Process)


Data Quality Control Process
GDPR
Direct Validation
On-site checks for basic errors
Post-Processing
Centralized verification and analysis
Expert Analysis
Manual review and decision-making

4. GOALS AND EXPECTED RESULTS

4.1. Main project objective

To develop and implement an integrated digital platform for the collection, processing, storage, and analysis of data from the National Forest Inventory of Ukraine, which will ensure institutional independence, high data quality and traceability, operational efficiency, secure operation in conditions of military risk, and full compliance with international standards in the field of forest and climate monitoring.

Achieving the main goal involves:

- Transition to open architecture

  Ensuring control by Ukrainian institutions over software, data structures, and processing algorithms; the possibility of independent auditing, flexible refinement, and integration without critical dependence on commercial suppliers.

- Creation of a unified digital NFI contour

  Combining field data collection, centralized storage, multi-level validation, analytics, and reporting into a single coordinated system (mobile application + server platform + web interface) that operates according to uniform rules and regulations.

- Ensuring high data quality and reproducibility

  Built-in multi-level quality management, inspired by BWI experience, with strong field-level QA and complementary central and expert checks (field, server, expert activities).

- Integration with remote sensing and other data sources

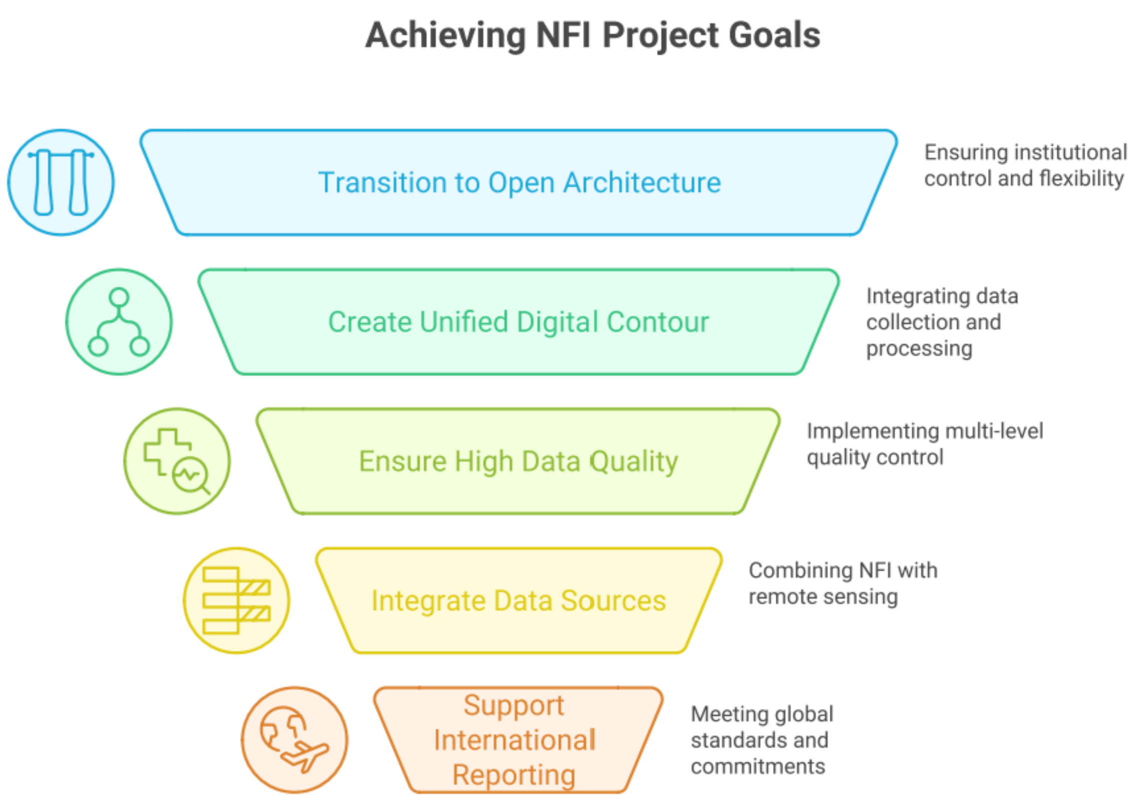
  Use of NFI as a ground reference for calibration and validation of satellite and aerospace products (including for inaccessible, mined, and hazardous areas), as well as for integration with national geographic information systems, cadastres, and environmental monitoring systems.

- Support for international reporting and European integration commitments

Ensuring the platform's compatibility with FAO FRA requirements, UNFCCC (LULUCF), the national greenhouse gas inventory system, EU approaches to forest and land use monitoring, including the expected requirements of the EUDR and other regulatory frameworks.

- Long-term sustainability and scalability

  Creating a solution that can function stably in the context of military and post-war challenges, be expanded with new indicators (biodiversity, carbon, fires, degradation, restoration), and support subsequent NFI cycles without having to build the system from scratch. (See: Achieving NFI Project goals)



4.2. Specific objectives

- Ensure full institutional ownership of the system through open architecture. Create a digital platform in which key components (database structure, validation algorithms, processing logic, exchange interfaces) are controlled by authorized Ukrainian institutions. The use of open technologies (open-source components) should guarantee:

  - the possibility of independent auditing;
  - no critical dependence on a single commercial developer;
  - flexibility in refinement in accordance with changes in NFI methodologies, legislation, and international requirements.

- Improve data quality, reliability, and traceability through a multi-level control system. Introduce formalized quality control based on a three-level model (field → server → expert), including:
  - automated checks when entering data in the field;
  - centralized post-processing with cross-checks, spatial analysis, and anomaly detection;
  - documented expert review and, if necessary, repeat measurements. Ensure that a complete audit trail is maintained for each record.
- The implementation of a multi-level data control system and automation of the field stage contribute to the optimization of the information collection and processing process, reduce the overall "data collection → results" cycle, and increase the speed and efficiency of field work by reducing the number of errors and repeat measurements. Through automatic validation, standardized procedures for data loading and processing, and a reduction in manual entry and duplicate operations, it is possible to:
  - significantly reduce the time between completion of field work and the formation of aggregate indicators,
  - ensure timely delivery of results for decision-making, reporting, and international commitments.
- Create a flexible and scalable platform for further development of NFI. Incorporate into the architecture the ability to:
  - add new indicators (carbon, biodiversity, climate change resilience, war damage, degradation, restoration);
  - expanding functionality without completely rebuilding the system;
  - adaptation to new methodological documents, reporting formats, and scientific research needs.
- Integrate the system with national and international information resources. Ensure technical and methodological compatibility with:
  - national geoinformation systems, land cadastre, forest management systems, protected area registers;

  - satellite and other Earth observation platforms for monitoring changes in forest cover, fires, clear-cutting, damage, and restoration;
  - international databases and formats (FAO FRA, LULUCF/UNFCCC, national greenhouse gas inventory, European information systems); with the aim of using NFI results as an official, recognized basis for national and international reporting.
- Ensure operation under military and security restrictions. Integrate the following capabilities into the system:
  - full offline work of field teams;
  - correct processing of data from inaccessible, mined, or dangerous areas by combining ground measurements with remote sensing and statistical methods;
  - transparent documentation of assumptions, models used, and restrictions for such areas.

These specific objectives specify the main goal of the project and define measurable benchmarks for the design, implementation, and evaluation of the effectiveness of the new DGP platform for Ukraine's NFI.

5. FUNCTIONAL OVERVIEW OF THE SYSTEM

5.1. General architecture

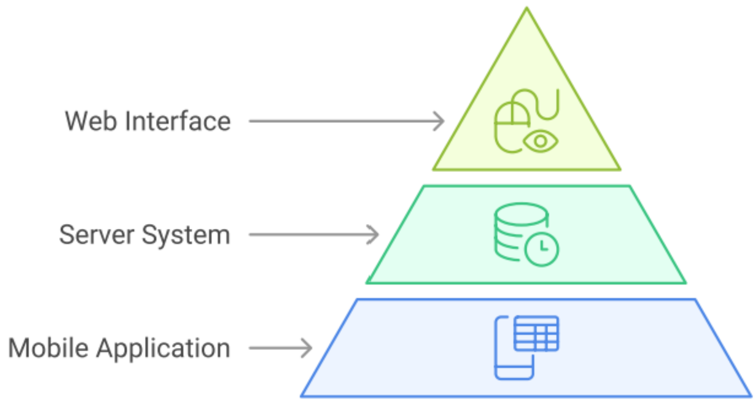
The DGP (Data Gathering and Processing) system is designed as an integrated multi-level platform that combines field data collection, centralized storage, multi-level quality control, analytics, and export of results into a single digital circuit. The architecture is built on the principles of:

- modularity (each component performs clearly defined functions);
- openness (use of open formats, documented APIs, and control by national institutions);
- security (role-based access, encryption, action auditing);
- resilience to field and military conditions (offline mode, reliable synchronization, redundancy);
- readiness for integration with other national and international information systems.

The system consists of three main components that work in synchronized mode (see: DGP system architecture):

- mobile application for field data collection;
- server system (central database and processing services);
- web interface for administration, quality control, and analytics.

DGP System Architecture



5.2. Mobile application

The mobile application is the official tool used by field teams to collect NFI data and must ensure stable operation in conditions of limited connectivity, difficult terrain, and increased risks. Main functions:

- Navigation to test sites with GPS/GNSS positioning
  - Display of target coordinates of the test site and current location
  - Signal quality indicators, distance to target, confirmation of arrival at the site
  - support for the official NFI site network with unique site identifiers.
- Structured forms for data entry in accordance with NFI guidelines
  - standardized forms for describing the plot, tree stand, undergrowth, regeneration, dead wood, damage, land use categories, etc.;
  - use of standardized classifiers, species codes, damage types, forest categories.
  - the ability to update forms and reference books through centralized management by the DGP.
- Photographic recording of objects with reference to coordinates and context

- storage of photos with geotags, time stamps, and links to specific areas/segments;
- use of photos as additional material for quality control and expert analysis.
  - Automatic data validation during entry (first level of quality control)
  - checking of mandatory fields, value ranges, formats;
  - logical checks (consistency of sums, values between variables);
  - warning messages for atypical but possible values with their marking for further verification.
- Offline mode with reliable synchronization
  - full functionality without internet access;
  - local encrypted data storage;
  - synchronization queue with conflict detection and operation log after connection restoration.
- Synchronization with the server
  - secure data transfer to and from the central system via secure channels;
  - receiving updates (reference books, configurations, form versions);
  - confirmation of successful upload and avoidance of duplicate records.

The mobile application must be cross-platform (primarily Android), optimized for use on secure/field devices, with an intuitive interface to reduce the likelihood of user errors.

5.2.1. Server system

The centralized server system is the core of the DGP and is responsible for data storage, processing, quality control, and integration. Main elements:

- Structured database (PostgreSQL/PostGIS)
  - centralized storage of all primary and derived NFI data;
  - support for spatial data (coordinates, plot geometry, map layers);
  - optimization for large data volumes and high-load queries.
- Service logic and API
- REST/GraphQL API for interaction between the mobile application, web interface, and external systems;
- Modular structure for implementation:

    - automated validations (second level of quality control);
    - aggregation, calculation of indicators, formation of samples;
    - change logging and data version management.
- Automated data processing and validation (server-side QA)
    - cross-checks between measurement cycles;
    - spatial checks of NFI network compliance;
    - detection of anomalies based on statistical rules;
    - assigning statuses to records (accepted, questionable, rejected, needs verification).
- Backup and recovery
    - regular backups;
    - storage in geographically dispersed locations;
    - tested recovery procedures to prevent data loss.
- Integration with external systems
    - support for data exchange with state registries and geoportals;
    - integration with Earth observation services, fire monitoring systems, land cover change monitoring systems, and EUDR-relevant platforms;
    - export of aggregated data and indicators in standardized formats for national and international reporting.
- Security and access
    - encryption of communication channels (TLS);
    - role-based access and user authentication;
    - access and change auditing, compliance with data protection requirements.

5.2.2. Web administration interface

The web interface (web office) is the main working environment for administrators, NFI coordinators, analysts, and quality control experts. Main functions:

- User and access rights management
    - creating, editing, and blocking accounts;
    - assigning roles (field team, regional coordinator, central analyst, administrator, etc.);
    - configuring access rights to individual modules and data sets.

- Monitoring the data collection process in near real time
  - displaying the status of work performed by region, team, and site;
  - control of synchronization and quality of collected data;
  - visualization of problem areas, anomalies, and omissions.
- Viewing, validating, and editing data with version control
  - access to detailed records for each site;
  - tools for expert analysis of identified anomalies (third level of quality control);
  - recording of all changes with indication of the author, time, and reasons for correction (audit trail).
- Report generation and data export
  - generation of standard reports (national summaries, regional breakdowns, cycle indicators);
  - customizable queries for analysts;
  - export in open formats (CSV, GeoPackage, JSON/XML, etc.) for further processing and publication.
- Map-based data visualization
  - integrated GIS panel displaying the network of sites, measurement results, and marked anomalies;
  - ability to overlay external layers (satellite images, maps of fires, mining areas, protected areas);
  - spatial analysis to identify patterns and support management decisions.

Thus, the overall architecture of the DGP provides a unified, transparent, and controlled cycle of work with NFI data — from field input to analytics and official reporting, taking into account wartime conditions, security requirements, and integration with the Ukrainian forest monitoring system.

6. Quality management: field-focused QA/QC inspired by BWI

The DGP quality management concept defines a three-level QA/QC system for Ukraine's NFI. This structure is not a copy of the German National Forest Inventory – BWI does not use a formal "three-level model" – but is inspired by its core principle: to ensure the highest possible data quality already in the field. The field team bears primary responsibility for the correctness and completeness of its measurements, and the software must provide them with the strongest possible support. Subsequent server- and expert-level checks are designed mainly to detect remaining inconsistencies, to provide feedback and training, and to identify systematic problems, not to replace proper field work or to "repair" data ex post.

DGP Quality Control System

Characteristic	Implementation	Task	Main Components	Focus
Level 1: Field Validation	Mobile application during data entry	Minimize technical and logical errors	Value ranges, logical consistency, mandatory fields, soft warnings, geospatial control, interface solutions	Quality input, reduce post-processing
Level 2: Server Validation	After data synchronization with central system	Ensure integrity, consistency, statistical reliability	Cross-cycle validation, statistical analysis, spatial consistency, automatic marking	System-wide filter, identify methodological problems
Level 3: Expert Control	Final stage, complements automated checks	Ensure informed decision-making, confirm overall quality	Analysis of flagged anomalies, selective verification, field re-measurements, documentation	Comprehensive, transparent, manageable process

6.1. Level 1: Field validation

Level 1 quality control is implemented directly in the mobile application during data entry at the sample site. Its task is to minimize the number of technical and obvious logical errors in the field without creating excessive restrictions for the team's work. Field validation works offline and is based on formalized rules agreed with the Methodological Guidelines of the NFI of Ukraine.

Main components:

- Control of value ranges

Permissible intervals are set for key tax assessment indicators, taking into account realistic limits for conditions in Ukraine, in particular:

- diameter at breast height (DBH);
- tree height;
- age;
- height/diameter of undergrowth;
- dead wood parameters;
- types of damage, etc.

Values that fall outside the acceptable ranges are marked as errors or as "suspicious" (depending on the degree of deviation).

- Checking the logical consistency of indicators

Rules are implemented to check the internal logic of the entered data, for example:

- the ratio of tree diameter to height (unrealistically low or high values);
- consistency of age, height, and diameter for major species;
- correspondence of land use category to the presence/absence of tree cover;
- logical consistency between damage types, tree condition, and tree parameters.

If illogical combinations are detected, the system issues a warning.

- Control of mandatory fields and structural completeness of records
  - checking the availability of the minimum required data set for each type of object (e.g., species + diameter for a tree, type of dead wood + diameter/length for dead wood elements);
  - verification of the sums of coverage, area, or categories, which should add up to 100% within the plot or the corresponding accounting entity.
  - Soft warnings

For values that are atypical but possible (e.g., very tall trees, extreme stocks, unusual combinations of species), the system:

- does not automatically block the entry;
- displays a clear message asking you to recheck the measurement;
- marks such records as requiring additional verification at subsequent control levels.

This allows real "extreme" values (e.g., after fires, windbreaks, clear-cutting, or in high-yield plantations) to be preserved without distorting the sample, but at the same time highlighting them for in-depth analysis.

- Geospatial control in the field

    — verification of the target coordinates of the sample plot (minimum permissible distance to the center);

    — recording of GPS/GNSS accuracy, measurement time, and team ID;

    — warning in case of significant deviation from the planned point or non-compliance with the official network.

- Interface solutions to reduce errors
    - use of drop-down lists, codes, and reference books instead of free text;
    - Unified units of measurement;
    - limiting manual input where standardized options are available;
    - clear messages in Ukrainian without technical jargon.

Level 1 checks are the most important step in quality assurance. Reliable corrections can only be made directly in the field. In line with BWI experience, Level 1 has the highest priority in the DGP system: wherever possible, errors are detected and corrected by the field team during the visit to the plot. Subsequent server and expert checks cannot replace proper field work; they mainly help to identify remaining inconsistencies and systematic problems and to provide feedback and training.

6.2. Level 2: Server validation

Level 2 quality control is implemented after field data is synchronized with the central DGP system. At this stage, advanced verification algorithms are applied that cannot be fully implemented at the mobile application level or are not practical to do so. The task of server verification is to ensure the integrity, consistency, and statistical reliability of NFI data across the entire sampling network. In addition, all Level 1 checks are repeated to ensure that all notes have been processed.

Main components:

- Cross-cycle validation and internal consistency checks

Wherever practicable, comparisons with data from previous inventory cycles are already supported in the field software (e.g. by displaying key variables from the last measurement for the same plot and issuing soft warnings in case of implausible changes). At server level, these cross-cycle checks are repeated and extended to the full sample, and additional internal consistency checks between related variables (stock, height, species composition, land use, etc.) are applied to identify remaining anomalies and systematic problems.

  - comparison of current values of key indicators (stock, height, species composition, age, dead wood, etc.) with data from previous cycles for the same inventory plots;
  - Identification of unrealistic changes (e.g., sharp jumps in stock without confirmation of logging, fires, or changes in composition; "rejuvenation" without natural or artificial causes)
  - checking internal consistency between related variables (e.g., the relationship between land use category, completeness, stand type, and stock);
  - generating a list of plots and records that fall outside expected trends.
- Statistical analysis of anomalies
  - automated detection of suspicious patterns at the level of:
    - individual teams or measurers (abnormally uniform values, "round" numbers, repeated combinations);
    - regions or forest types (significant deviations from typical distributions);
    - individual indicators (extreme values without logical explanations);
    - application of thresholds, control ranges, interquartile analysis, robust metrics;
    - prioritization of cases for expert review to focus resources on the most critical anomalies.
- Spatial consistency of data
  - verification that the coordinates of sample plots correspond to the official NFI network (5×5 km, unique identifiers, no duplications),

complementing the real-time navigation and shift checks implemented in the field software;

- analysis of the spatial distribution of key indicators to identify systematic errors (e.g., displacement of all plots of one brigade);
- the ability to cross-check with external spatial layers (forest fund, administrative boundaries, protected areas, combat/mining zones, satellite change maps) to confirm or refute atypical values;
- recording of cases where spatial inconsistencies indicate potential navigation or site identification errors.

- Automatic marking of questionable records and queuing for expert analysis
  - Each record, site, or indicator can receive the status:
  - "accepted" (all checks passed);
  - "warning" (atypical but potentially realistic values);
  - "needs verification" (significant anomalies, spatial/logical inconsistencies);
  - "rejected/error" (obvious technical failures or incorrect values);
  - automatic generation of lists for further expert review (Level 3) and, if necessary, organization of repeat measurements;
  - storage of the entire history of changes and decisions in the audit trail, ensuring transparency and reproducibility of the process.

Level 2 acts as a "system-wide filter": it not only detects errors in individual records, but also allows you to identify methodological, technical, or organizational problems (quality of team work, incorrect settings, incorrect reference books), creating a basis for rapid response and further improvement of the entire NFI system.

6.3. Level 3: Expert control

Level 3 is the final stage of the quality control system at DGP and complements the automated checks of the previous levels with a professional assessment. Its task is to ensure informed decision-making regarding non-standard, anomalous, or critically important data, as well as to confirm the overall quality of NFI information.

Key elements:

- Analysis of flagged anomalies

- experts process records automatically marked at Level 2 as "requires verification" or "warning";
- For each anomaly, the following are taken into account:
  - the context of the site (previous cycles, forest type, history of logging, fires, damage, military action);
  - related indicators (e.g., sharp change in stock along with a change in species composition or land use category);
  - additional data sources (field photographs, remote sensing data, information from forest users or management bodies);
- Based on the results of the analysis, the expert:
  - confirms the values as accurate;
  - initiates clarification or re-verification;
  - classifies the record as erroneous with appropriate correction.
- Selective verification of a portion of "normal" data (e.g., 5%)
  - in addition to working with anomalies, a statistically justified random check of a portion of data that has not been flagged by automated algorithms is performed;
  - This allows:
    - assess the effectiveness of automated checks;
    - identify potential "hidden" systematic errors;
    - confirm the overall level of data reliability;
  - The results of random checks can be used as a basis for:
    - clarifying validation rules;
    - additional training of individual teams;
    - adjusting methodological instructions.
- Field re-measurements
    - for some of the sites selected based on the analysis results (critical anomalies, suspected systemic errors, new or complex conditions), repeat visits are organized;
    - re-measurements can be performed:
      - by a special control team;
    - The results of re-measurements are used for:
      - confirmation or refutation of primary data;

- assessing errors in field measurements;
- calibration of methods and approaches to staff training;

- in the case of confirmed systematic deviations, entire data blocks may be flagged and, where appropriate, excluded from estimation or adjusted using transparent, documented correction rules; in all cases, additional requirements may be established for future cycles.
- Documentation of decisions, corrections, and procedures (audit trail)
  - Each expert intervention (confirmation, correction, rejection, recommendation for re-measurement) is recorded in the DGP system:
    - indicating the user (expert);
    - date and time;
    - reasons (justification, sources used, results of re-measurements);
    - the nature of the changes made;
- A complete audit trail is generated, which:
    - ensures the traceability of all decisions;
    - allows you to reproduce the processing history of any record;
    - serves as the basis for internal and external quality audits;
- Standardized expert review protocols are developed to minimize subjectivity and ensure a consistent approach across the system.

Level 3 transforms the quality control system from a set of technical filters into a comprehensive, transparent, and manageable process. The combination of automated tagging, selective control, repeat measurements, and formalized documentation of decisions ensures that the results of Ukraine's NFI can be reasonably used in both national and international reporting, including assessments of the impact of war, changes in forest cover, and long-term trends.

7. TECHNICAL APPROACH

7.1. Technological basis of the system

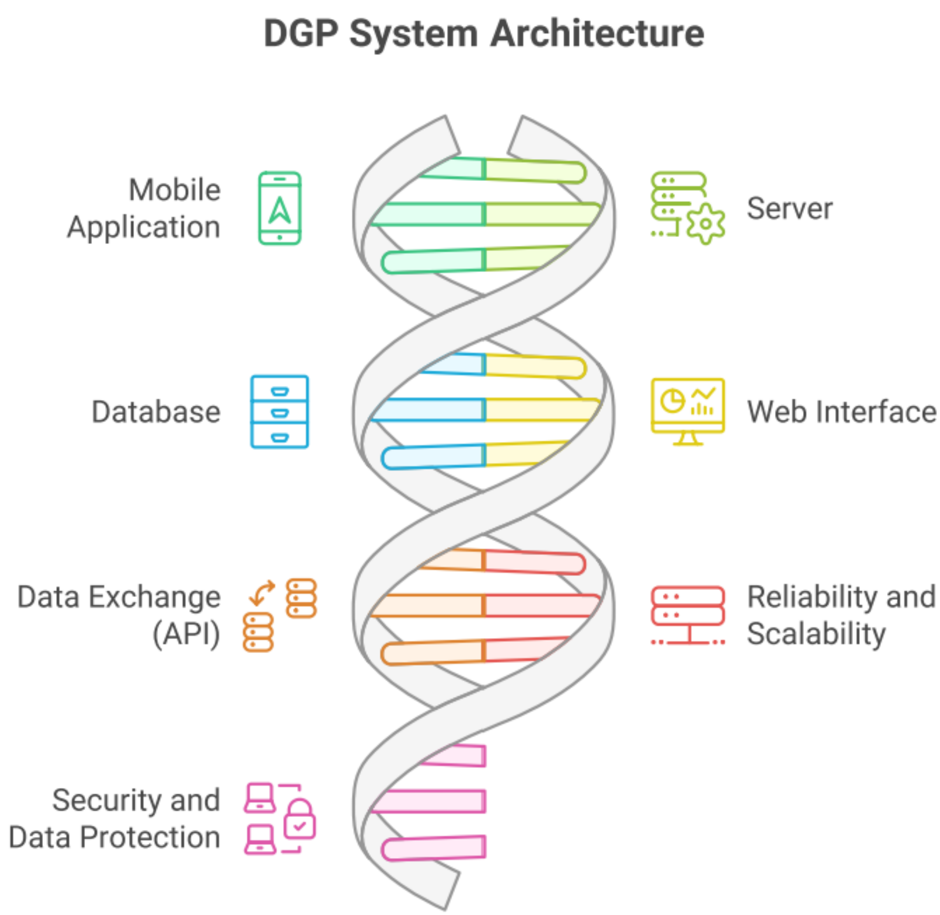
To build the system, it is proposed to use proven, open, and accessible technologies that do not tie Ukraine to a single supplier and can be supported by national specialists.

Key decisions:

- Mobile application
  Development based on cross-platform technologies that allow it to work on most tablets and smartphones (primarily Android). This reduces equipment costs, simplifies updates, and provides the same functionality for all teams.
- Server
  Use of common open solutions (e.g., Python or Node.js) for data processing, quality checks, report generation, and interaction with other systems. These technologies are well documented and supported by a large professional community.
- Database
  Use of PostgreSQL as a reliable open system for storing NFI data, with an additional module for working with coordinates and maps. This allows you to securely store large amounts of information and easily use it for analysis and visualization.
- Web interface . Creation of a convenient web office for administrators and analysts based on modern web technologies. The interface should include:
  - data viewing in tables;
  - report generation;
  - display of areas and results on a map;
  - tools for quality control and monitoring of field work progress.
- Data exchange (API)
  Use of standard, well-documented data exchange protocols between the mobile application, server, web office, and external systems. This makes it possible to:
  - integrate NFI with other state registries and geoportals;
  - connect additional modules or services as needed without completely rebuilding the system.
  - Reliability and scalability. If necessary, the system can be deployed in multiple instances (backup servers), with the possibility of gradual

expansion without interrupting operation. Open tools are used to automate updates, backups, and data protection.

General approach: technologies must be open, understandable, supported in Ukraine, and simple enough for long-term maintenance without dependence on a single company or closed software product. (See: Technological basis of the system)



7.2. Security and data protection

The DGP system must work with official government data, so security is one of the key requirements. Protection is built into the architecture, settings, and rules of use.

Basic principles:

- Data transmission protection .

  All data between the mobile application, server, and web account is transmitted in encrypted form. This makes it impossible to intercept or tamper with information.

- Personal accounts

  Each user has an individual account. Access to the system is only possible after authorization. Shared logins are not allowed.

- Separation of access rights

  Field teams, coordinators, analysts, and administrators can only see the data and functions they need for their work. Only authorized persons are allowed to manage methodologies, reference books, and critical settings.

- Regular backups

  System data is regularly copied and stored on secure backup sites for recovery in case of failure or attack.

- Audit trail

  All key operations (data changes, confirmations, corrections, settings) are logged. This allows you to track the history of changes and perform audits.

- Protection of NFI geographic coordinates (sensitive data)

  The geographic coordinates of NFI inventory points are sensitive information and:

  - are not displayed in open access, public reports, web maps, or external interfaces;
  - are only available to a limited group of authorized users within the closed system;
  - For external users, public materials, and integrations, generalized spatial references may be used—for example, the coordinates of the corners of grid squares (5×5 km or other agreed-upon grid size), without the ability to precisely identify specific sample plots.
  - All operations with coordinates (viewing, exporting, analysis) are recorded in the activity log.

- Physical and organizational security

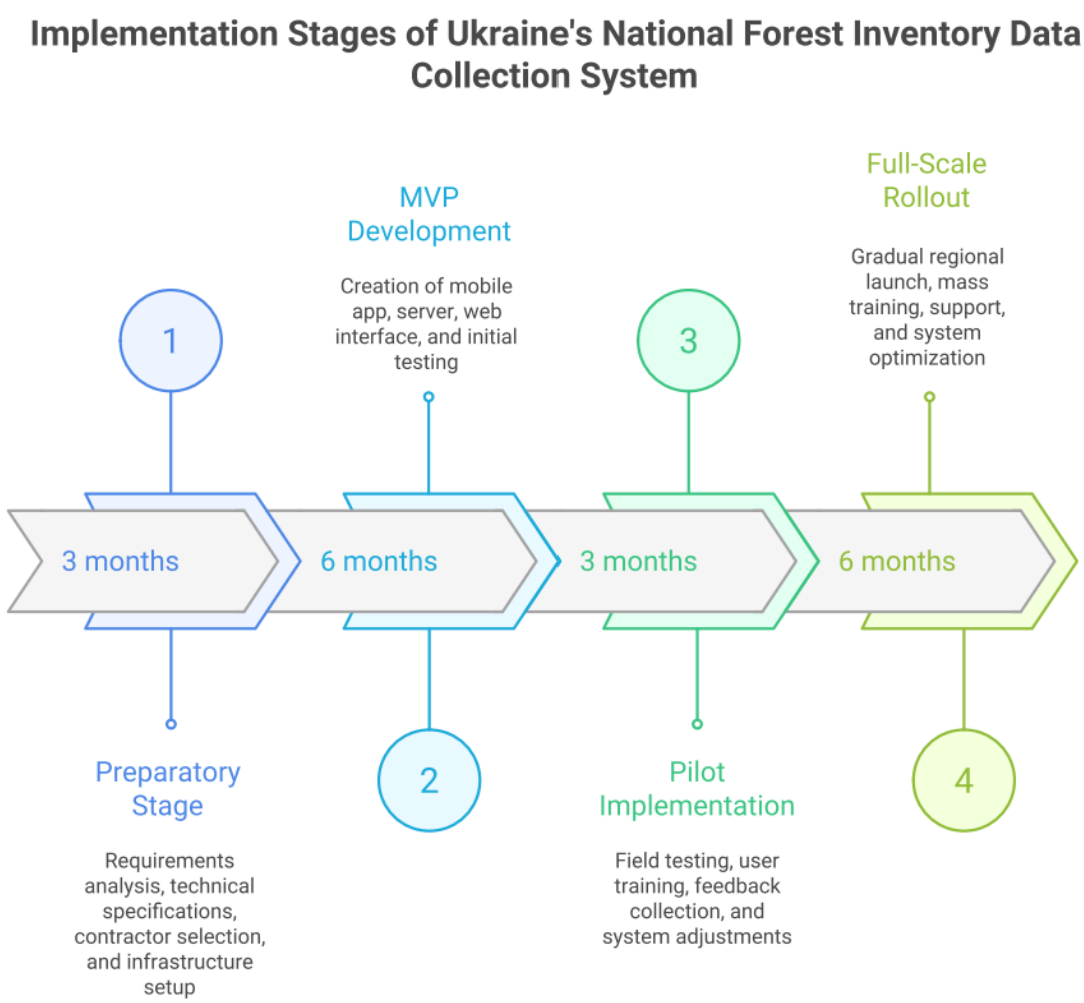
  Servers are located in secure data centers or government IT infrastructures. There are regulations on password changes, procedures for revoking access when personnel changes, and basic cyber hygiene rules for users.

This approach ensures not only data integrity and protection, but also an adequate level of confidentiality for critical elements of the NFI, primarily the coordinates of inventory points.

8. IMPLEMENTATION PLAN

8.1. Implementation stages

Stage 1: Preparatory (3 months) (See: Implementation stages of Ukraine's national forest inventory data collection system). The purpose of this stage is to clearly define requirements, delineate roles, and prepare the basis for high-quality development.



Main actions:

- Detailed analysis of requirements

- clarification of functional and non-functional requirements for the system together with the NFI Center, the State Forestry Agency, field teams, analysts, and IT specialists;
- alignment of the data structure with the NFI Methodological Guidelines and international standards (FRA, LULUCF, etc.);
- determination of rules for working with sensitive data (especially the coordinates of sample plots).
  - Preparation of technical specifications
    - Formulation of official technical specifications for the development of DGP and a mobile application;
    - description of requirements for quality, security, integration, support, and training.
- Selection of a contractor through a transparent procedure
  - holding a tender or competitive selection with the requirement to transfer rights to the source code and documentation to state institutions;
  - evaluation of the contractor's experience in open solutions, geodata, and secure systems.
- Preparation of infrastructure
  - determination of the hosting platform (state data center, cloud solutions with an appropriate level of security);
  - backup planning;
  - basic organizational agreements on support and administration.

Stage 2: Development of a minimum viable product (MVP) (6 months). The goal is to create a working minimum version of the system that covers key needs and allows for a pilot test.

Main actions:

- Development of a mobile application (basic version)
  - Forms for the main NFI data blocks
  - basic field checks;
  - offline mode and synchronization.
- Creation of the server part and database
  - central NFI database;

- basic set of automatic checks (Level 2);
- simple API for exchange between the mobile application and the server.
- Development of a web interface (first release)
  - data viewing, simple collection monitoring;
  - user management.
- Initial testing
  - Stability testing;
  - elimination of critical errors;
  - adaptation of the interface based on feedback from future users.

Result of the stage: a working prototype of the system, ready for field testing.

Stage 3: Pilot implementation (3 months). The goal is to test the system in real conditions, identify weaknesses, and refine it before scaling.

Main actions:

- Pilot on a limited number of sites
  - approximately 100 inventory sites in different regions with different types of forests and access conditions;
  - full cycle testing: collection → transfer → verification → analysis.
- Training of the pilot user group
  - training for field teams and coordinators;
  - short instructions and video materials;
  - feedback on the usability of the interface and verification logic.
- Feedback collection and analysis of results
  - recording technical problems and non-obvious errors; user suggestions;
  - assessment of data quality and ease of use.
- System adjustments
  - improving the mobile application, checks, and web interface.
  - refinement of reference books, formats, validation rules.

Stage result: a systematically tested and improved version, ready for large-scale use.

Stage 4: Full-scale implementation (6 months). The goal is to transition Ukraine's NFI to the new system in all regions.

Main actions:

- Gradual rollout across regions;
  - Phased launch to avoid overloading support;
  - Prioritization of regions with better access conditions for rapid accumulation of experience.
- Mass training of users
  - A series of training sessions for all field teams, regional coordinators, and analysts;
  - creation of permanently available instructions, FAQs, and a support hotline.
- Support and technical assistance
  - prompt troubleshooting and updates;
  - consulting users during the active phase of field work.
- Optimization and stabilization
  - fine-tuning of quality checks;
  - adaptation to special situations (hard-to-reach, mined areas, remote sensing data);
  - preparation for using the system as a permanent platform for subsequent NFI cycles.

Upon completion of this phase, the DGP becomes the primary tool for collecting and processing Ukraine's NFI data, with proven performance, clear operating rules, and the potential for further development without changing the basic architecture.

9. STRATEGY FOR MIGRATING HISTORICAL DATA AND ALIGNING WITH PREVIOUS NFI CYCLES

To ensure the continuity of national statistics, compatibility with previous NFI cycles, and removal of reservations regarding the "resetting" of history, the DGP system must include a clearly defined strategy for the migration and harmonization of existing data.

9.1. Migration principles

1. Continuity of time series

- Historical NFI data collected using previous systems and tools shall be transferred to the DGP with maximum preservation of content, structure, and metadata, where possible.
- The ability to form long time series for key indicators (stocks, areas, structures, changes) necessary for international reporting and trend analysis is ensured.

2. Transparency of transformations

- All transformations performed during migration (changes in formats, codes, classifications, units of measurement, table structures) are documented in an auditable form.
- A description is generated for each type of data: "from where/to where/how converted," including rules for aggregation, recoding, and filling in gaps.

3. Differentiation of data quality levels

- Historical data are marked according to reliability levels (e.g. "fully reconciled", "partially reconciled", "limited use") depending on the completeness of the documentation, the quality of the source data, and the correctness of their interpretation.

This allows:

- use the best available data;
- at the same time, honestly reflect limitations in official calculations and reporting.

9.2. Data migration stages

- Inventory and audit of existing data
  - Collection and cataloging of all available NFI arrays from previous cycles (databases, export files, reporting tables, metadata, technical documentation).
  - Assessment of their integrity, completeness, and compliance with official methodological documents at the time of collection.
- Harmonization of classifications and structures
  - Development of correspondence tables between:
    - old and new classifiers of species, forest types, land use categories, damage types, etc.;
    - old table structures and the new DGP database schema.
  - If necessary, introduction of special "historical" fields or mappings to avoid loss of information.
- Technical migration to DGP
- Step-by-step loading of historical data into the central DGP database:
  - preserving the original values;
  - recording the date, source, and persons responsible for each migration block.
  - Consistency check: test comparisons of aggregated results (national/regional level) before and after migration.
- Identification of limitations and uncertainties
  - Areas or periods where the source data is of limited quality or where complete technical documentation is missing are marked with appropriate warnings.
  - In official publications and reports for such segments:
    - the data source is clearly indicated;
    - wider confidence intervals or methodological caveats are provided where necessary.

9.3. Harmonization of methodologies and ensuring comparability

1. Methodological documentation

- In parallel with the technical migration, a separate methodological document is being prepared, describing:

  - the differences between cycles (changes in forms, plot designs, sets of indicators);
  - the impact of these changes on the comparability of results.
- This document becomes the official reference for national and international reporting.

2. Statistical adjustments as needed

- Reconciliation factors or model approaches may be applied to key indicators if changes in methodology or instruments have led to systemic shifts.

All such corrections must:

- be approved methodologically;
- be implemented transparently in the DGP;
- be accompanied by a public description.

All corrections are stored together with the initial values.

3. Openness to independent verification

- Migration mechanisms, correspondence tables, and comparison results (before/after) are stored in the system and can be verified:
  - by internal auditors;
  - scientific institutions;
  - international experts and partners.
- This alleviates key concerns of skeptics regarding loss of continuity and manipulation of historical data when transitioning to a new system.

Implementing this strategy not only allows for the transition to a modern open platform, but also preserves the value of previous NFI cycles, ensures comparability over time, and increases confidence in the entire statistical line of assessments of the state and dynamics of Ukraine's forests.

9.4. Main risks of the project

1. Technical risks
   Risk: integration difficulties with existing systems and unstable operation in field conditions (offline, weak connection, device failures). Ways to reduce risk:

- detailed technical analysis of available interfaces (API) at the preparatory stage;
- phased integration (basic functions first, then expansion);
- use of open formats and well-documented protocols.
- mandatory offline mode with reliable local data storage;
- testing the application in real field conditions during the pilot phase;
- Recommendations on device types and protective equipment.

2. Organizational risks
Risk: Resistance to change on the part of users (habit of using old tools, distrust of the new system).

Ways to reduce risk:

- involvement of field team representatives, coordinators, and analysts in development and testing;
- a simple and intuitive interface;
- Systematic training, instructions, ongoing support.

Risk: Lack of qualified IT specialists to support the system.
Ways to reduce risk:

- Inclusion of a component for training our own support team in the project.
- use of common technologies for which it is easy to find specialists in Ukraine.

3. Financial risks : Insufficient or unstable funding for the full cycle (development–pilot–scaling–support).
Ways to reduce risk:

- phased budget planning with clearly defined results at each stage;
- involvement of several donors/partners with agreed requirements;
- prioritization of critical functions (so that the system remains operational even with partial funding).

4. Institutional and regulatory risks: Change in leadership, priorities, or lack of a clear "owner" of the system.

Ways to reduce risk:

- formalization of the role of responsible institutions (orders, regulations, rules);
- enshrining the requirement to use the system for NFI in regulatory documents;
- transfer of rights to the code and documentation to state institutions.

Risk: Inconsistency between methodological documents and implementation in the system. Ways to reduce risk:

- parallel updating/refinement of NFI methodological guidelines during development;

- involvement of methodologists in all key technical decisions.

5. Security and confidentiality risks: Unauthorized access to sensitive data, especially the coordinates of test sites. Ways to reduce risk:

- clear restrictions on access to coordinates, no public display of coordinates;

- differentiation of access rights, logging of all operations;

- data encryption, placement of servers in a secure environment.

Risk: Cyberattacks, attempts to destroy or distort data. Ways to reduce risk:

- regular backups;
- multi-level protection (passwords, two-factor authentication, monitoring of suspicious activity);

- incident recovery plan.

6. Risks associated with military conditions: Inability to access some areas due to hostilities, mining, and movement restrictions. Ways to reduce risk:

- officially establishing approaches to the use of remote sensing and statistical methods for such territories;

- Transparent documentation of assumptions and limitations

- flexibility of the system to designate areas as "temporarily inaccessible" with separate accounting.

Risk: Damage to equipment, loss of equipment or local data. Ways to reduce risk:

- mandatory synchronization whenever possible;
- Data encryption on devices;

- backup devices and clear instructions for users.

7. Data quality risks: Human error — measurement errors or deliberate simplification of work. Ways to reduce risk:

- multi-level quality control system (Levels 1–3);

- selective repeat measurements, assessment of team performance;

- regular training and feedback.

All these risks must be taken into account in the project management plan with responsible persons and clearly defined response procedures.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1. Key conclusions

1. Developing our own open-source system is critical to ensuring institutional independence, technological sovereignty, and long-term sustainability of Ukraine's NFI, without dependence on a single commercial supplier.
2. Adapting the principles of Germany's BWI (quality management, transparent algorithms, complete data change history) makes it possible to build a system that complies with best international practices, while taking into account the legal, organizational, and security characteristics of Ukraine.
3. The proposed architecture (mobile application + server platform + web interface) provides the necessary flexibility, scalability, and the possibility of further development of the system without its complete overhaul in the future.
4. The integration of NFI with remote sensing data and national geoinformation resources is a key prerequisite for reliable forest monitoring in conditions of military action, mining, and limited access to some territories, allowing changes to be correctly taken into account even where field measurements are impossible.
5. The introduction of a formalized quality control system at three levels (field, server, expert) significantly increases the reliability, reproducibility, and trust in NFI results, which is especially important for official statistics, climate reporting, and international partners.
6. A special regime for handling sensitive data, primarily inventory point coordinates, is a necessary condition for protecting national interests and security, and must be technically and normatively enshrined within the new system.
7. The proposed phased implementation plan (requirements analysis → MVP → pilot → scaling) is realistic, allows to reduce risks, take into account user feedback in a timely manner, and ensure a smooth transition to the new platform without disrupting NFI cycles.

Taken together, these conclusions confirm the feasibility and urgency of creating an integrated open DGP system as a strategic tool for a modern, transparent, and sustainable National Forest Inventory of Ukraine.

10.2. Recommendations

1. Start preparing for the development of the system without delay

- Initiate procurement procedures to select a developer with clear requirements: open source code, transfer of rights to the state, compliance with NFI methodology and security requirements.
- In the tender documentation, separately specify the requirements for quality control, offline mode operation, protection of sample plot coordinates, and integration with relevant forest information and decision-support systems.

2. Ensure systematic cooperation with German and other international experts

- Formalize a mechanism for consulting with BWI experts and partners within the SFI project.
- Use their experience to build a quality management system, data structure, process organization, and avoid common mistakes.

3. Prepare a training program and change management plan

- Develop a step-by-step training plan for field teams, coordinators, analysts, and administrators (training sessions, video tutorials, reference materials).
- Provide for a transition period when the new system runs in parallel with existing processes, with active feedback collection.
- Work separately on communication to explain the benefits of the new system to users and reduce resistance to change.

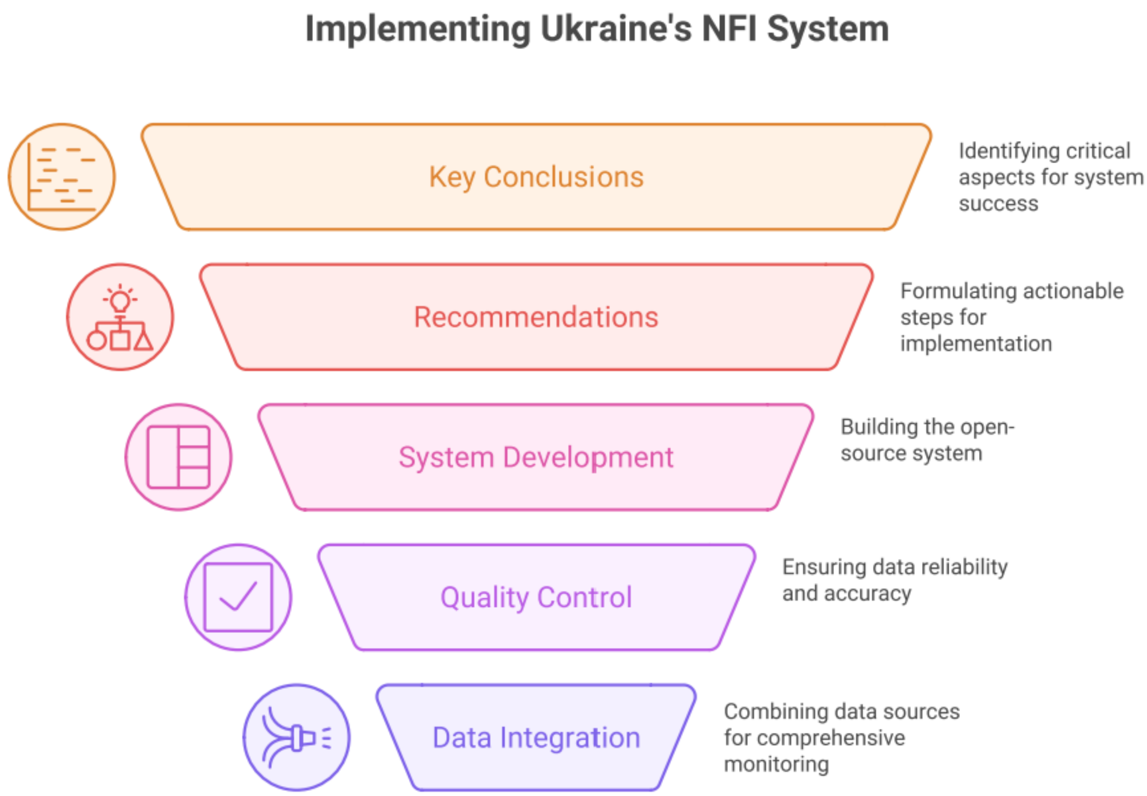
4. Ensure long-term funding and support for the system.

- Allocate resources not only for development and piloting, but also for maintenance, updates, security, adaptation to new requirements, and integration with the State Land Cadastre and international platforms.
- Establish a responsible institution (State Forestry Agency/NFI Center or other authorized body) that will be the official "owner" of the system.

5. Legislate the key principles of the system's operation

- Officially establish the requirement to use the new platform for NFI.
- define rules for access to and protection of sensitive data (especially the coordinates of test sites);
- Integrate provisions on multi-level quality control into methodological documents.

Implementing these recommendations will not only create new software, but also build a stable, controlled, and internationally recognized NFI system in Ukraine. (See: Implementation Ukraine's NFI system)



11. GLOSSARY

NFI – National Forest Inventory of Ukraine; a state statistical and scientific system of selective forest surveys to obtain representative information on the state, stocks, structure, and changes in forest resources at the national level.

DGP (Data Gathering and Processing) – a system for collecting and processing NFI data; an integrated digital platform that includes a mobile application, server part, and web interface for receiving, verifying, storing, analyzing, and exporting data.

BWI (Bundeswaldinventur) – Federal Forest Inventory of Germany; a national forest inventory system used as a benchmark for developing approaches to Ukraine's NFI (especially in terms of open architecture and multi-level quality control).

MVP (Minimum Viable Product) – the minimum viable version of a product; the first working version of a system that contains the basic functionality necessary for testing in real conditions and further improvement.

API (Application Programming Interface) – a set of rules and protocols that allow different software components and systems to exchange data in a standardized way.

RBAC (Role-Based Access Control) – role-based access control; an access control model in which user rights are determined by their roles (e.g., field crew, administrator, analyst).

State Forestry Agency – State Agency of Forest Resources of Ukraine; central executive body responsible, in particular, for state policy in the field of forestry.

NFI Center – an authorized national institution/structure responsible for the organization, methodological support, data processing, and development of the national forest inventory system.

FAO (Food and Agriculture Organization of the United Nations) – coordinates, among other things, the global assessment of forest resources (FRA) and provides methodological guidelines for NFI.

FRA (Forest Resources Assessment) – FAO Global Forest Resources Assessment; an international initiative to collect, compile, and analyze information on the world's forests.

UNFCCC – United Nations Framework Convention on Climate Change; an international treaty under which countries report on greenhouse gas emissions and removals, including in the land use and forestry sector.

LULUCF (Land Use, Land-Use Change and Forestry) – a climate reporting sector covering changes in carbon stocks on different types of land, including forests.

EUDR (EU Deforestation Regulation) – EU regulation on preventing the import of products associated with deforestation; creates a demand for reliable, transparent, and verified information on the origin of forest resources.

Remote sensing (Remote Earth Observation) – a set of methods for observing the Earth's surface from spacecraft, aircraft, UAVs, etc. (optical, radar, hyperspectral sensors) used to monitor forests, fires, land cover changes, and damage.

LiDAR (Light Detection and Ranging) – a remote sensing technology that uses laser pulses to measure the height and structure of forests with high precision; used to estimate stocks, tree height, and stand structure.

GIS (geographic information system) – software tools for working with spatial (cartographic) data: storage, analysis, visualization, and combination of different geospatial layers.

Geoportal – a web platform for accessing geospatial data and maps, which allows you to view, download, and integrate cartographic information.

Offline mode – a mode of operation of a mobile application without an Internet connection, with the ability to store data locally and synchronize it later when a connection becomes available.

Audit trail/change log – a complete record of all important data operations (who, when, what was changed, on what basis); provides transparency, the ability to trace data history, and conduct audits.

Data traceability – the ability to trace the path of data from initial field measurements to final indicators and reports, including all edits and expert decisions.

Multi-level quality control – a data verification system that includes:

- operational control in the field (mobile application);
- automated server verification and anomaly analysis;

- expert review, selective re-measurements, and documentation of decisions.

Inventory plot – an area (of forest) standardized in shape and size, on which measurements are taken and basic taxation indicators and other parameters are described in accordance with approved methodologies during the national inventory process.