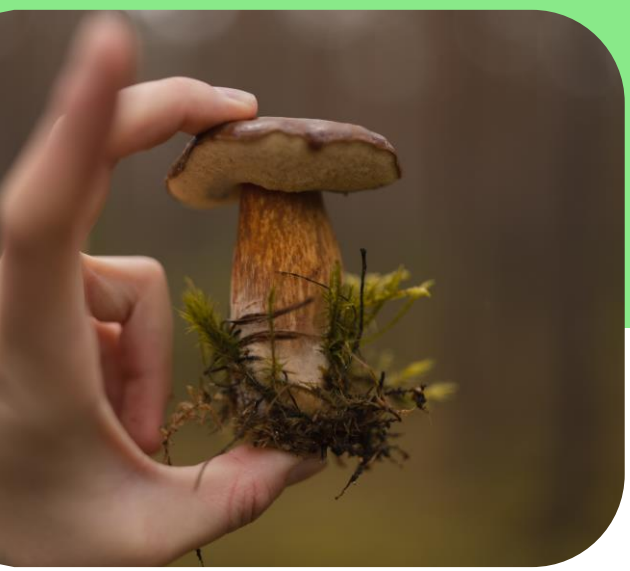

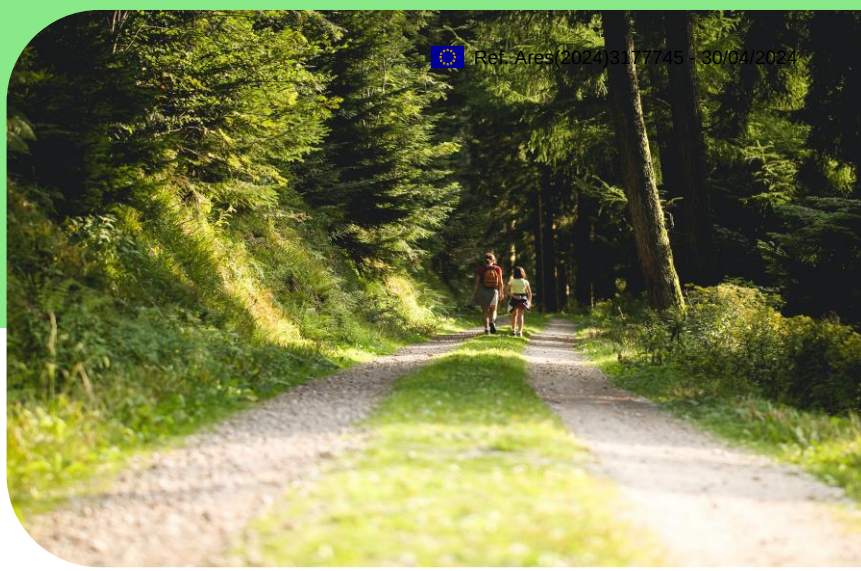

forest 4.0

WP4 Scientific excellence and education activities development

D4.1: Development of smart forestry open data infrastructure

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Funded by the European Union
Grant agreement N° 101059985

Funded by the European Union. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

Project information

Grant Agreement No	101059985
Project Acronym	Forest 4.0
Project Title	Creation of the centre of excellence in smart forestry
Type of action	HORIZON Coordination and Support Actions
Horizon Europe Call Topic	HORIZON-WIDERA-2022-ACCESS-01-01-two-stage
Project Duration	1 May 2023 – 30 April 2029 | 72 months
Project Website	www.forest40.lt
EU Project Advisor	Doru-Leonard IRIMIE
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Document information

Work Package	4
WP Lead Beneficiary	Lnu
Relevant Task(s)	4.1
Deliverable | Version | Status	Work in progress
Deliverable Lead Beneficiary	Lnu
Responsible Author	Arianit Kurti
Reply to	
Deliverable type | Dissemination level[1]	Public
Due Date of Deliverable	2024-04-30
Actual Submission Date	2024-04-30
Version | Status	
Contributors	
Reviewer(s)	

[1] ***Deliverable type*** R: Document, report; DEM: Demonstrator, pilot, prototype, plan designs; DEC: Websites, patents filing, press & media actions, videos, etc.; DATA: Data sets, microdata, etc; DMP: Data management plan; ETHICS: Deliverables related to ethics issues; SECURITY: Deliverables related to security issues; OTHER: Software, technical diagram, algorithms, models, etc.
Dissemination level: PU – Public, fully open, e.g. web (Deliverables flagged as public will be automatically published in CORDIS project's page); SEN – Sensitive, limited under the conditions of the Grant Agreement; Classified R-UE/EU-R – EU RESTRICTED under the Commission Decision No2015/444; Classified C-UE/EU-C – EU CONFIDENTIAL under the Commission Decision No2015/444; Classified S-UE/EU-S – EU SECRET under the Commission Decision No2015/444

Document History

Version	Changes	Date	Contributor
01	Structure of the report and initial layout	2024-04-12	Arianit Kurti
02	Principles of Open Data and Open Science	2024-04-19	Mexhid Ferati, Fisnik Dalipi, Zenun Kastrati
03	State of the art of the open forestry data infrastructure in Lithuania	2024-04-19	Gintautas Mozgeris
04	Initial complete draft	2024-04-22	Arianit Kurti
05	Structural review	2024-04-24	Kęstutis Skridaila (ART21)
06	Structural review	2024-04-25	Jimmy Johansson
07	Final version – complete draft	2024-04-29	Arianit Kurti
08	State of the art of the open forestry data infrastructure in Sweden	2024-04-30	Jimmy Johansson
09	Final version	2024-04-30	Arianit Kurti

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Executive summary

This deliverable focuses on the development of a smart forestry open data infrastructure. Recognizing the significance of research infrastructure highlighted by the EU Research Agenda, we emphasize the need to establish a robust research infrastructure with high-quality resources. Such infrastructure is essential for scientific advancement, enabling research, and driving economic growth. The smart forestry open data infrastructure should adhere to the principles of open science and open data, aiming to enhance accessibility, transparency, and collaboration in scientific research. These principles include availability, data quality, permanence, and no usage costs.

In this context, we explore various Swedish agencies that provide open data resources relevant to the forestry value chain. Additionally, we delve into an in-depth overview of Lithuanian open data resources. To conclude this deliverable, we propose an initial set of research groups, and their infrastructure and equipment needs to achieve the goals of the Forest 4.0 Center of Excellence.

Table of Contents

1. Introduction

Research infrastructures plays an important role in advancement of science, support for the economic growth as well as enabler for the researchers to conduct their work. Having this in mind the development of an appropriate research infrastructure is of utmost importance for the establishing the Center of Excellent as well as reaching the envisioned results.

Having this in mind we believe that CoE should develop a research infrastructure based on high quality resources that would provide researchers with access to state-of-the-art facilities and services. These resources are essential for fostering innovation and developing cutting-edge technologies based on IoT and AI to address global challenges and drive the green and digital transition within forest sector. We consider that this approach is also in line with the EU Research Agenda that focuses on prioritization of research infrastructures, emphasizing the need to broaden access and advance the European research infrastructure ecosystem to boost innovation. For illustration, declarations like the Brno Declaration[2] call for global support in developing a thriving research infrastructure ecosystem. Development of the research infrastructure will have also tremendous bearing on the collaboration and wider societal and business impact of the CoE Forest 4.0. Research infrastructures shall serve as critical inputs to the research system to foster collaboration and enabling impactful research to be developed. In this aspect we consider that research infrastructure should be the core component of the CoE Forest 4.0 strategy as a vital instrument for generating new knowledge, promoting collaboration, and driving scientific progress.

With regard to the forest sector as a prime focus of CoE Forest 4.0 development of a smart forestry open data infrastructure is a crucial area that combines technology innovation, environmental stewardship, and collaborative efforts with diverse stakeholder for long lasting impact. Development of open forestry data shall bring numerous benefits to tackle numerous challenges within the forestry value chain in terms of a consistent geospatial data ecosystem, accurate monitoring of forest losses and restoration efforts, decision support as well as predictive analysis using machine learning. As a results multiple international projects have started focusing on these aspects. Some worth mentioning include:

[2] https://www.consilium.europa.eu/en/press/press-releases/2022/12/02/research-infrastructures-council-adopts-conclusions/

Forest Data Partnership[3], Open Forest Protocol[4], and Smart Forest Atlas[5]. The common denominator of these initiatives is that they provide a digital platform for stakeholder to engage with open forestry data to tackle imminent challenges. These initiatives demonstrate the power of data-driven approaches in promoting sustainable forestry practices, combating deforestation, and fostering global collaboration. The use of the technological tools and platforms created necessary precondition for a more resilient and ecologically balanced world. They can provide a good pointers for the efforts planned to be conducted as a part of the CoE Forest 4.0. This report further continues with an overview of open science and open data principles that is further followed with the state-of-the-art description of the open forestry data in Sweden. Furthermore, the report continues with the presentation of the current state of the open forestry data in Lithuania. The report then continues with the overview of the identified research infrastructure needs for CoE and is finalized with a summary and a conclusion section.

2. Principles of open data and open science

This section provides an overview of principles used to govern open data and open science. Initially we define the principles defining the open science and later we proceed with those defining open data. Furthermore, we present these principles in the light of activities conduced at Linnaeus University as one of the beneficiaries of this project.

2.1. What is Open Science

Open Science aims to make the scientific process and its outputs more accessible, transparent, and collaborative. While benefits of Open Science include transparency, reproducibility and scientific progress, its implementation can be challenging without being able to address data privacy concerns and establishing funding models. The key principles of Open Science include:

- **Open Access**: Making scientific publications freely available to the public through digital repositories or open-access journals to allow anyone to consume the research findings without any barriers (Suber, 2012).
- **Open Data**: Sharing the data used in scientific studies that allows anyone to access, reuse, and redistribute it, within the scope of considering appropriate ethical considerations (Wilkinson et al., 2016).

[3] https://www.forestdatapartnership.org
[4] https://www.openforestprotocol.org
[5] https://atlas.smartforests.net/en-gb/

- **Open Methodology**: Providing detailed descriptions of the methods and protocols used in a study, allowing others to understand the study process and offer the possibility to replicate the research (Nosek et al., 2015).
- **Open Collaboration**: Encouraging scientists to work together across disciplines, institutions, and national boundaries, which will promote interdisciplinary research and easy exchange of ideas (Cummings and Kiesler, 2005).
- **Open Education**: Making educational materials, such as lecture notes, videos, and course materials, freely available online in order to democratize access to knowledge and support lifelong learning (Weller, 2014).

2.2. What are Open Data Principles

The Open Data Principles are a set of guidelines for making data openly available and accessible, which include:

- **Availability and Access**: Data should be available and downloadable in its entirety in a convenient and modifiable form for all persons and groups (Open Knowledge Foundation, 2015).
- **Reuse and Redistribution**: The data should be allowed to be reused and redistributed under an open license, and should be machine-readable (Open Knowledge Foundation, 2015).
- **Metadata**: Datasets should include metadata that clarifies data's origin, content, structure, and context to help in its discovery, understanding, and use (Wilkinson et al., 2016).
- **Data Quality**: Data should be accurate, complete, and up-to-date to the largest extend and without errors and limitations, otherwise, those should be documented (Auer et al., 2007).
- **Permanence**: Data should be available for a long period and ensure continued access and relevance (Dunning et al., 2017).
- **Usage Costs**: There should be no cost for accessing or using the data, with the exception when reproduction requires a minimal and reasonable cost (Open Knowledge Foundation, 2015).

2.3. Open Science in Sweden

In Sweden, the Association of Swedish Higher Education Institutions (SUHF) has developed a roadmap for open science implementation at Swedish universities. Moreover, Sveriges dataportal is Sweden's national data portal aiming to serve as a platform where various organizations include and access public digital resources for development and innovation.

There is a way to assess the quality of open datasets through the FAIR guidelines, which stands for Findable, Accessible, Interoperable and Reusable, and essentially

means that the data should be possible to find, then gain access to them, should be compatible with other similar data, and finally ability to reuse them.

In terms of FAIR, the Swedish national portal contains the majority of datasets in interoperable data format, according to a study conducted by (Dalipi et al, 2022). The same study also discovered that most data descriptors were of a good quality with accurate documentation. Some issues still linger with the portal containing data in PDF or text form which lack interoperability as well as some broken links (Dalipi et al, 2022).

More specifically, Linnaeus University perspective[6], which is based on UNESCO and EU Open Science frameworks, aims to ensure that research benefits everyone in the best possible way. Aa such, it expresses a strong support for the open science movement through facilitating and adopting open science practices.

Linnaeus University's Vision 2030 aligns with the core idea of open science, maintaining that knowledge should be freely communicated to society, and also provide suitable channels for society to be able to contribute to and shape research.

The goal of Linnaeus University's open science project is to be guided by the principle of "as open as possible, as closed as necessary", in order to realize and ensure academic freedom in the digital age.

3. State-of-the-art of open forestry data infrastructure in Sweden

Open data in Sweden are rather important and used across diverse sectors. Forestry and land use data are also very important in Sweden there are numerous resources of open geodata that are available. Some of the sources where open geodata are available among others include Statistics of Sweden's Open Geodata[7]. Statistics Sweden provides open geodata through the Geodata Portal, managed by Lantmäteriet[8] (the Swedish Mapping, Cadastral, and Land Registration Authority). These open geodata can be categorized into three types, namely 1) Grid statistics, 2) Preschools and 3) Agency and municipality offices. The first is data under the responsibility of Statistics Sweden pursuant to the Geographic Environmental Information Ordinance (SFS 2010:1770). It concerns open geodata pertaining to grid statistics adapted to the European reference system ETRS89,

[6] https://lnu.se/en/meet-linnaeus-university/open-science/
[7] https://www.scb.se/en/services/open-data-api/open-geodata/
[8] https://www.lantmateriet.se

preschools and agency and municipal offices published as part of the EU INSPIRE Directive. More about open GeoData can be found at GeoData Portal[9].

Sweden's Environmental Protection Agency[10] has, in conjunction with several other Swedish agencies and organizations, taken the initiative to produce the National Land Cover Database[11] (NMD). Land cover and land use maps are an important source of information for activities involving biological diversity, sustainable development, ecosystem services, civil planning and climate and risk management. The National Land Cover Database is comprised of a base map and complementary 'added value' layers. The different layers are available for download at the NMD website.

Swedish National Forest Inventory (NFI)[12] is another resource in the open forestry data landscape. The open data provided by the Swedish National Forest Inventory include data that describe the state and changes in Sweden's forests. Data cover all land use classes except urban land and sea and fresh water. The data collection is focused on forest land and particularly productive forest. Sample plots cover the whole Sweden, however, with a higher density in Southern Sweden. The real coordinates of the sample plots are protected. The information collected is used for multiple purposes, for example, as a basis for forestry, energy, and environmental policy in Sweden.

The Swedish National Forest Data Lab[13] is also a resource of open forestry data. The primary aim of this initiative is to promote open data, digitalization, and innovation throughout the forest sector. The offer both large and small operators' opportunities to create knowledge and innovative solutions for sustainable forest and landscape management. A diverse data set offer opportunities for researchers and other interested parties to find information about forest damages, forest gems, protected nature etc. Swedish Forest agency further has a government assignment to update and developing open basic forest data using laser scanning. The geodata is made available through the national forest data lab. The Swedish Forest Agency is the responsible authority for statistics on production, employment, as well as environmental and social issues in forestry. Statistics are available in a database. Statistics concerning annual wood consumption

[9] https://www.geodata.se/geodataportalen/srv/swe/catalog.search#/search?resultType=swe-details&_schema=iso19139*&type=dataset%20or%20series&from=1&to=20
[10] https://www.naturvardsverket.se/en/
[11] https://www.naturvardsverket.se/en/services-and-permits/maps-and-map-services/national-land-cover-database/
[12] https://www.slu.se/en/Collaborative-Centres-and-Projects/the-swedish-national-forest-inventory/
[13] https://skogsdatalabbet.se/

by the forest industry is further available through Biometria[14]. Linked to Forest Agency and Land Registry databases is Silvaboreal[15]. Silvaboreal contains information covering all known National forestry field experiment in Sweden.

Swedish University of Agricultural Sciences (SLU) Forest Map[16] is another resource of the open. Forestry data. SLU Forest Map contains several raster maps created by co-processing field inventories from Sweden's National Forest Inventory, surface models from Lantmäteriet's stereo-matched aerial photographs, and satellite images from Sentinel-2. Each raster map cell (12.5 x 12.5 metres) describes the volume per tree species, basal area with mean height, basal area with mean diameter, and biomass. The volume maps provide an idea of the timber resources categorised by pine, spruce, beech, oak, birch, and other deciduous trees. SLU Forest Map has been developed and produced by the Division of Forest Remote Sensing at the Department of Forest Resource Management, SLU Umeå.
The Open forestry data infrastructure in Sweden is a valuable resource for research to gain new knowledge as well as for innovators to come up with new services and solutions that utilizes forest data as a main resource. In this aspect as a part of the strategic development of Forest 4.0 CoE it will be crucial to develop partnership and exchange of the experiences with some of the agencies and other actors currently engaged and maintaining the open forestry data infrastructure in Sweden.

4. State-of-the-art of open forestry data infrastructure in Lithuania

The conditions for use of forestry data in Lithuania depends on the type of data and the user. Usually, the data is accessible through the Lithuanian geo-spatial information infrastructure and its portal (geoportal.lt). The conditions are universal for all data in the infrastructure. I.e. metadata, samples, and preview services are free for anyone, however, register users have access expanded rights to access open data. Usually, data can be ordered and downloaded for free. Nevertheless, there are some access limitations for specific data sets. The key pricing principles are:

- Spatial data and data service prices are determined considering the needs of users and the value they provide to individual user groups.

[14] https://www.biometria.se/publikationer/statistik-och-rapporter/virkesfoerbrukningsstatistik/
[15] https://www.silvaboreal.com/
[16] https://www.slu.se/en/Collaborative-Centres-and-Projects/the-swedish-national-forest-inventory/foreststatistics/slu-forest-map/

- Prices and rates are determined based on market research analysis, evaluating the needs and capabilities of individual user groups, including those of the public.
- When establishing prices for spatial data and rates for data services, it is considered that data can be used by many users without losing its value, therefore prices and rates should be accessible to the widest possible range of users.
- Prices and rates may be differentiated according to user groups, considering the specific needs of these groups and the benefits they receive.

Cost allocation principles:

- The sale of spatial data and data services revenue is not aimed at covering their production (creation) and update costs.
- As a rule, the costs of producing (creating) spatial data are high, therefore covering costs with revenue would be an unfeasible task and would limit the accessibility of spatial data and data services to large user groups.
- The costs of data and services intended to meet the needs of the public administration sector are covered by state budget allocations.

We present a review of Lithuanian open geospatial data, with the objective of simulating applications relevant to sustainable forest management. By linking open geospatial data sources to their suitability for addressing specific tasks in forest management, access was facilitated through expert evaluation. This review draws heavily on the work of D. Tiškutė-Memgaudienė et al. (2020) in their study 'Open geospatial data for sustainable forest management: Lithuanian case,'.

There is a wealth of open geospatial data sources covering the territory of Lithuania, providing invaluable information for forest inventory and management purposes. These sources begin with fundamental datasets such as the Georeferenced Spatial Data Set of the Republic of Lithuania at a 1:250,000 scale, developed in accordance with the standards of the EuroRegionalMap international project, and the Spatial Data Set of Georeferenced Cadastral Base (GRPK). Continuing, additional datasets cater specifically to forest management needs, including the State Cadastral Data for Protected Areas of Lithuania, data on Bogs and Peatlands, Natural Habitats of EU Importance, and General Restrictions on Forest Management in NATURA 2000 sites, among others. Key data essential for effective forest management, such as the Forest State Cadastre of Lithuania, provides comprehensive information ranging from forest management plans in both private and state-owned forests to assessments of forest conditions following natural events such as fires and windstorms, as well as details on forest compartments and land use. Furthermore, it's worth noting

that some datasets are available in multiple formats, accommodating both open-source software like QGIS (e.g., GML) and commercial software such as ArcGIS (e.g., ESRI FileGeodatabase, ESRI Shapefile, etc.). Additionally, users of this portal have access not only to Inspire download services (WFS) but also to Inspire view services (WMS), both of which adhere to standards set by the Open Geospatial Consortium (OGC).

Table 1- Open geo-spatial data available at national level (source D. Tiškutė-Memgaudienė et al. (2020))

Name of open geo-spatial data	Service type in geoportal.lt	Author	Data format	Forest management tasks
Forest State Cadastre data	Dataset, Inspire view service, Inspire download service	State Forest Survey service under the Ministry of Environment, since 2023 SC Center of Registers	ESRI shape, WMS, WFS	1, 2, 4-20 *
Boundaries of state forest areas	Inspire view service, Inspire download service	State Forest Survey service under the Ministry of Environment	WMS, WFS	1, 2 *
The high resolution layer of forest	Dataset	Environmental Protection Agency	TIFF	9, 11, 14, 15 *
Natural habitats of EU importance	Dataset, Inspire view service	The Institute of Botany of Nature Research Centre	ESRI FileGeodatabase, ESRI Shape, etc., WMS	2, 5, 6, 11, 16-19 *
Natural habitats of EU importance (boundaries)	Inspire view service	The Institute of Botany of Nature Research Centre	WMS	2, 5, 6, 11, 16-19 *
Natural habitats of EU importance	Dataset	SE GIS-Centras	GML	2, 5, 6, 11, 16-19 *
Bogs and peatlands of Lithuania (2018 evaluation by LFN)	Inspire view service	Lithuanian Fund for Nature	WMS	2, 9, 11-15 *
GRPK – Spatial data set of (geo) reference base cadastre	Inspire view service, Inspire download service	Ministry of Agriculture of the Republic of Lithuania	WMS, WFS	1, 2, 7-20 *

GRPK – Spatial data set of (geo) reference base cadastre (static)	Dataset	Ministry of Agriculture of the Republic of Lithuania	ESRI FileGeodatabase, ESRI Shape, etc.	1, 2, 7-20 *
GRPK – Spatial data set of (geo) reference base cadastre (dynamic)	Dataset	Ministry of Agriculture of the Republic of Lithuania	ESRI FileGeodatabase, ESRI Shape, etc.	1, 2, 7-20 *
GRPK map – Georeferential Base Map at Scale 1:10 000	Other Services	Ministry of Agriculture of the Republic of Lithuania	PDF	1, 2, 7-20 *
ERM_250LT – georeference spatial data set of the territory of the Republic of Lithuania at scale 1:250 000 according to the requirements of the international project EuroRegionalMap	Dataset, Inspire view service	National Land Service under the Ministry of Agriculture	ESRI File Geodatabase, WMS	9-14, 20 *
View service of Free State Land Fund data	Inspire view service	National Land Service under the Ministry of Agriculture	WMS	14, 17, 18 *
Free State land fund information interactive electronic service	Inspire view service	National Land Service under the Ministry of Agriculture	WMS	14, 17, 18 *
The National atlas of the Republic of Lithuania in digital format. Forests	Inspire view service	National Land Service under the Ministry of Agriculture	WMS	9-11, 14, 15, 20 *
The National atlas of the Republic of Lithuania in digital format. Forest density	Inspire view service	National Land Service under the Ministry of Agriculture	WMS	9-11, 14, 15, 20 *
General restrictions of forest management in NATURA 2000 sites	Inspire view service	State service for protected areas under the Ministry of Environment	WMS	1, 2, 4-6, 9, 11-13, 15, 16-18 *
Data of State Cadastre for Protected Areas of Lithuania	Dataset, Inspire view service	State service for protected areas under the Ministry of Environment	ESRI FileGeodatabase, ESRI Shape, etc., WMS	1, 2, 4-20 *

Land Parcel Identification System (KZS) Database	Dataset	SE GIS-Centras	GML	11, 14, 15, 18 *
Data Base of Limited Land Use Areas of the Republic of Lithuania at scale 1:10 000 SŽNS_DR10LT	Dataset, Inspire view service	National Land Service under the Ministry of Agriculture	ESRI FileGeodatabase, WMS	1, 2, 4-20 *
Data Base of Limited Land Use Areas of the Republic of Lithuania at scale 1:10 000 SŽNS_DR10LT (dynamically updated) SŽNS_DR10LT	Dataset	National Land Service under the Ministry of Agriculture	ESRI Shape	1, 2, 4-20 *
Data Base of Limited Land Use Areas of the Republic of Lithuania at scale 1:10 000 SŽNS_DR10LT	Dataset	SE GIS-Centras	GML	1, 2, 4-20 *

*Forest management tasks the data set could be used for: 1 – forest inventory; 2 – forest management planning; 3 – monitoring of silviculture activities; 4 – afforestation/reforestation planning; 5 – final harvesting planning; 6 – thinning planning; 7 – forest logistics; 8 – forest fire protection; 9 – environment protection; 10 – recreation planning; 11 – biodiversity assessment; 12 – wildlife management; 13 – game management; 14 – land use change monitoring; 15 – wetland management; 16 – economic evaluation; 17 – real estate management; 18 – EU subsidies management; 19 – pest control; 20 – historical heritage.

In addition to the mentioned above geospatial data, there are some other sources of forest and forestry related information in Lithuania, usually managed and delivered by State Forest Service. The State Forest Service is one of the official statisticians in Lithuania. The State Forest Service compiles and publishes official statistics related to Lithuanian forests. The list of official statistical works for each year is provided on the website of the Lithuanian State Data Agency. Official statistics related to Lithuanian forests include facts on forest land area, areas of forest compartments, including the share of mature forest stands, forest land proportion, timber volume and volume increment. State Forest Service provides open data on forest use and private forests in the country, including analysis of private forest estates, economic evaluation of all and state-owned forests. State Forest Service provides the data of State Forest Accounting, which includes detailed summary information on forest characteristics, updated annually. It also publishes annual Forest Yearbooks. The data to conduct the State Forest Accounting and Forest Yearbooks basically comes from the Forest State Cadastre

and the Lithuanian National Forest Inventory, which is conducted using sampling methods.

Usually, the data mentioned above is available for free and downloadable from official sites. Nevertheless, there are numerous issues, related to the availability and quality of open forest data in Lithuania:

- The role of Forest State Cadastre keeper was recently transferred to SC Center of Registers, which is a state owned, but still profit seeking company, thus, the open access to stand-level forest resource data may be restricted in the future.
- The continuous update of Forest State Cadastre has been interrupted due to restructured state forest management and does not cover private forests since 2019.
- The content of Forest State Cadastre is focused first of all on the informational needs for forest management planning, therefore, it will be revised to address the conventional demands for cadasters.
- Changing EU legislation may require additional information which is not secured by the Forest State Cadastre (e.g. wall-to-wall geographic data on land uses for GHG accounting in LULUCF sector, MRV system for carbon farming in forests, demands of expected European forest monitoring law, etc). Therefore, the forest resource information system in Lithuania will require an upgrade soon.
- Lithuanian NFI provides valuable information both for decision makers and research. However, applicability of such information is limited due to limited access to NFI data. E.g. locations of NFI sample plots are considered as confidential information. New sampling stage should be introduced with information freely available for any NFI data user. The last two points are actively addressed by the Forest 4.0 project.

In conclusion, the available datasets appear to cater to a wide range of needs for sustainable forest management in Lithuania. Thus, the availability of data can hardly be considered a limiting factor in the advancement of digital technologies in both state and private forestry sectors in the country. However, the quality of open forest data is starting to diverge from the current demands of forest management. New requirements are emerging that are challenging to address using traditional approaches, despite data accessibility. Therefore, there is a need to reassess both the content and the methods of forest data delivery to users, indicating a promising area of activity for the Center of Excellence in Forest 4.0.

5. Research Infrastructure of CoE

There is some equipment planned to be purchased for the needs of CoE, which will expand the functionality of currently operational solutions used at VMU. The equipment is associated to the main directions of research and development at CoE, which are introduced in Fig. 1.

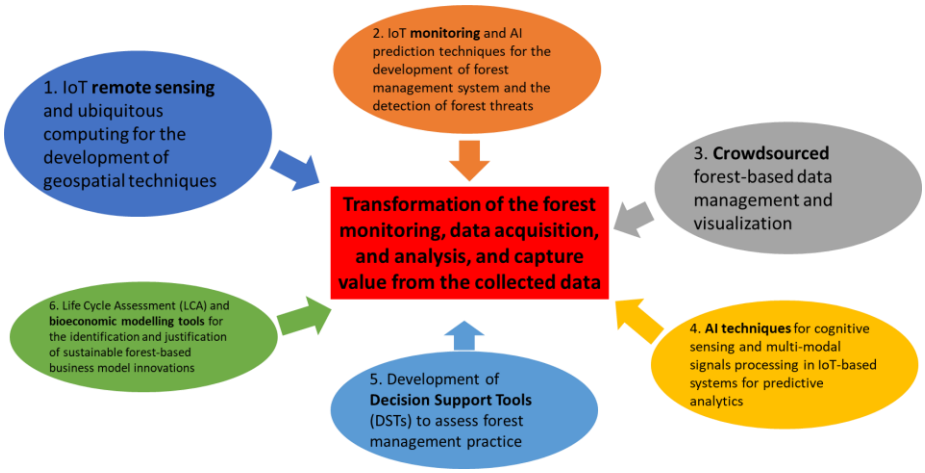

Fig. 1. Main research and development directions of the CoE.

The equipment related to the topic 1 (IoT remote sensing and ubiquitous computing for the development of geospatial techniques) is supposed to expand the functionality of relevant equipment already available and used at VMU (Fig. 2).

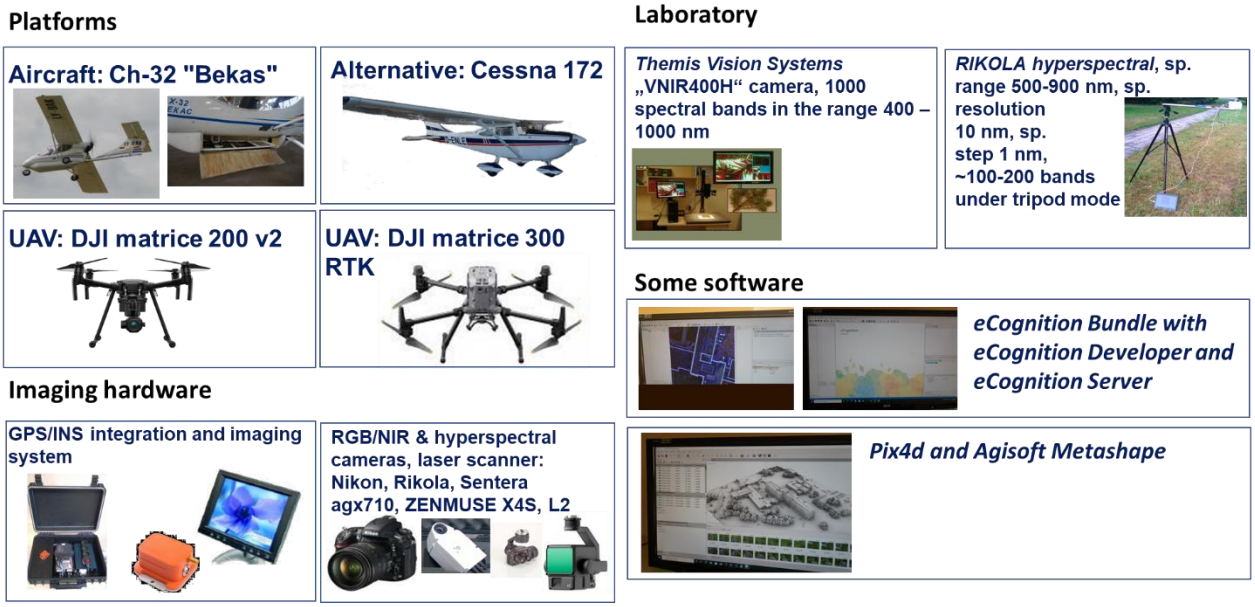

Fig. 2. Remote sensing equipment currently available at VMU and supposed for expanding within Forest 4.0.

The following is the list of new equipment planned to be purchased during 2024 (manufacturer and models are optional, as the equipment will be purchased following the open procurement procedures and may be different):

- Mobile laboratory on the base of 4x4 MB Vito, equipped for Themis Vision camera, transporting samples, all imaging equipment, drones, reflectance panels, also installing laser scanner;
- Long range laser scanning and hyperspectral imaging system for manned aircraft: option Riegl VUX-240 lidar, Applanix AP+30 AV GNNS/IMU, Sensor controller, software, aviation container for Cessna, including SWIR hyperspectral camera: option SPECIM AFX17 hyperspectral system with associated software;
- Short range laser scanning system for UAV: option RECON-XT laser mapping system with a backpack and vehicle mounting option;
- Some specialized software for processing of specific data, e.g. TerraSolid software, LAStools.

The equipment best fitting the objectives of topic 2 (IoT monitoring and AI prediction techniques for the development of forest management system and the detection of forest threats) will much be coordinated with the tools and solutions concentrated at VMU's Aukštaitija station of integrated monitoring, to strengthen the performance of it's long-term forest ecosystem monitoring and modelling platform. The following equipment is supposed to be purchased or installed:

- Set of equipment to monitor eco-physiological condition of trees
- Set of equipment to measure the greenhouse gases.
- Set of equipment to investigate chemical air properties.
- Eddy Covariance tower and installation for carbon flux measurements
- Mobile towers for GHG flux measurements under different forestry conditions
- Equipment for demonstration of eco-physiological processes in forest ecosystems.

IoT platform for new forestry-related data collection in the whole life-cycle of the forest and related products (topic 3) is associated with purchasing following or compatible equipment: IoT control platform LORIOT (SaaS), GW Loric One gateways and monitoring devices.

New equipment which is allocated to topic 4 (AI techniques for cognitive sensing and multi-modal signals processing in IoT-based systems for predictive analytics)

is expected mostly to support all the data storage and related AI research. It includes data storage platform, GPU computations cluster and CPU computations cluster.

No specific equipment is planned to support the topic 4 (Development of Decision Support Tools (DSTs) to assess forest management practice).

Topic 6 Life Cycle Assessment (LCA) and bioeconomic modelling tools for the identification and justification of sustainable forest-based business model innovations will be supported with:

- SimaPro Power user license + API subscription + Extra user;
- System to investigate, model and demonstrate the greenhouse gas emissions from forest soils, biomass and waste.

6. Summarizing remarks

Forest 4.0 Centre of Excellence (CoE) development should be established on a high-quality research infrastructure with advanced facilities for innovation in IoT and AI, aligning with the EU Research Agenda. The focus of smart forestry open data infrastructure is crucial for sustainable forestry practices, addressing challenges in the forestry value chain, and supporting global collaboration. The smart forestry open data shall be based on open science and open data principles such as: transparency, collaboration and sharing, reproducibility, equity and inclusion, public engagement, and accountability. The forestry open data resources in Sweden and Lithuania identified as a part of this report shall serve as main input points for Forest 4.0 ecosystem of open data. This ecosystem shall serve as a basis of research infrastructure and equipment to be established as a part of CoE Forest 4.0. Th e research groups equipped the right equipment will be the most vital factor for the success of CoE to bring business innovation and economic growth in the forestry sector in Lithuania.

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