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Advancing Student Skills in Environmental Monitoring Using Earth Observation and LiDAR Data

Environmental Monitoring Practices, EO/LiDAR Market Analysis, and Competency Framework for Smart Environmental Monitoring

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Abbreviation / Acronym	Full Form	Context / Note
AHN	Actueel Hoogtebestand Nederland	Dutch national LiDAR elevation model
AI	Artificial Intelligence	
API	Application Programming Interface	
AU	Algebra Bernays University	Lead partner institution, Croatia
BEV	Federal Office of Metrology and Surveying	Austria (Bundesamt für Eich- und Vermessungswesen); provider of national LiDAR elevation products
BFW	Federal Research and Training Centre for Forests, Natural Hazards and Landscape	Austria (Bundesforschungszentrum für Wald); national forest inventory and remote sensing
BKG	Federal Agency for Cartography and Geodesy	Germany (Bundesamt für Kartographie und Geodäsie)
BMK	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology	Austria (Bundesministerium für Klimaschutz); policy coordination and Copernicus engagement
CAP	Common Agricultural Policy	EU agricultural funding framework; referenced in context of EO-based compliance monitoring (AMS)
CODE-DE	Copernicus Data and Exploitation Platform — Germany	DLR national EO data platform
CORINE	Coordination of Information on the Environment	EU land cover mapping programme (CORINE Land Cover / CLC)
CRS	Coordinate Reference System	
DACUM	Developing A CUrriculuM	Occupational analysis methodology used in WP2 A2.3 competency framework development
DEM	Digital Elevation Model	
DGU	State Geodetic Administration	Croatia (Državna geodetska uprava); national geospatial data authority
DHMZ	Croatian Meteorological and Hydrological Service	Croatia (Državni hidrometeorološki zavod)
DLR	German Aerospace Centre	Germany (Deutsches Zentrum für Luft- und Raumfahrt); develops EO methods and

		tools
DSM	Digital Surface Model	
DTM	Digital Terrain Model	
EEA	European Environment Agency	Provides Copernicus services, thematic datasets, and country environmental indicators
ELY	Centres for Economic Development, Transport and the Environment	Finland (Elinkeino-, liikenne- ja ympäristökeskus); regional environmental authorities
EO	Earth Observation	
EO/LiDAR	Earth Observation and Light Detection and Ranging	Used collectively throughout the report to refer to remote sensing and active sensor technologies
EU	European Union	
FMI	Finnish Meteorological Institute	Finland (Ilmatieteen laitos); meteorology and hydrology monitoring
GAP	Competency Gap / Gap Analysis	Used in the context of WP2 A2.3 skills gap assessment
GDAL	Geospatial Data Abstraction Library	Open-source library for raster and vector geospatial data processing
GDPR	General Data Protection Regulation	EU Regulation 2016/679; applied to interview data anonymisation
GEDI	Global Ecosystem Dynamics Investigation	NASA spaceborne LiDAR mission; referenced for forest and biomass monitoring
GIS	Geographic Information System	
GNSS	Global Navigation Satellite System	
HEI	Higher Education Institution	
INSPIRE	Infrastructure for Spatial Information in Europe	EU Directive 2007/2/EC; geospatial data interoperability framework
InSAR	Interferometric Synthetic Aperture Radar	SAR-based technique for displacement and deformation mapping; referenced for subsidence monitoring
JRC	Joint Research Centre	European Commission research body; publications referenced in methodology
LAZ	Compressed LAS format	Standard compressed LiDAR point cloud file format
LiDAR	Light Detection and Ranging	Active remote sensing technology using laser pulses
LULUCF	Land Use, Land Use Change and Forestry	EU climate accounting sector; referenced in context of Finnish forest monitoring
LWF	Bavarian State Institute for Forestry	Germany (Bayerische Landesanstalt für Wald und Forstwirtschaft); interviewed organisation (DE-G2-Klemmt)
ML	Machine Learning	
ML/AI	Machine Learning and Artificial Intelligence	
MML / NLS	National Land Survey of Finland	Finland (Maanmittauslaitos); geospatial infrastructure and LiDAR data provider
MOOC	Massive Open Online Course	
NFI	National Forest Inventory	Referenced for Finland (MS-NFI) and Austria
NLS	National Land Survey of Finland	See also MML
NSO	Netherlands Space Office	Referenced in context of Dutch EO data access workflows

NSDI	National Spatial Data Infrastructure	Referenced in context of Croatian national datasets
PALSAR	Phased Array type L-band Synthetic Aperture Radar	JAXA/ALOS-2 SAR sensor; referenced alongside GEDI for forest and biomass monitoring
PDOK	Publieke Dienstverlening Op de Kaart	Dutch national geospatial data platform; referenced alongside AHN LiDAR
PR2	Progress Report 2 / Research Report 2	GreenScope WP2 consolidated deliverable
QA/QC	Quality Assurance / Quality Control	
QGIS	Quantum GIS	Open-source desktop geographic information system; referenced as primary GIS tool across partner countries
RDI	Research, Development and Innovation	Referenced in context of SAMK project- and thesis-based learning activities
ROS	Robotic Operating System	Open-source robotics middleware; listed in SAMK institutional mapping (Q2)
SAMK	Satakunta University of Applied Sciences	Partner institution, Finland (Satakunnan ammattikorkeakoulu)
SAR	Synthetic Aperture Radar	Active microwave remote sensing technology; Sentinel-1 SAR referenced throughout
SAR/InSAR	Synthetic Aperture Radar / Interferometric SAR	Referenced as an advanced EO skill area
SARPROZ	SAR Processing Tool	InSAR time-series processing software; identified in professional interview data
SNAP	Sentinel Application Platform	ESA toolbox for Sentinel data processing; referenced in tools and platforms section
SPO	Study Programme Ordinance	German HEI regulatory framework (Studien- und Prüfungsordnung); critical constraint for THRO curriculum changes
SPSS	Statistical Package for the Social Sciences	Statistical analysis software; referenced in THRO institutional mapping
SQL	Structured Query Language	Referenced in context of data processing and validation skills
STAC	SpatioTemporal Asset Catalog	Open standard for cataloguing and accessing EO data; identified in interview data
SYKE	Finnish Environment Institute	Finland (Suomen ympäristökeskus); key national environmental monitoring institution
THRO	TH Rosenheim — Rosenheim University of Applied Sciences	Partner institution, Germany (Technische Hochschule Rosenheim)
UAV	Unmanned Aerial Vehicle	Drone; used for aerial data collection including LiDAR and photogrammetry
UBA	German Environment Agency	Germany (Umweltbundesamt); national environmental monitoring and reporting authority
WFD	Water Framework Directive	EU Directive 2000/60/EC; referenced as key regulatory driver for water monitoring across partner countries
WP2	Work Package 2	GreenScope work package covering research activities A2.1–A2.3
WWA	Water Management Authority	Germany (Wasserwirtschaftsamt); several interviewees from Bavarian WWA offices (DE-G1-Gruesser, DE-G2-Huber, DE-G2-Buckel)

Executive summary

Environmental degradation, climate change, and biodiversity loss are increasing the need for more accurate, scalable, and timely environmental monitoring across Europe. Policy frameworks such as the **European Green Deal** and the **EU Biodiversity Strategy for 2030** require monitoring systems capable of supporting evidence-based environmental decision-making.

Earth Observation (EO) technologies, particularly those developed under the **Copernicus programme**, together with **LiDAR**, provide new opportunities for continuous and high-resolution monitoring. However, their integration into operational workflows and higher education programmes remains uneven across Europe.

This report presents the results of **Work Package 2 (WP2)** of the GreenScope project, combining:

- a comparative analysis of environmental monitoring practices across partner countries
- a market and skills analysis based on expert interviews and desk research
- a competency framework and GAP analysis developed through the **DACUM methodology**

The research included **20 interview inputs** from professionals working in public authorities, research institutions, universities, consultancies, and EO/LiDAR service companies across **Croatia, Finland, Germany, the Netherlands, and Austria**.

The findings show that **traditional field-based monitoring remains dominant**, while EO and LiDAR are increasingly used but not yet consistently integrated into operational workflows. Employers report **growing demand for professionals with practical EO, LiDAR, GIS, and automation skills**, particularly in areas such as Python-based geospatial processing, workflow automation, and multi-source data integration.

The DACUM process identified **four key professional roles**:

- EO and LiDAR Data Analyst
- Smart Environmental Monitoring Specialist
- Geospatial Data Scientist
- Research and Policy Advisor

The report concludes that future curricula should prioritise **practice-oriented learning**, real-world datasets, interdisciplinary problem-solving, and stronger collaboration with industry and public-sector organisations to better align higher education with evolving labour market needs.

1. Introduction

The imperative to monitor, understand, and protect natural environments has rarely been more pressing. A range of EU frameworks, including the **European Green Deal**, the **EU Biodiversity Strategy for 2030**, and the **Water Framework Directive**, require Member States to generate **reliable, timely, and spatially comprehensive data** on environmental conditions.

These frameworks place increasing emphasis on:

- **continuous monitoring** rather than periodic reporting
- **spatially explicit data** across large geographic areas
- **evidence-based decision-making** for climate, biodiversity, and resource management

At the same time, newer policy developments, such as the **EU Forest Monitoring Regulation (2023)**, further extend monitoring obligations, particularly in areas such as **forest condition, carbon stocks, and ecosystem health**.

Traditional monitoring approaches, including field surveys and in-situ measurements, remain essential. However, on their own, they are **insufficient to meet the scale, frequency, and complexity** of current policy requirements.

In this context, **Earth Observation (EO)** and **LiDAR** technologies offer significant potential. Satellite-based EO systems, particularly those developed under the Copernicus programme, enable **regular, large-scale observation of land, water, and atmospheric systems**, while LiDAR provides **high-resolution three-dimensional data** on terrain and vegetation structure.

Despite their availability, the integration of these technologies into **operational monitoring systems and higher education curricula remains uneven**, limiting their full potential.

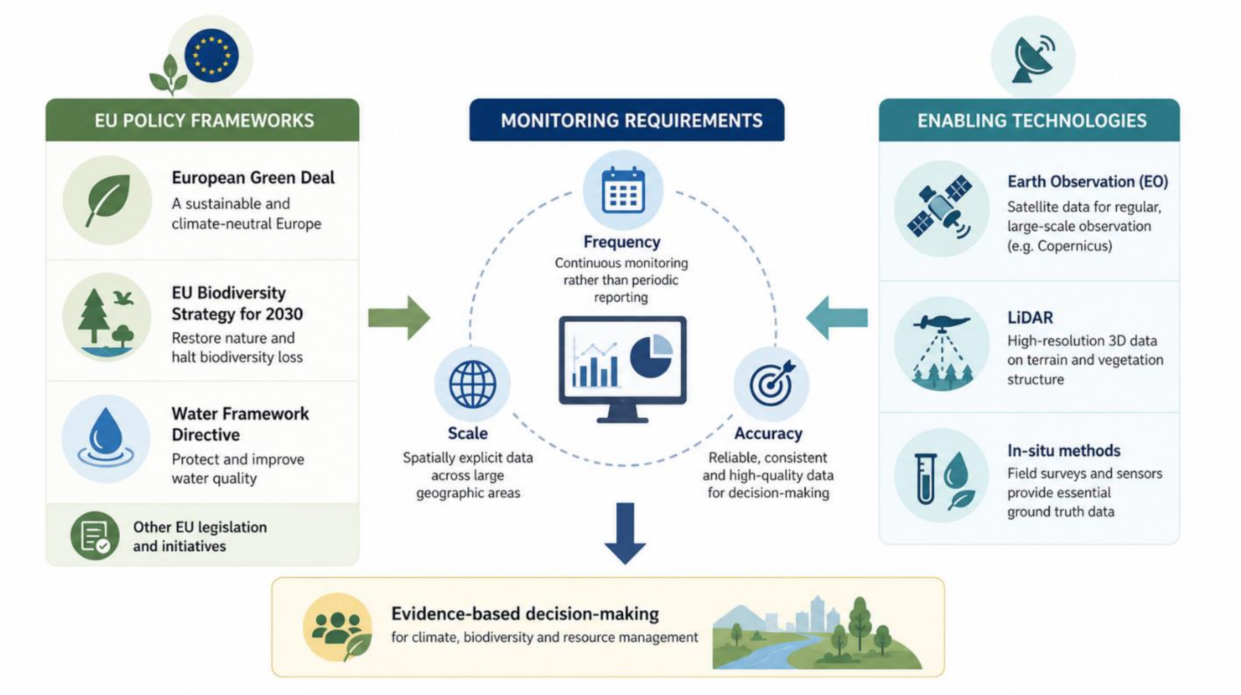

Figure 1 EU policy and environmental monitoring ecosystem.

The **GreenScope project** addresses the gap between **technological capability and workforce readiness** in environmental monitoring.

While EO and LiDAR technologies are increasingly accessible, there is a **persistent mismatch** between:

- the **skills required** by industry and public agencies
- the **competences provided** by higher education programmes

Graduates often possess **theoretical knowledge** of GIS and remote sensing but lack the **practical, operational skills** needed to work with real-world EO and LiDAR data in professional contexts.

The overall objective of the project is to support higher education institutions in **integrating EO and LiDAR competences into their curricula** in a structured and sustainable way.

Within this framework, **Work Package 2 (WP2)** provides the analytical foundation for curriculum development. Its purpose is to:

- analyse **current environmental monitoring practices** across partner countries
- identify **labour market needs and skills gaps**
- define **competency requirements** for emerging professional roles

These outputs are used to inform **Work Package 3 (WP3)**, which focuses on the design of **training modules and learning resources** aligned with real-world requirements.

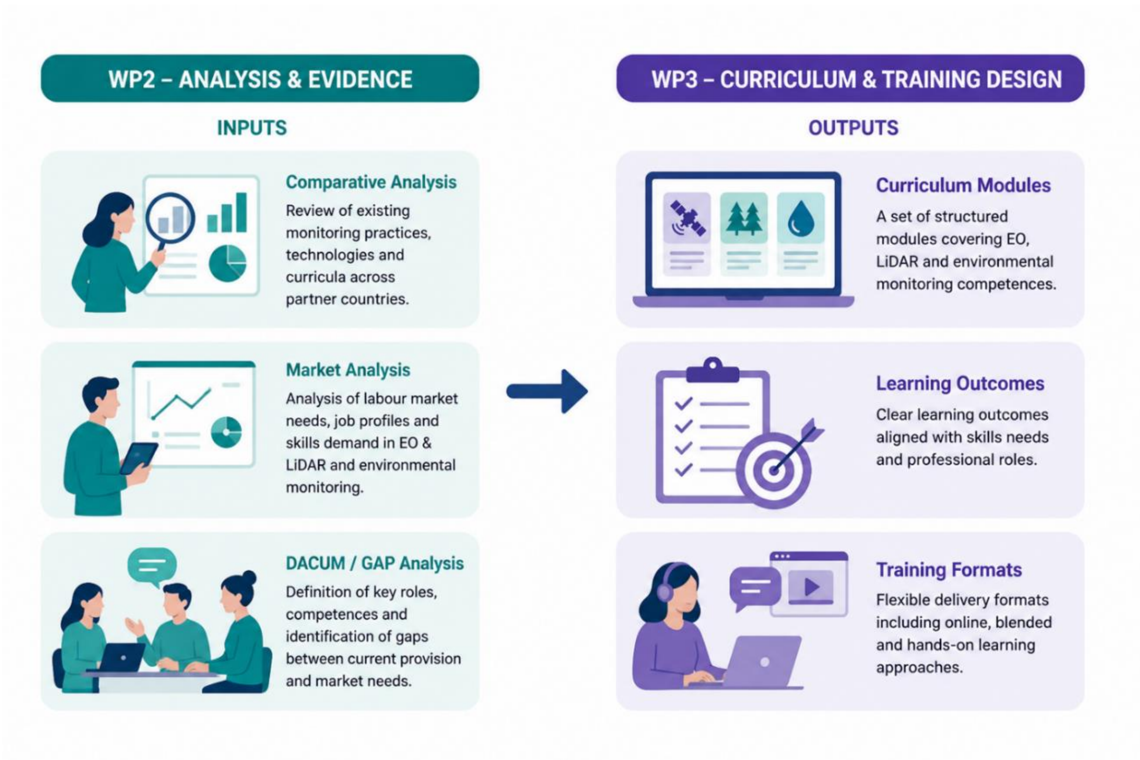

Figure 2 WP2 as a foundation for the curriculum & training development in WP3.

This report consolidates the findings of WP2 and provides a **structured evidence base** for curriculum development.

It is designed to:

- present **key insights from cross-country analysis and stakeholder engagement**
- define **skills gaps and competency needs** in EO and LiDAR-based monitoring
- support the development of **practice-oriented, labour market-relevant educational programmes**

The report therefore serves as a **bridge between research and curriculum design**, ensuring that subsequent project outputs are grounded in **empirical evidence and professional practice**.

1. Research methodology

The research activities of WP2 were structured around a **three-phase model**: **Exploration** (Activity A2.1), **Application** (Activity A2.2), and **Translation** (Activity A2.3). This phase design was deliberate: the Exploration phase established the **factual and contextual basis for subsequent inquiry**; the Application phase converted that contextual knowledge into **direct engagement with market actors and institutional practice**; and the Translation phase formalised the accumulated evidence into **structured competency frameworks** suitable for informing curriculum design.

Figure 3 WP2 research model.

Each phase employed distinct research instruments adapted to its specific purpose, while maintaining consistency across partner institutions through the use of common templates, shared coding frameworks, and centralised quality assurance procedures coordinated by the lead partner, AU.

1. Phase 1 — Exploration (A2.1): Comparative analysis of monitoring practices

The first phase focused on **mapping existing environmental monitoring practices** across partner countries through desk research.

Each partner completed a **structured national mapping template**, covering five thematic domains:

- forest and vegetation monitoring
- water and hydrological systems
- biodiversity and habitats
- land use and land cover
- natural hazards

For each domain, partners documented:

- **monitoring methods in use**
- **responsible institutions**
- **data sources and platforms**

- **relevant policy and regulatory frameworks**

Sources included **national strategy documents, agency reports, and EU-level resources**, such as Copernicus services, EEA datasets, and JRC publications.

2. Phase 2 — Application (A2.2): Market analysis and expert interviews

The second phase examined **labour market needs and skills demand** using a mixed-method approach.

This included:

- desk-based market analysis
- **semi-structured expert interviews**
- mapping of selected **higher education programmes**

Interviews were conducted by all partners using a **common interview guide**, ensuring consistency across countries. Each partner carried out **three to six interviews**, with sessions lasting 30 to 60 minutes.

The stakeholder interview sample was designed as a purposive expert sample, aiming **to capture both established environmental monitoring practices and more advanced EO/LiDAR-oriented workflows across different organisational contexts**. To ensure comparability between partner countries while preserving flexibility for national contexts, all consortium partners followed a common interview framework and stakeholder guidance document.

Two types of professionals were targeted:

- **Group 1**: experts in traditional environmental monitoring
- **Group 2**: specialists working with EO and/or LiDAR technologies

Table 1 Overview of stakeholder interviews conducted in A2.2.

Country	Total interviews	Group 1 Traditional monitoring	Group 2 EO/LiDAR professionals	Main domains represented
Croatia	3	1	2	Tourism, marine monitoring, applied ecology, GIS
Finland	3	1	2	Environmental monitoring, drones, geospatial services
Germany	6	2	4	EO services, geospatial analysis, environmental applications

Netherlands	5	0	5	EO services, infrastructure monitoring, LiDAR analytics
Austria	3	1	2	Forestry, hazards, EO services, environmental agencies
Total	**20 interview inputs**	**5**	**15**	Multi-sector environmental monitoring

Interviewees were selected based on the following criteria:

- direct professional involvement in environmental monitoring or geospatial analysis;
- practical experience with monitoring workflows, environmental reporting, or EO/LiDAR applications
- representation of different organisational environments, including public authorities, research institutions, higher education institutions, consultancies, and private-sector EO/LiDAR service providers
- relevance to the environmental domains addressed within GreenScope, including forestry, water systems, biodiversity, land use, natural hazards, infrastructure, and coastal monitoring.

All data was **anonymised in line with GDPR requirements**.

In parallel, partner institutions (AU, SAMK, THRO) conducted **internal programme mapping**, providing the baseline for the subsequent GAP analysis.

3. Phase 3 — Translation (A2.3): DACUM process and GAP analysis

The third phase translated the collected evidence into a **structured competency framework**.

This was achieved using the **DACUM methodology**, adapted into a two-step process:

1. development of **draft role profiles and competencies** based on WP2 findings
2. **review and validation** by all consortium partners

This process resulted in a set of **professionally grounded competency profiles** aligned with labour market needs.

A **GAP analysis** was then conducted to compare:

- the **current state** of higher education provision
- the **desired competency profile** identified through DACUM

To ensure consistency and reliability, all partners worked with:

- common templates and guidelines

- shared analytical frameworks

Outputs were reviewed centrally by the lead partner (AU), with cross-validation by SAMK.

All interview data and research outputs were handled in accordance with GDPR-compliant data management procedures. The final competency framework reflects a jointly validated, cross-national evidence base.

2. Environmental Monitoring Across Partner Countries: Practices, EO/LiDAR Integration, and Gaps

This chapter synthesises environmental monitoring practices, technology integration levels, and capacity gaps across the five GreenScope partner countries: **Croatia, Finland, Germany, the Netherlands, and Austria**. The analysis combines findings from the national mapping reports developed in **Activity A2.1** and stakeholder interviews conducted in **Activity A2.2**.

Although all countries operate within a shared European policy framework — including the **Water Framework Directive, INSPIRE, the Habitats and Birds Directives, and the Copernicus Programme** — their implementation differs significantly in terms of institutional organisation, data infrastructure, and technological maturity. Understanding these differences is essential for designing a curriculum that addresses **real, context-specific skills needs** rather than a generic European average.

2.1. Austria

Austria has a **well-developed but institutionally fragmented monitoring system**, shaped by its federal structure and the complexity of Alpine environments. Key organisations include:

- **BEV** - geospatial infrastructure and LiDAR
- **BFW** - forest monitoring
- **Umweltbundesamt** - environmental reporting
- **BMK** - policy coordination and Copernicus engagement

A defining feature of the Austrian system is the gap between **high awareness of EO technologies and limited operational integration**. The **Cop4Austria study (2024)** found that around **84% of surveyed professionals were familiar with Copernicus products**, yet routine use in operational workflows remains inconsistent, especially at regional and local levels. Fragmentation is further reinforced by the absence of a central coordinating structure for EO implementation.

Traditional field-based methods continue to dominate monitoring activities related to forests, water systems, and biodiversity. At the same time, Austria demonstrates strong operational expertise in **Alpine hazard monitoring**, particularly through the use of LiDAR and sensor systems for landslide and avalanche risk assessment.

Sentinel data is increasingly used in agriculture and land-cover monitoring, while **InSAR** supports ground deformation analysis. However, stakeholders frequently noted that the spatial resolution of standard Copernicus products is often insufficient for local administrative needs. Although Austria has strong national LiDAR infrastructure, access to raw datasets varies across federal states, limiting broader ecological and research applications.

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Current workflows are primarily GIS-based, with some use of Python and automated processing, but stakeholders highlighted the lack of shared standards, coordinated training, and operational integration.

From a curriculum perspective, Austria represents a strong example of the transition from **technology awareness to operational implementation**, while its expertise in Alpine hazard monitoring provides an important domain-specific case study for GreenScope.

2.2. Croatia

Croatia's environmental monitoring system is **institutionally fragmented**, with responsibilities divided across organisations such as:

- **DHMZ** - meteorology and hydrology
- **Croatian Waters**
- **Croatian Forests Ltd.**
- **Ministry of Economy and Sustainable Development**

Although Croatia has formally adopted EU environmental frameworks, operational implementation remains uneven. Stakeholders highlighted that the main challenge is **not the lack of data**, but rather issues related to **data quality, accessibility, interoperability, and workflow organisation**. In practice, many professionals prefer using **Copernicus datasets** because they are more consistent, standardised, and easier to integrate into analytical workflows than some national datasets.

Traditional field-based methods continue to dominate monitoring activities across forestry, water management, and biodiversity. One of the most significant weaknesses identified is the **absence of an updated National Forest Inventory**, which has not been renewed since 2005–2009. This creates a major information gap in a highly important environmental sector.

Water monitoring systems are more developed, although Croatia's complex **karst hydrology** presents additional monitoring challenges that are difficult to address through station-based approaches alone.

EO technologies are increasingly used in research and project-based activities. **Sentinel-2** supports land monitoring, while **Sentinel-3** is mainly used in research contexts. However, operational integration into routine agency workflows remains limited.

The strongest example of technological maturity is found in **Adriatic coastal and marine monitoring**, where EO technologies are already operationally applied for:

- water quality monitoring
- seagrass mapping
- pollution detection

Croatia also possesses national LiDAR coverage, but its broader use remains constrained by **limited accessibility and administrative barriers**. Current workflows rely mainly on **QGIS and ArcGIS**, with stakeholders reporting that a substantial amount of time is spent on data preparation and cleaning rather than analysis itself.

From a curriculum perspective, Croatia highlights the importance of developing **operational workflows, data governance practices, and practical EO integration skills**. At the same time, its coastal and marine EO applications provide a strong regional case study for future GreenScope learning activities.

2.3. Finland

Finland has a **technically advanced and data-rich environmental monitoring system**, coordinated through several specialised national institutions:

- **SYKE** - environmental monitoring
- **FMI** - meteorology and hydrology
- **Luke** - forest inventory and LULUCF monitoring
- **National Land Survey (NLS/MML)** - geospatial infrastructure and LiDAR
- regional **ELY Centres** - regional environmental administration

The system demonstrates strong expertise within individual domains, although stakeholders highlighted that **cross-institutional coordination and integration of heterogeneous datasets remain significant operational challenges**.

Traditional field-based methods continue to form the backbone of monitoring activities. Finland's strongest example of integrated monitoring is the **Multi-Source National Forest Inventory (MS-NFI)**, which combines field measurements, EO data, LiDAR, and aerial imagery to produce continuous national-scale forest assessments.

Another highly advanced example is the **Area Monitoring System (AMS)** used for CAP compliance. The AMS integrates **Sentinel-1 data and machine learning workflows** into operational agricultural monitoring, demonstrating a mature example of large-scale EO integration in practice.

Finland also benefits from **open national LiDAR data** provided through the National Land Survey. LiDAR is widely used in research and commercial projects, although applications are often project-based rather than embedded within continuous monitoring systems. This can create temporal mismatches between LiDAR datasets and more frequently updated EO data.

Python-based geospatial workflows, cloud platforms, and **QGIS** are widely used, particularly in research and consultancy environments. However, interviews consistently showed that the main challenge is **not data availability or awareness**, but rather the ability to automate, scale, and integrate workflows across different institutional systems.

From a curriculum perspective, Finland demonstrates that even highly advanced monitoring systems face important operational integration challenges. At the same time, the **MS-NFI and AMS systems provide**

strong real-world examples of scalable EO integration that can directly support GreenScope curriculum development.

2.4. Germany

Germany's environmental monitoring system is **highly advanced but structurally heterogeneous**, reflecting the country's federal governance model. Monitoring responsibilities are distributed across the **16 federal states**, while federal agencies such as:

- **UBA** - environmental protection
- **BfG** - hydrology
- **BSH** - maritime monitoring
- **BKG** - cartography and geodesy

provide coordination standards and national infrastructure.

This structure supports strong regional expertise but also creates significant variation in monitoring methods, data formats, and update cycles, limiting national-level consistency and interoperability.

Traditional field-based methods remain central across all monitoring domains. Forest monitoring is based on the **Bundeswaldinventur** and in addition **state-based forest inventories**, which provides long-term continuity but differs in implementation between the states and is not fully open for external use.

Water monitoring systems are well-developed and decentralised. Bavaria was identified as a particularly advanced example, with operational use of **LiDAR for flood modelling and hydraulic planning**.

Germany also has extensive national and regional LiDAR infrastructure, including openly available high-resolution datasets and, in some cases, raw point clouds. However, differences in technical specifications, formats, and update cycles create interoperability challenges.

EO technologies are widely used across land-cover mapping, agriculture, and research applications, particularly through organisations such as **DLR** and **Helmholtz**. Nevertheless, the level of operational deployment varies significantly across regions and sectors.

A key finding from stakeholder interviews is that the primary skills gap is **not a lack of EO or LiDAR awareness**, but rather insufficient competences in:

- structured geospatial data management
- workflow organisation
- dataset tracking and interoperability
- management of data throughout the full analytical lifecycle

"Students in every science degree program must learn how to handle EO and LiDAR data as a fundamental skill, similar to statistics, scientific writing, etc."

From a curriculum perspective, Germany demonstrates that **high technical capability alone is not sufficient without standardised workflows and effective data management practices**. The findings therefore highlight the importance of workflow-oriented and operational competences alongside technical EO/LiDAR knowledge.

2.5. The Netherlands

The Netherlands represents the **most operationally mature environmental monitoring system** among the GreenScope partner countries. Monitoring responsibilities are clearly coordinated through:

- **Rijkswaterstaat** - water management
- regional water boards
- **Wageningen Environmental Research** - forestry and environmental monitoring
- **Netherlands Space Office** - satellite data coordination

Strong alignment between national and regional institutions, combined with a long-standing commitment to **open data and water management**, has created a monitoring ecosystem where EO and LiDAR are fully embedded in operational decision-making.

The clearest example is the **AHN national airborne LiDAR programme**, which provides a continuously updated, standardised, and openly accessible national LiDAR dataset. AHN data is routinely used in:

- flood modelling
- urban planning
- infrastructure assessment
- terrain analysis

The Netherlands also uses **InSAR at national scale** for land subsidence monitoring, which is particularly important in a country where large areas lie below sea level. EO technologies are operationally integrated into agriculture, habitat monitoring, and regulatory compliance workflows, with many processing pipelines already highly automated. AI-based classification methods are also increasingly applied in commercial and operational contexts.

Despite this high level of maturity, stakeholders identified several ongoing challenges. LiDAR remains relatively underused in ecological applications, while the growing scale and complexity of datasets increase the need for competences in:

- machine learning
- uncertainty analysis
- large-scale workflow automation
- communication of analytical outputs to non-technical decision-makers

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From a curriculum perspective, the Netherlands provides the strongest example of **full operational EO/LiDAR integration** and highlights the importance of advanced competences related to automation, AI-supported analysis, and translating data into actionable decisions.

2.6. Comparative overview

The table below summarises system maturity, EO/LiDAR integration, key infrastructure, main gaps, and the most significant practitioner insight for each partner country.

Table 2. Comparative monitoring profile across partner countries.

Country	System maturity	EO/LiDAR integration	Key infrastructure	Main gap	Key insight from practice
Croatia (HR)	Developing	Low–Medium (stronger in coastal EO)	Sentinel data, CORINE, national LiDAR (restricted), national institutions	Fragmentation, limited interoperability, outdated forest inventory	Data preparation and harmonisation take more time than analysis; need for near-real-time monitoring
Finland (FI)	Advanced	Medium–High (fully operational in specific systems like CAP monitoring)	Open LiDAR (NLS), SYKE/FMI platforms, Sentinel, biodiversity databases	Integration across systems, automation, validation lag	Combining data sources and automating workflows are key bottlenecks
Germany (DE)	Advanced (heterogeneous)	Medium–High (strong regional variation)	LiDAR (states r), CODE-DE, ATKIS, federal and state inventories	Lack of standardisation across regions	Structured data management is the most consistently missing competence
Netherlands (NL)	Fully operational	High (embedded in workflows and decision systems)	AHN LiDAR, PDOK, NSO data access, dense sensor networks	Scaling analytics and linking data to decisions	Main challenge is translating EO outputs into actionable insights
Austria (AT)	Intermediate	Medium (high awareness, partial operational use)	BEV LiDAR, Copernicus services, national open data platforms	Lack of coordination, limited operational workflows	EO is valued but not embedded in everyday practice at local level

2.7. Common patterns across five countries

Across all five countries, **environmental monitoring remains strongly anchored in traditional field-based methods**, including forest measurements, water sampling, biodiversity surveys, and hazard assessments. Field data continues to play a critical role by validating EO and LiDAR outputs and supporting compliance with EU environmental directives. As a result, **EO and LiDAR are primarily used to complement and extend traditional monitoring rather than replace it**.

A clear common pattern across all countries is the widespread use of **Sentinel-1 and Sentinel-2** data. Sentinel-2 is mainly used for land cover, vegetation, and water quality monitoring, while Sentinel-1 supports agricultural monitoring and deformation analysis through InSAR. This creates a **shared technological foundation** that can support curriculum development across different national contexts.

The research also revealed a consistent gap between **awareness of EO technologies and their operational integration**. Although stakeholders across all countries are familiar with Copernicus services and Sentinel products, fully automated and repeatable EO workflows remain relatively uncommon. This pattern appears in different forms across all partner countries:

- in **Croatia**, EO is often used in exploratory or project-based workflows
- in **Germany**, adoption varies significantly between Länder and is frequently project-driven rather than operational
- in **Finland**, advanced systems coexist with institutional fragmentation and data silos
- in **Austria**, awareness and infrastructure are strong, but coordination remains limited

All five countries also possess national LiDAR infrastructure, yet its use in environmental applications such as forestry, biodiversity, and wetland monitoring remains less developed than in topographic mapping and planning.

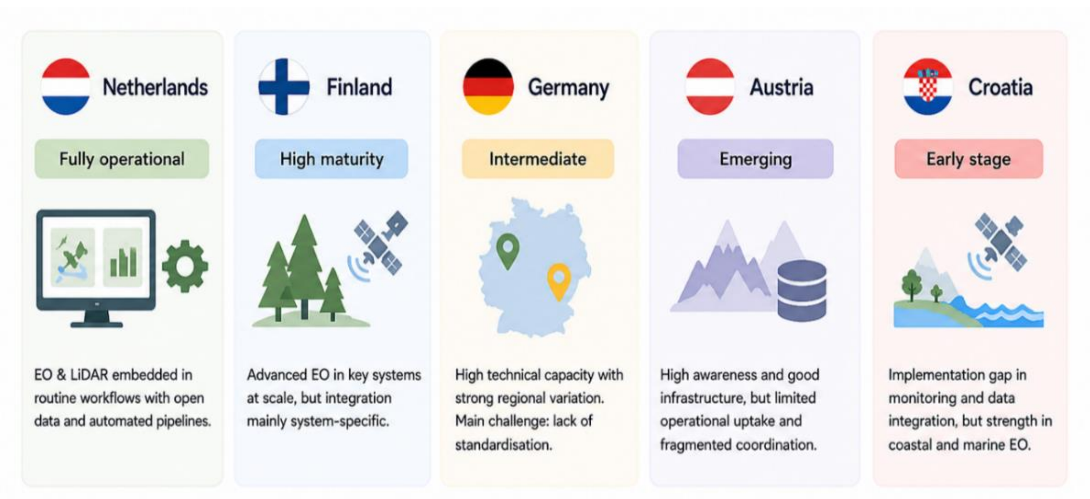

Figure 4 LiDAR integration maturity by partner country.

The countries differ most clearly in their level of operational integration. **The Netherlands represents the most mature system**, where AHN LiDAR, InSAR subsidence monitoring, and automated compliance workflows are already integrated into decision-making processes. Finland demonstrates strong expertise in forest and environmental monitoring systems, while Germany shows highly uneven development across regions. Austria possesses strong technical potential but lacks central coordination, whereas Croatia still faces significant implementation gaps, particularly in terrestrial monitoring, despite demonstrating notable strengths in coastal and marine EO applications.

Each country also contributes a distinct area of expertise that can directly support future curriculum case studies:

- **The Netherlands** — water management and subsidence monitoring
- **Finland** — boreal forest monitoring
- **Germany** — regional EO/LiDAR environmental applications
- **Austria** — Alpine hazard monitoring
- **Croatia** — coastal and marine EO applications

2.8. Implications for WP3 Curriculum Development

The skills gap identified across all five countries is primarily **practical and operational rather than conceptual**. Professionals generally understand the potential of EO and LiDAR technologies, but many lack the ability to build automated workflows, manage heterogeneous datasets, and translate outputs into decision-relevant products.

As a result, the curriculum should prioritise **hands-on operational competences** over general technology awareness. This includes:

- working with real EO and LiDAR datasets
- building reproducible workflows and automated pipelines
- integrating EO, LiDAR, and in-situ data
- validating results and communicating uncertainty

The differences in maturity levels between countries also highlight the need for a **modular curriculum structure**. A shared foundation in Sentinel and LiDAR fundamentals should be combined with advanced, domain-specific modules reflecting national strengths and real operational practice.

Case studies should directly reflect the monitoring environments identified in the research:

- **Croatia** — coastal and marine monitoring
- **Finland** — forest inventory and environmental monitoring
- **Germany** — hydraulic and regional LiDAR applications
- **The Netherlands** — subsidence and infrastructure monitoring
- **Austria** — Alpine hazard monitoring

Finally, the findings show that **field validation and uncertainty assessment must be integrated into EO and LiDAR training**, rather than treated as separate topics, as both were consistently identified as key skills gaps across interview groups.

Co-funded by the European Union

3. EO and LiDAR market analysis

This chapter summarises interview findings from traditional environmental monitoring professionals (Group 1) and EO/LiDAR-oriented specialists (Group 2) across the partner countries. It focuses on how monitoring is currently carried out, what limits wider EO/LiDAR use, and which skills are missing to support the transition from traditional to EO/LiDAR-enabled practice. The results provide a direct evidence base for the GreenScope curriculum and training materials in WP3 and for practice-oriented activities in WP4.

3.1. Profiles of interviewed professionals and organisations

The interview sample covers public authorities, national and regional research institutes, universities of applied sciences, EO service companies, engineering and consulting firms, and municipal or regional administrations. Across these organisations, professionals work in domains such as water and hydrology, forestry, biodiversity and Natura 2000, land use, coastal and marine monitoring, infrastructure, and climate-related hazards.

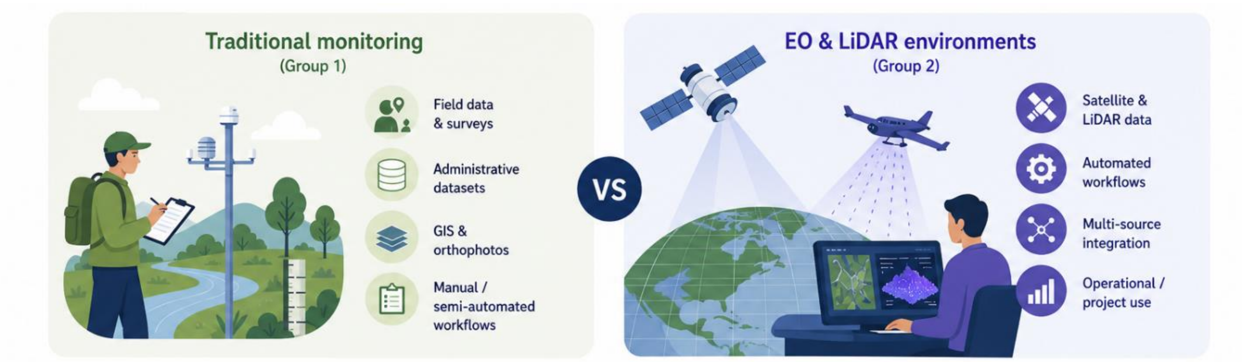

Figure 5 Environmental monitoring context - two main groups.

Group 1 – traditional monitoring professionals work mainly in statutory agencies, research institutes, and universities of applied sciences. They are responsible for designing and running monitoring programmes, managing field campaigns and in-situ sensor networks, processing administrative datasets, and producing GIS-based analyses and reports for regulatory and planning purposes. Their daily work is anchored in long-standing monitoring frameworks, indicators, and reporting cycles.

Group 2 – EO/LiDAR-oriented professionals are employed in EO service companies, engineering and consulting firms, specialised research institutes, and technologically advanced public authorities. They run or design EO/LiDAR workflows for applications such as deformation monitoring, flood and hydraulic modelling, forest inventory, urban and infrastructure planning, agricultural monitoring, and coastal water quality assessment. For them, EO and/or LiDAR data form a core part of the analytical toolkit.

Together, these two groups illustrate the **current transition path** in environmental monitoring: from traditional, field-centred systems with limited EO/LiDAR use, towards hybrid monitoring approaches where EO and LiDAR are integrated into operational workflows.

3.2. Current monitoring practices and use of EO/LiDAR

This section outlines how environmental monitoring is currently performed in traditional contexts (Group 1), how EO and LiDAR are used in more advanced organisations (Group 2), and where the main gaps lie between these two ends of the spectrum.

3.2.1. Traditional monitoring methods and workflows (Group 1)

In traditional monitoring organisations, **field data collection and in-situ measurements remain the operational backbone** of everyday work. Monitoring regimes are defined by statutory obligations, regular survey campaigns, and project-based studies, with core inputs coming from sampling networks, sensor stations, orthophotos, and administrative datasets such as cadastres, CORINE layers, statistical series, and internal databases. This pattern is consistent across all Group 1 participants: from the Croatian institute working on coastal tourism spatial analysis, to the Finnish Environment Institute managing lake and biodiversity data across fragmented agency systems, to the German water management and research professionals engaged in flood protection and environmental monitoring.

Workflows typically follow a familiar sequence: defining the monitoring task, collecting or acquiring data, preparing and harmonising datasets, performing analysis, and producing maps, tables, and reports for internal or external users. The most time-consuming stages are consistently reported to be **data preparation and integration** -- cleaning, re-projecting, and combining multiple datasets with different formats, reference systems, and quality levels before any higher-level interpretation can begin. As one German research assistant noted, poor data integration between institutes and project partners represents one of the most persistent operational bottlenecks, with much of the actual analytical work consumed by cleaning and harmonising inputs from inconsistent sources.

Tools are dominated by **desktop GIS (mainly QGIS and, in some contexts, ArcGIS) and office software**, complemented by domain-specific systems for data entry, modelling, or reporting. Automation is limited: while some recurring tasks are supported by templates or simple scripts, most processing steps remain manual or semi-automated, and update frequencies for monitoring outputs are constrained by staff time and reporting cycles rather than by data availability.

EO and LiDAR are generally **recognised and sometimes used but remain peripheral** to core workflows. They may be employed for specific projects, pilots, or research collaborations (e.g. a one-off coastal analysis, a LiDAR-based flood study, or a forest structure assessment), yet they are rarely embedded as standard inputs in routine monitoring chains. In practice, traditional professionals already bring strong **domain knowledge, indicator frameworks, QA/QC routines, and GIS skills**, but lack the practical EO/LiDAR competences needed to go beyond occasional use. Austrian public sector respondents noted that while free EO data are valuable, spatial resolution is often still too coarse for local operational decisions — a constraint that reinforces reliance on field-based methods.

In several cases, EO/LiDAR capability exists not within the organisation but through external contractors or project partners. The German flood protection specialist illustrates this dynamic starkly: his team relies on outsourced drone LiDAR for river bed monitoring, but bureaucratic procurement procedures and strict flight condition requirements (low turbidity, appropriate water levels) mean that the data acquisition process itself consumes the majority of available project time. The result is a workflow that is EO/LiDAR-enabled in principle but operationally constrained in practice — a pattern likely to be common in public sector water management across multiple partner countries.

The interviews point to a consistent set of missing elements that prevent these professionals from becoming regular EO/LiDAR users:

- Limited experience with **discovering and selecting appropriate EO/LiDAR data** for specific monitoring questions (e.g. which Sentinel product, what resolution is sufficient).
- Little or no hands-on practice with **EO preprocessing and time-series preparation**, including cloud masking, mosaicking, and stacking multi-temporal datasets.
- **Minimal scripting and automation skills**, especially in Python, making it difficult to handle larger datasets and repeat analyses efficiently.
- Limited experience in **integrating EO/LiDAR outputs with existing field measurements and administrative data** in a coherent workflow.
- Uncertainty about how to **validate EO/LiDAR-derived indicators and communicate their uncertainty and fitness-for-purpose** in regulatory or management contexts.
- Insufficient familiarity with **version control and structured data management practices** — including file naming conventions, metadata, and project documentation — which creates downstream problems for reproducibility and collaborative work.

These gaps define the **starting point** for GreenScope: traditional monitoring professionals are strong in environmental and institutional knowledge but need structured support to incorporate EO and LiDAR into their existing workflows.

3.2.2. EO and LiDAR applications in practice (Group 2)

EO/LiDAR-oriented organisations demonstrate what more **mature EO/LiDAR practice** can look like in environmental and infrastructure monitoring. Across the interviews, typical applications include:

- **Infrastructure and built environment** – InSAR-based deformation monitoring for railways and buildings, stability assessment of dams and critical infrastructure, and 3D modelling of industrial plants and urban areas for planning, simulation, and training.

- **Flood and water management** – High-resolution terrain models from LiDAR for hydraulic simulations, floodplain delineation, dam safety assessment, and stormwater planning, often combined with EO-derived land cover and soil information.
- **Forestry and land use** – Use of national and drone-based LiDAR for forest inventory, canopy height and structural biodiversity metrics, combined with Sentinel time series for disturbance detection and land cover change monitoring.
- **Agriculture and vegetated landscapes** – Application of Sentinel-1 and Sentinel-2 data for crop monitoring, vegetation indices, and land management decisions.
- **Marine and coastal environments** – EO-based monitoring of water quality, algal blooms, pollution events, and coastal change.
- **Climate-related hazards** – Subsidence and ground-motion analysis, wildfire damage mapping, and risk assessment at regional and national scales.

These applications rely on a **combined data and tool stack**: Sentinel-1 and Sentinel-2 as the main satellite backbone, supplemented by Landsat and other missions; national LiDAR datasets and aerial imagery; occasionally commercial EO and LiDAR products for very high resolution; and a technical environment centred on Python, QGIS, SNAP, CloudCompare, LasTools, PostGIS, photogrammetry software, and domain-specific modelling tools.

The interviews reveal **three broad levels of maturity** among Group 2 organisations:

- **Fully or near-fully operational workflows** – EO/LiDAR pipelines are automated end-to-end (e.g. deformation monitoring services, national forest monitoring components, CAP compliance systems) and embedded in routine decision processes.
- **Advanced but project-based use** – EO/LiDAR are essential for research and innovation projects (e.g. experimental 3D plant models, biodiversity studies, one-off hazard analyses), but are not yet standard across all institutional activities.
- **Partial or exploratory integration** – EO/LiDAR are used for specific tasks within contracts or projects, often through external providers, while the majority of workflows remain reliant on traditional data and tools.

Even in EO/LiDAR-intensive environments, professionals highlight **gaps on the "other side" of the transition**: they see a need for stronger environmental interpretation, indicator design, communication with non-technical stakeholders, and closer collaboration with traditional monitoring experts. This confirms that the skills gap is **two-sided**: traditional professionals need EO/LiDAR competences, while EO/LiDAR specialists need deeper domain, communication, and integration skills.

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A note on the two-sided nature of EO/LiDAR maturity: Even within Group 2, the range of integration is substantial. At one end, some organisations operate fully automated InSAR deformation monitoring pipelines serving infrastructure clients at scale, while others runs routine global forest monitoring workflows using cloud-native data architectures. At the other end, specialist public agencies apply EO and LiDAR in a project-based mode, with operational rollout still in progress. Between these poles sit organisations with partial or service-dependent integration. One of them occupies a particularly instructive position as an applied sciences higher education institution: it uses terrestrial and drone LiDAR for teaching and applied research — including 3D scanning of industrial plants for digital twin creation — while simultaneously preparing students for operational professional contexts that the institution itself has not yet fully reached. This reflects a broader pattern in which HEIs must train for environments beyond their own current practice.

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3.3. Data sources, tools, and platforms for EO/LiDAR

3.3.1. Data sources

Across both groups, professionals work with a combination of **satellite EO data, LiDAR and aerial data, in-situ measurements, and administrative datasets**.

- **Open satellite data**
    - Copernicus Sentinel-1 and Sentinel-2 form the common EO backbone, providing SAR and optical data for land cover, vegetation, water, and hazard applications.
    - Landsat and other long-running missions are used where historical time series are needed.
    - In some cases, additional missions (e.g. PALSAR, GEDI) support forest and biomass or vegetation structure applications.
    - German practitioners access Sentinel data primarily via CODE-DE, the national Copernicus data access portal, which provides additional preprocessing services and regional context relevant to German public sector workflows.
- **LiDAR and aerial imagery**
    - National airborne LiDAR datasets are widely available in several partner countries and are used for terrain modelling, forest structure, and urban applications.
    - Drone-based LiDAR and aerial imagery are used in research and pilot projects where very high resolution or specific timing is required.

    - It is important to note that open national LiDAR coverage is not uniform across partner countries: Croatia has had no publicly available national LiDAR dataset since 2023, creating a significant structural constraint that forces Croatian practitioners to rely on project-specific or commercially procured acquisitions.

- **In-situ and administrative data**
    - Field measurements, sensor networks, GNSS observations, and laboratory analyses remain central for calibration, validation, and variables that cannot be derived from remote sensing.
    - Administrative datasets (cadastres, land registries, statistical series, protected area boundaries) provide legal and management context and are routinely integrated with spatial analyses.
- **Commercial and specialised data**
    - High-resolution commercial EO or LiDAR products are procured selectively where freely available data do not meet local spatial or temporal requirements, particularly for urban, infrastructure, or small-scale hazard applications.
- **Copernicus thematic services and derived products**
    - Several professionals work with Copernicus Land Monitoring Service products, the European Ground Motion Service (EGMS) for subsidence and deformation applications, and Sentinel-5P data for atmospheric monitoring of NOx and particulate matter. These ready-to-use products lower the entry threshold for organisations without full EO processing capacity.

Selection criteria are similar across organisations: open access and low cost, appropriate spatial and temporal resolution for the application, reliable metadata and documentation, and increasingly **technical accessibility via APIs and cloud-ready catalogues**.

3.3.2. Tools and platforms

The interviews reveal a clear difference between the typical tool environments in traditional and EO/LiDAR-oriented settings.

Group 2 – EO/LiDAR-oriented organisations

In advanced contexts, EO/LiDAR processing is centred on a **Python-based open-source stack** combined with specialised tools:

- **Python** with libraries for raster/vector processing, numerical analysis, and machine learning. Python-based workflows typically combine core geospatial libraries — **GeoPandas, GDAL, Rasterio** — with machine learning frameworks such as Scikit-Learn, and are increasingly developed and shared via **Jupyter notebooks** with Git-based version control for reproducibility.

- **QGIS** for visualisation, exploratory analysis, and cartography.
- **SNAP** for Sentinel preprocessing, particularly SAR workflows.
- **CloudCompare** and **LasTools** for LiDAR point cloud visualisation, filtering, and classification.
- **PostGIS** and other database platforms for structured spatial data management and analysis.
- **Photogrammetry software** for generating point clouds and 3D models from aerial and drone imagery.
- Domain-specific modelling tools (e.g. hydraulic and engineering models) that consume EO/LiDAR-derived inputs.
- **SARPROZ and StaMPS** for advanced InSAR time series processing.
- **AgiSoft Metashape and Pix4D** for photogrammetric point cloud generation from drone imagery.
- **eCognition** for object-based image analysis.
- **STAC-compatible** catalogues for cloud-native EO data discovery and access.
- Global Mapper for general geodata handling.
- ForstamtGIS and ClusterWIS/KlimaWIS in German forestry agency contexts.
- HydroTec Tools for hydraulic modelling workflows.
- Levels of automation vary from partially scripted workflows to fully automated pipelines that run regular monitoring products.

Group 1 – traditional monitoring organisations

In more traditional contexts, the dominant tools are:

- Desktop GIS (primarily QGIS, sometimes ArcGIS) for mapping, basic analysis, and reporting.
- Office software (particularly spreadsheets) for data cleaning, tabular analysis, and reporting.
- Domain-specific desktop tools for data entry and regulatory reporting.

EO-specific tools (e.g. SNAP) and scripting environments are used **only selectively**, often by a small number of more technically oriented staff. Most workflows remain manually executed, with limited reuse of code or processing chains.

This contrast underlines a central finding: the **tool gap is primarily about practical geospatial data literacy and automation**, not about awareness of EO and LiDAR as concepts. Traditional professionals already work with spatial data in GIS environments but lack routine experience with Python-based processing, EO/LiDAR-specific tools, and database-backed workflows that are standard in more advanced organisations.

For GreenScope, these patterns confirm that curriculum and training materials should:

- prioritise **Python-centred, open-source workflows** that can be adopted in both academic and public-sector environments;
- explicitly teach how to move from **manual GIS operations to scripted, reproducible workflows**;
- show how EO/LiDAR-oriented tools (SNAP, CloudCompare, LasTools, PostGIS) fit into complete monitoring chains, not as isolated software packages.
- explicitly address data discovery and access infrastructure — including national portals such as CODE-DE, STAC catalogues, and Copernicus thematic services — so graduates understand not only how to process data but where to reliably find it in their national or sectoral context.

3.4. Perceived benefits of EO/LiDAR compared to traditional methods

Professionals highlight several recurring advantages of EO and LiDAR over purely traditional approaches:

- **Large-area, systematic coverage** – EO and LiDAR make it possible to monitor entire river basins, forest regions, coastlines, or infrastructure networks in a consistent way, which would be logistically or financially impossible using only ground surveys.
- **Improved temporal frequency and speed** – Once workflows are in place, EO-based products can be updated regularly, supporting trend analysis, early detection of change, and faster reaction to emerging risks. Historical satellite archives allow retrospective analysis that traditional monitoring rarely provides.
- **Cost-effectiveness at scale** – Although initial investments in skills and workflows can be substantial, continued use of open EO data and periodically updated LiDAR datasets reduces marginal costs for repeated assessments, especially over large or remote areas.
- **Consistency and repeatability** – EO and LiDAR products reduce variability related to different survey teams, instruments, or sampling conditions, improving comparability over time and between regions.

These benefits are particularly valued in contexts where monitoring obligations are expanding, but staff and field resources remain constrained.

At the same time, respondents emphasise clear **limitations** and the continued central role of ground-based data:

- EO products may not provide sufficient spatial resolution for very local phenomena, or sufficient temporal resolution for rapidly changing conditions, unless complemented by higher-resolution or commercial data.

- Processing and interpreting EO/LiDAR outputs can be complex, especially for organisations with limited technical capacity, which can slow adoption despite positive attitudes.
- Many parameters required for regulatory reporting or detailed management decisions cannot be derived from remote sensing alone and still depend on **field measurements, GNSS observations, and laboratory analyses**.

Professionals therefore see EO and LiDAR as **tools that extend the reach and efficiency of existing monitoring systems**, provided that outputs are carefully validated and interpreted in context.

3.5. Barriers to wider EO/LiDAR adoption

This section synthesises the main barriers that limit wider and more systematic use of EO and LiDAR across both traditional monitoring organisations and EO/LiDAR-oriented contexts. It distinguishes between organisational and skills-related challenges, data and workflow issues, and structural constraints related to regulation, infrastructure, and costs.

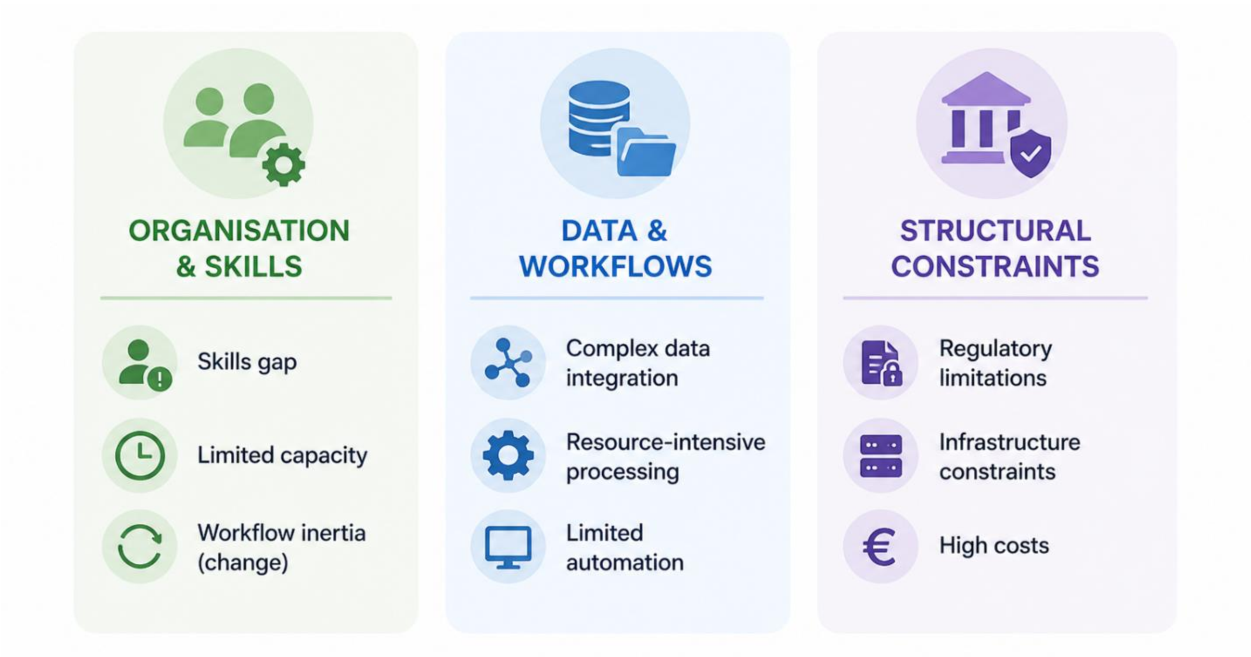

Figure 6 Barriers to EO & LiDAR adoption.

1. **Organisational and skills-related barriers**

Across countries and organisation types, the most frequently cited barriers are linked to **people, time, and institutional priorities**:

- **Limited in-house capacity and time –** Traditional monitoring teams are fully occupied with existing statutory tasks and reporting cycles, leaving little space to experiment with new EO/LiDAR workflows alongside established methods.

- **Shortage of EO/LiDAR and data science skills –** Many organisations lack staff with practical experience in EO processing, LiDAR handling, and scripting. Recruitment of such profiles is difficult, particularly in the public sector where competition with private companies is strong.

- **Dependence on single experts or small teams –** Where EO/LiDAR expertise exists, it is often concentrated in one person or a very small team. This creates vulnerabilities and limits the scale at which new methods can be embedded institution-wide.

- **Workflow inertia and organisational risk aversion –** Monitoring and reporting procedures are deeply embedded; changing them requires not only technical changes but also organisational decisions and, in some cases, regulatory adjustments. Without explicit mandates or dedicated funding, EO/LiDAR initiatives tend to remain isolated pilots.

- **Developer–domain mismatch –** where EO/LiDAR routines are built by technically oriented developers without deep domain knowledge, outputs can be technically correct but operationally misaligned. As one senior LiDAR specialist noted, the skills shortage means that processing routines are sometimes designed by people who understand the code but not the underlying environmental or infrastructure process, creating quality and interpretability problems downstream.

These factors mean that, even where interest is high, **organisations struggle to invest sustained effort** into building and stabilising EO/LiDAR workflows.

2. Technical and data-related barriers

A second group of barriers relates to **data complexity, processing demands, and integration challenges**:

- **Complexity of multi-source integration –** Organisations find it challenging to combine EO, LiDAR, in-situ measurements, and administrative datasets in coherent workflows. Understanding formats, metadata, and necessary preprocessing steps requires specialised knowledge that is often scarce.

- **Resource-intensive processing –** Large EO archives and dense LiDAR point clouds place high demands on storage, computing power, and workflow design. Where automation is weak, processing chains rely on many manual steps, making regular updates and scaling difficult.

- **Mismatch between data characteristics and application needs –** For some tasks, freely available satellite data lack sufficient spatial resolution, while in other cases temporal revisit or LiDAR update cycles do not match the dynamics of environmental or urban change. Organisations must then choose between accepting these limitations or purchasing more expensive commercial data.

- **Hard physical limits of optical EO –** some environmental parameters cannot be derived from satellite data regardless of resolution or processing sophistication. The Finnish Environment

Institute specifically identified phosphorus concentration in water bodies as a variable that cannot be measured optically, requiring continued in-situ monitoring. Understanding where EO genuinely cannot substitute for field measurement is an important competence in itself.

These challenges contribute to the perception that EO and LiDAR add **extra complexity** to already demanding monitoring tasks, rather than simplifying them

3. Regulatory, infrastructural, and cost constraints

Finally, interviewees point to structural constraints that are often beyond the control of individual teams:

- **Regulatory restrictions, especially for drones** – Aviation and data protection regulations can restrict or delay drone-based LiDAR and imagery campaigns, limiting the feasibility of regular high-resolution data collection.

- **Infrastructure and IT limitations** – Some organisations lack sufficient computing capacity, storage, or network performance for handling large EO/LiDAR datasets efficiently. In others, security policies restrict use of cloud services or modern collaboration tools.

- **Upfront investment and licensing costs** – While open EO data reduce acquisition costs, initial investments in hardware, training, software, and workflow development remain substantial. Licensing costs for specialised software can limit the number of staff who can work with EO/LiDAR tools.

Together, these factors help explain why EO and LiDAR, despite widely recognised benefits, are **not yet fully embedded in routine monitoring practice**. They also highlight that skills development must be paired with **workflow-oriented curriculum design** that acknowledges infrastructure, regulatory, and organisational realities, preparing graduates to navigate these constraints in practice.

4. Country-specific structural barriers

The barriers described above are not uniform across the GreenScope partner countries; in several cases they reflect specific national infrastructure gaps and policy environments that shape what is feasible in practice.

- In **Croatia**, the absence of a publicly available national LiDAR dataset since 2023, combined with slow bureaucratic data access processes, limits the ability of organisations to build reproducible, up-to-date workflows. Compounding this, spatial planning documents remain available only in PDF format, impeding the kind of automated geospatial integration that EO-based monitoring increasingly requires.
- In **Germany**, the competitiveness with the industry makes recruiting staff with EO/LiDAR skills extremely difficult for public research institutions working at standard civil service salary scales. At the same time, state-level restrictions on the use of AI tools in official forestry workflows add a further layer of constraint that is not faced by counterparts in other partner countries.

- In **Austria**, the Cop4Austria study (BMK/FFG, 2024) found that while 84% of environmental professionals are aware of Copernicus data, EO and LiDAR remain largely absent from routine operational workflows. The primary barrier is not awareness but integration: spatial resolution is frequently too coarse for local-level operational decisions, and access, download, and incorporation of EO products into existing GIS workflows remains cumbersome for public sector teams. Organisational workflows, training, and resourcing consistently lag behind the technical possibilities, and there is no central national hub or coordination mechanism to support systematic EO uptake across agencies.
- In the **Netherlands**, legacy decision-support systems in infrastructure management are not designed to ingest geospatial analytics products. This creates what practitioners describe as a "last-mile analytics" gap — a structural disconnect between what EO workflows can deliver and what operational teams can actually use within their existing information systems.
- In **Finland**, data discovery can remain a practical barrier even for technically capable teams, as EO data are distributed across multiple sources and formats., adding time and uncertainty to the early stages of monitoring projects.

These country-specific patterns confirm that curriculum design and institutional support strategies cannot be uniform across the GreenScope partnership. Targeted attention to national data infrastructure, regulatory environments, and labour market conditions is necessary if training programmes are to be genuinely responsive to the contexts in which graduates will work.

3.6. Skills needs across traditional and EO/LiDAR roles

This section synthesises what employers and supervisors across traditional monitoring and EO/LiDAR-oriented organisations expect from graduates, which skills are realistically developed after entry, which competences are hardest to find, and which new skills are likely to grow in importance over the next three to five years.

1. Skills expected on day one

Across both groups, there is strong agreement that graduates should arrive with solid foundations rather than fully specialised expertise. Core entry-level expectations include:

- **EO and remote sensing fundamentals:** conceptual understanding of how satellite sensors and LiDAR work, what types of information they provide, typical resolutions and limitations, and awareness of main open data sources (e.g. Sentinel, Landsat).
- **GIS and CRS basics:** the ability to work confidently in GIS (typically QGIS), handle vector and raster data, understand coordinate reference and elevation systems, and perform basic spatial operations such as re-projection, overlay, and extraction.

- **Basic Python scripting and data handling:** competence to retrieve digital data from open repositories, run and adapt simple processing scripts, and carry out basic statistical and tabular analysis rather than relying solely on graphical user interfaces.
- **Environmental domain understanding:** background knowledge in relevant domains (e.g. water systems, forests, biodiversity, land use) sufficient to interpret spatial patterns and indicators in context, not just as abstract datasets.
- **General analytical and problem-solving skills:** the ability to structure a task, follow a workflow from data acquisition to result, check plausibility, and document steps clearly.

Employers emphasise that these foundations should be in place at the point of hire so that new staff can contribute meaningfully to ongoing projects and progressively take on more complex EO/LiDAR work.

2. Skills typically developed on the job

Interviewees also recognise that some competences are best developed in practice, once graduates are embedded in real organisational contexts. These include:

- **Client and stakeholder communication:** translating technical outputs into clear, decision-relevant messages for non-specialists, such as municipal planners, asset managers, or policy-makers, and adjusting the level of detail to different audiences.
- **Service and workflow design:** designing end-to-end monitoring services, including data source selection, workflow optimisation, quality control, and integration of EO/LiDAR products into existing institutional procedures and information systems.
- **Cloud-native and large-scale processing:** working with cloud platforms, APIs, and distributed computing to handle large EO/LiDAR datasets at scale, which often depends on organisation-specific infrastructure and policies.
- **Organisation-specific tools and standards:** learning in-house systems, national data portals, sector-specific modelling tools, and internal conventions for documentation, quality assurance, and reporting.

These skills depend heavily on the specific domain, regulatory environment, and client base of each organisation, and are therefore seen as appropriate targets for on-the-job development rather than preconditions for employment.

3. Hardest-to-find skills in junior professionals

Despite good disciplinary knowledge, professionals across countries and sectors report a consistent set of gaps in junior hires:

- **Experience with real operational datasets:** many graduates are used to clean, small, well-documented teaching datasets and struggle with fragmented administrative data, noisy field measurements, large multi-temporal satellite archives, and dense LiDAR point clouds. Problems with basic tasks such as coordinate transformation, georeferencing, and handling mixed projections are common.

- **Scripting and automation beyond "hello world":** Python (or similar) is often listed on CVs, but employers find that many juniors cannot independently build or adapt scripts for routine processing, data fusion, or batch operations. As a result, workflows remain more manual and time-consuming than they need to be.
- **Translation from technical output to decision support:** junior professionals often focus on producing technically correct maps and indicators but find it difficult to explain what these mean for concrete decisions, including limitations, uncertainties, and trade-offs.
- **Structured data management:** weaknesses in organising files, naming conventions, metadata, and versioning make it hard to reuse and share data within projects. Employers stress the need for systematic thinking about how data are stored and documented over the full project life cycle.
- **Handling and communicating uncertainty and data quality:** understanding data origins, accuracy, and reliability—and being able to communicate uncertainty transparently—is frequently missing, leading to over-confidence in model outputs or misinterpretation of EO/LiDAR products.
- **Interdisciplinary "big-picture" thinking:** many juniors are technically capable in narrow tasks but struggle to integrate environmental processes, data science, and user needs into a coherent overall perspective.
- **Combined remote sensing and programming competence**: organisations across multiple countries report that junior candidates tend to be strong in one area but weak in the other

These gaps are seen as major bottlenecks for effective use of EO and LiDAR in both traditional and advanced monitoring settings.

4. Emerging skills for the next 3–5 years

Looking ahead, interviewees outline a set of skills that will become increasingly important as monitoring practices evolve:

- **AI and machine learning for EO/LiDAR:** competences in applying machine learning and AI to EO time series, LiDAR point clouds, and multi-sensor data, including model training, validation, and responsible use, are expected to be a major growth area.
- **Multi-sensor data fusion and integration:** the ability to combine EO, LiDAR, in-situ measurements, process/IoT data, and administrative information into coherent workflows, aligning spatial and temporal resolutions and managing the resulting complexity.

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- **Cloud-scale and API-based workflows:** working fluently with cloud platforms, data cubes, and API-driven access to large EO catalogues is anticipated to move from niche to mainstream in many organisations.
- **Validation, calibration, and quality assurance of automated outputs:** as automation and AI are increasingly used, skills in designing robust validation strategies, performing accuracy assessments, and critically evaluating automated products will be essential to maintain credibility and trust.
- **Advanced data structuring and "data hygiene":** deciding what data to retain, how to structure and index it for future reuse, and how to distinguish valuable information from unnecessary "data waste" are seen as emerging professional competences.
- **Professional attitudes and adaptability:** beyond technical skills, employers highlight the importance of reliability, readiness for continuous learning, and a constructive attitude towards rapid technological and environmental change, including awareness of the resource footprint of digital tools.
- **Responsible use of AI tools and awareness of regulatory constraints**: AI tools are not yet permitted in all official workflows and that understanding when and how AI can be responsibly applied — including awareness of computational costs and regulatory frameworks — will be an important professional competence.

Figure 7 Employer expectations and skills outlook.

Collectively, these findings suggest that future-oriented curricula should deepen technical skills in EO, LiDAR, and data science while simultaneously strengthening data management, uncertainty handling, and interdisciplinary reasoning, preparing graduates to operate in increasingly automated, data-rich, and responsibility-sensitive monitoring environments.

4. DACUM methodology and workshop process

The DACUM (Developing a Curriculum) approach was used to translate interview findings and national analyses into concrete occupational roles and skills requirements for smart environmental monitoring. It is based on the principle that skilled practitioners are best placed to define the competences needed in real work environments, rather than relying only on academic or institutional assumptions.

In GreenScope, the process followed two main steps:

- **Step 1 – Synthesis** – Interview findings (traditional and EO/LiDAR professionals), comparative monitoring practice analysis, and a review of European EO and geospatial job profiles (e.g. from professional associations and industry) were synthesised into draft role profiles and an initial competency framework.
- **Step 2 – Validation and refinement –** These draft profiles and competencies were circulated to all partners and selected experts for review against regional labour-market needs, existing curricula, and graduate profiles. Partners proposed modifications, additions, and prioritisation adjustments, which were integrated into the final framework.

The main outputs of this process are:

- a set of **four key professional role profiles** relevant to smart environmental monitoring using EO and LiDAR
- a **competency framework** structured across a small number of core domains, indicating which competences are core, important, or desirable for each role

Detailed DACUM charts (duties, tasks, tools, behaviours) can be provided as an annex where needed for programme-level design

4.1. Key professional roles

The DACUM process identified four representative roles that capture the main ways EO and LiDAR are used in environmental monitoring and decision support. These roles are not job titles in a strict sense, but archetypes that help structure curriculum and skills development.

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Figure 8 Key roles in smart environmental monitoring.

4.1.1. EO and LiDAR data analyst

The **EO and LiDAR data analyst** processes and analyses Earth Observation and LiDAR datasets to extract environmental information for reporting, decision-support, or further modelling. This role typically appears in industry, public agencies, and research organisations at the interface of geospatial data engineering and environmental science.

- **Core activities:** data acquisition and preprocessing (including quality control), classification and feature extraction, time-series and change detection analysis, accuracy assessment and validation, and preparation of maps, charts, and technical reports.
- **Typical background:** geomatics, geography, environmental science, or engineering with a strong GIS/remote sensing component.

4.1.2. Smart environmental monitoring specialist

The **Smart environmental monitoring specialist** designs and manages monitoring systems that combine EO, LiDAR, field data, and other sensors for ongoing environmental assessment. This role is common in public environmental bodies, consultancies, and NGOs.

- **Core activities:** defining monitoring objectives, selecting and combining data sources, designing practical workflows, integrating EO/LiDAR outputs with in-situ and administrative data, preparing environmental reports for authorities, and communicating results and limitations to stakeholders.

- **Typical background:** environmental science, ecology, or geography, upskilled with EO/LiDAR and geospatial methods.

4.1.3. Geospatial data scientist

The **Geospatial data scientist** applies data science and machine learning methods to EO and other geospatial datasets to build predictive models, automated processing pipelines, and decision-support tools. This role is more common in industry and applied research labs.

- **Core activities:** developing and tuning ML models for EO/LiDAR data, designing automated processing chains, implementing cloud-native workflows, fusing multiple sensor and data types, and ensuring validation and quality control at scale.
- **Typical background:** computer science, data science, or quantitative geography with strong programming skills and remote sensing training.

4.1.4. Research and policy advisor in environmental monitoring

The **Research and policy advisor** uses EO, LiDAR, and other geospatial evidence to inform environmental policy, research agendas, or institutional decisions. This role appears in research institutions, international organisations, public agencies, and consulting firms.

- **Core activities:** synthesising EO/LiDAR and other monitoring results, integrating them with scientific literature and policy frameworks, assessing the effectiveness of monitoring systems, and communicating evidence-based recommendations to decision-makers.
- **Typical background:** environmental policy, sustainability studies, or geography, with strong analytical and communication competences and basic understanding of EO/geospatial methods.

4.2. Competency framework (overview)

The DACUM process organised competences into **five core domains** that apply across these roles. Each domain contains specific competencies that can be prioritised as **Core** (expected at entry), **Important** (developed within 6–12 months), or **Desirable** (advanced/specialised). Detailed competency matrix by role is provided in Annex D: Detailed competency matrix by role.

Table 3 Core competency domains.

Domain	Focus	Key competencies
Data acquisition and management	Accessing and managing EO/LiDAR data	data sources (Sentinel, Landsat, LiDAR), sensor characteristics, data management (formats, metadata), APIs and data portals
Data processing and	Transforming data	preprocessing, classification, time series analysis, SAR/LiDAR processing, machine learning,

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analysis	into information	automation, validation
Environmental application and interpretation	Applying data to real problems	forests, water, biodiversity, land use, hazards, integration with field data, contextual interpretation
Communication and reporting	Turning results into decisions	maps and visualisation, reporting, uncertainty communication, stakeholder presentation, workflow documentation
Professional and cross-disciplinary skills	Enabling real-world use	interdisciplinary work, problem solving, project management, ethics and GDPR, continuous learning

Across all roles and domains, three cross-cutting competency needs stand out:

1. **Working with real, complex datasets** rather than only with small, cleaned examples.
2. **Integrating multiple data sources** (EO, LiDAR, field, administrative, IoT) into coherent workflows.
3. **Translating analysis into decisions**, including communicating uncertainty and limitations clearly.

These cross-cutting competencies provide a direct bridge between the DACUM results and the curriculum and training design carried out in subsequent work packages.

The DACUM results confirm that the main challenge for smart environmental monitoring is not access to EO and LiDAR technologies, but the ability to integrate them into real monitoring workflows and decision processes. This requires a balanced combination of technical (EO/LiDAR and data processing), analytical (problem-solving, integration, validation), and communication skills, rather than narrow, tool-specific remote sensing expertise.

5. GAP analysis

5.1. Current state — what HEI curricula cover

The institutional mapping at Algebra Bernays University (Croatia), TH Rosenheim (Germany), and SAMK (Finland) shows that EO/LiDAR-relevant competences are present across all three institutions, but in a fragmented and discipline-specific way rather than as a coherent environmental monitoring curriculum. Readiness levels, however, differ substantially: THRO has domain depth but limited EO/LiDAR practice; SAMK has distributed digital and sensor competences that are not yet oriented towards environmental monitoring; and AU is at the earliest stage, with strong data/AI foundations but no geospatial infrastructure, no EO/LiDAR course content, and no staff with EO or LiDAR specialisation.

1. **Foundational competences**

All three institutions provide **strong foundational competences** in data science, engineering, and environmental technologies relevant to EO/LiDAR integration, although the level of geospatial specialisation varies significantly.

Algebra Bernays University (AU) offers programmes in Data Science, Artificial Intelligence, Computer Science, Software Engineering, Applied Computer Engineering, and Cyber Security. Students develop competences in machine learning, big data, deep learning, data visualisation, databases, and information security. While these programmes provide strong analytical and programming foundations relevant to EO/LiDAR, geospatial content is currently absent. Approximately **150 students per year** enrol across relevant BSc and MSc programmes, alongside **10–20 doctoral candidates annually**.

Satakunta University of Applied Sciences (SAMK) provides relevant foundations through programmes in Electrical and Automation Engineering, Energy and Environmental Engineering, Construction and Municipal Engineering, Data Engineering, and Artificial Intelligence. Topics include robotics, machine vision, environmental monitoring, surveying, machine learning, autonomous systems, and data analytics. Around **50–100 students per year** participate in these programmes. SAMK also has staff expertise in AI, environmental monitoring, climate technologies, and statistical methods.

TH Rosenheim (THRO) offers strong domain-specific environmental and engineering competences through programmes in Civil Engineering and Environmental Technology. Relevant topics include water management, environmental measurement technologies, environmental simulation, soil protection, wastewater treatment, green technologies, Industrial IoT, and networked systems. Approximately **95 students per year** enrol across related Bachelor and Master programmes. THRO also has significant institutional expertise in EO/LiDAR, particularly through staff experience in forestry-related LiDAR campaigns and environmental research projects.

2. **Partial EO/LiDAR coverage**

THRO and SAMK already include partial EO/LiDAR-related content, while **AU currently has no EO/LiDAR integration**.

At **THRO**, selected modules introduce LiDAR, sensors, and environmental monitoring concepts, including comparisons between satellite imagery and aerial photography. Tools such as **QGIS, CloudCompare, SPSS and Orange** are already used in teaching and analysis. However, students do not yet work directly with operational EO/LiDAR datasets or complete end-to-end monitoring workflows. The institution also possesses **LIDAR equipment** like a SLAM-Handheld-LiDAR and processing equipment.

At **SAMK**, EO/LiDAR topics appear across robotics, machine vision, environmental monitoring, surveying, urban planning, and applied RDI activities. The institution already possesses **AI computing infrastructure and LiDAR equipment**, although these are mainly used in robotics and automation contexts rather than environmental monitoring.

At **AU**, EO/LiDAR and GIS content are currently absent from the curriculum. The university does not yet use dedicated GIS software such as QGIS or ArcGIS, and staff do not have specialised EO/LiDAR expertise. However, strong integration opportunities exist within existing AI and data science courses, including machine learning, spatial-temporal analytics, deep learning, and big data processing.

3. Summary of the current state

Across all three institutions, several common patterns emerge:

- **strong foundations in AI, data science, and environmental engineering**
- **partial EO/LiDAR coverage at THRO and SAMK**, but no dedicated integration at AU
- **absence of complete operational EO/LiDAR workflows** within existing curricula
- distributed expertise at SAMK and THRO, but limited institutional capacity at AU
- infrastructure gaps focused more on curriculum integration and staff training than equipment acquisition

At THRO, curriculum expansion is additionally constrained by institutional procedures requiring a change in Study and Examination Regulations and thus Senate approval for new standalone modules. As a result, short-term GreenScope integration will need to focus primarily on embedding EO/LiDAR content within existing courses rather than creating entirely new modules.

5.2. Desired state — what the market needs

The DACUM competency framework and interview-based market analysis indicate that entry-level EO/LiDAR roles require a more integrated and application-oriented skill set than current curricula consistently provide. For the EO and LiDAR Data Analyst and the Smart Environmental Monitoring Specialist roles in particular, graduates should be able to:

- access and manage EO and LiDAR data sources;

- perform standard preprocessing, classification, and basic change detection;
- apply EO/LiDAR in at least two environmental application domains;
- integrate EO outputs with in-situ and administrative data;
- communicate results and uncertainties clearly to non-specialists.

At Algebra Bernays, this implies moving from general data analytics to **explicit geospatial and EO/LiDAR applications** within existing modules. Machine Learning, Deep Learning, Data Mining, and Big Data courses would need to incorporate remote sensing use cases (e.g. land cover classification, anomaly detection in satellite imagery, LiDAR point cloud segmentation) and teach students how to work with spatial data structures and EO-specific challenges. Computer Science and Software Engineering courses would need to move towards building **operational geospatial platforms** and APIs that can handle EO data streams, rather than focusing solely on abstract system examples.

At TH Rosenheim, the desired state involves moving from sensor theory and isolated LiDAR examples towards **practical EO/LiDAR workflows** in environmental and civil engineering modules. Courses such as Hydraulic Engineering and Water Management, Environmental Measurement Technology, and Environmental Simulation could include hands-on EO/LiDAR-based terrain modelling, flood hazard analysis, and environmental monitoring scenarios using real datasets. Given existing staff expertise in large-scale LiDAR campaigns and EO-based forestry projects, there is clear potential to embed these competences more systematically into teaching.

At SAMK, the desired state is to connect existing robotics, AI, and environmental courses into **coherent EO/LiDAR monitoring use cases**, moving beyond implicit use of spatial data in robotics and computer vision towards explicit treatment of EO and LiDAR in environmental monitoring and urban applications. This includes systematic use of EO data in Environmental Monitoring, Surveying, and Data Analytics courses, and the integration of EO/LiDAR datasets into space-related studies.

Across all three institutions, the desired state therefore includes:

- explicit EO/LiDAR content embedded into existing data/AI and environmental modules;
- hands-on workflows from data access to decision-relevant outputs;
- stronger integration of communication, uncertainty handling, and application context into technical teaching.

5.3. Priority gaps

Based on the institutional mappings and the wider skills analysis, several **priority gaps** emerge that directly inform WP3 curriculum development.

1. **EO/LiDAR as integrated applied content, not just theory or examples**

- Algebra Bernays has strong modules in ML, deep learning, big data, and visualisation, but EO/LiDAR and geospatial content are not yet integrated and would be entirely new in most modules.
- THRO covers LiDAR and EO conceptually in sensor-focused courses, but practical exercises do not yet use EO/LiDAR datasets, meaning students do not experience complete EO/LiDAR workflows.
- SAMK uses spatial and image data in several courses and projects, but EO and LiDAR are not yet systematically framed as environmental monitoring tools.

2. **Hands-on experience with EO/LiDAR datasets in environmental application contexts**
    - All three institutions highlight the need for “on-the-point examples and teaching material” and **ready-to-use practical exercises** that show the possibilities of EO and LiDAR within the limited time available in existing modules.
    - Current practice uses real-world data mainly in robotics, automation, and generic analytics projects, but not yet in clearly structured EO/LiDAR environmental case studies.
3. **Geospatial and EO literacy for data/AI students**
    - At Algebra Bernays, data and AI students have strong methodological skills but limited exposure to spatial data structures, coordinate systems, or EO-specific challenges, which are essential for EO and LiDAR Data Analyst and Geospatial Data Scientist roles.
4. **Bridging sensor-level knowledge and EO/LiDAR monitoring workflows**
    - THRO students learn how LiDAR works and see airborne examples, but do not yet carry through from sensor concepts to full monitoring chains (e.g. from point clouds to terrain models to flood/hazard assessments).
5. **Structured EO/LiDAR curriculum ownership and coordination**
    - SAMK notes that EO/LiDAR-related topics are distributed across multiple programmes and courses, with no single discipline clearly owning leadership of EO/LiDAR curriculum development, which can hinder coherent integration.

These gaps align with, and add institutional detail to, the market-driven gaps identified in the DACUM and interview analysis (e.g. limited experience with real EO/LiDAR workflows, insufficient scripting and automation for geospatial tasks, weak integration of technical analysis and decision-support communication).

5.4. Cross-disciplinary gaps

The institutional mappings also reveal **cross-disciplinary gaps** that cut across technical content and are critical for GreenScope's curriculum design.

First, there is a **gap between generic data/AI skills and environmental interpretation**. Algebra Bernays students are well trained in ML, deep learning, and big data technologies, but their exposure to environmental or geospatial application contexts is limited and would need to be introduced mainly via EO/LiDAR-based case studies. SAMK's programmes combine robotics, AI, and environmental topics, but EO/LiDAR is not yet systematically linked to environmental monitoring questions; content is scattered across automation, energy, construction, and data engineering modules without a unifying environmental narrative. TH Rosenheim's environmental and civil engineering modules offer strong domain content, yet students currently see EO/LiDAR only in short sensor sections rather than as end-to-end tools for environmental interpretation.

Second, there is a **gap in the communication of analytical results and uncertainty**. None of the three mappings describe dedicated training in communicating geospatial uncertainties, limitations, and data quality aspects in professional contexts, despite recognising the importance of stakeholder communication and practical examples. This mirrors interview findings that graduates often treat data as exact and struggle to explain reliability and limitations to non-technical audiences.

Third, the mappings highlight a **gap between research-style or exploratory analytics and operational service delivery**. Algebra Bernays emphasises research-level opportunities for EO/LiDAR in the joint doctoral programme, while SAMK underscores project-based learning and applied RDI activities using real-world datasets. However, in all three institutions, there is limited explicit focus on designing services and workflows that deliver timely, fit-for-purpose products under real-world constraints of time, infrastructure, and client needs. This gap directly echoes employer observations that graduates are trained to find the "best possible analytical solution" rather than the fastest reliable and communicable result.

Taken together, these cross-disciplinary gaps confirm that WP3 should not only introduce more EO/LiDAR content, but also explicitly integrate environmental interpretation, uncertainty communication, and operational service thinking into GreenScope's learning materials and curriculum designs.

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6. Recommendations for curriculum and MOOC Development

This section translates the gap analysis, competency framework, and interview findings into concrete recommendations for GreenScope curriculum and MOOC development. The aim is to provide a structured set of design priorities and building blocks that can support the work of the curriculum lead institution.

6.1. Overall design principles

The curriculum and MOOC should be guided by a small set of clear principles:

- **Workflow-oriented, not tool-oriented** – Learning units should follow end-to-end monitoring workflows (from question → data → processing → validation → decision) rather than focusing on isolated tools or techniques.
- **Real data, real problems** – EO/LiDAR and ancillary datasets from partner organisations should be used wherever possible, so that students work with realistic data volumes, quality issues, and multi-source integration challenges.
- **Modular and adaptable** – Content should be structured into modules that can be adopted in full (e.g. as a new course) or embedded as components into existing programmes across different disciplines (data science, engineering, environmental science, etc.).
- **Balanced technical and interpretive focus** – Technical EO/LiDAR processing competences should be consistently linked to environmental interpretation, communication, and decision support, not taught in isolation.

6.2. Core curriculum components

Based on the identified competency domains and gaps, the curriculum and MOOC could include the following core components:

1. **Spatial data and EO/LiDAR fundamentals**
    - Geospatial basics: coordinate systems, projections, raster vs vector, elevation models.
    - EO and LiDAR concepts: sensor types, resolutions, revisit times, typical products, and limitations.
    - Data access: open EO catalogues, national LiDAR datasets, and basic data retrieval workflows.
2. **EO/LiDAR processing and automation**

- Standard preprocessing (e.g. geometric/radiometric correction, cloud masking) using open-source tools.
- Introductory land cover classification and feature extraction, with practical exercises.
- Basic time-series analysis and change detection on multi-temporal satellite data.
- Pragmatic scripting with Python for batch processing, data fusion, and reproducible workflows.

3. **Environmental applications and case studies**
    - Thematic modules aligned with partner strengths (e.g. water and flood mapping, forestry and biomass, coastal/marine monitoring, urban planning and hazards).
    - Each module built around a real case from a partner, including problem framing, data selection, processing, and interpretation.
4. **Validation, uncertainty, and quality**
    - Designing simple validation schemes using field or reference data.
    - Computing basic accuracy metrics and discussing sources of error.
    - Communicating uncertainty and fitness-for-purpose to non-specialist audiences.
5. **Communication and decision support**
    - Map and visualisation design principles tailored to environmental decision-making.
    - Short reporting formats (briefs, dashboards, presentations) that summarise methods, key findings, and limitations clearly.
    - Examples of how different stakeholders (engineers, planners, policy-makers) use EO/LiDAR outputs.
6. **Introductory AI and ML for EO/LiDAR**
    - Conceptual introduction to applying ML to EO/LiDAR (classification, segmentation, anomaly detection).
    - Simple hands-on examples using small, carefully structured datasets, with emphasis on validation and responsible use.

Figure 9 Core curriculum components.

6.3. Alignment with roles and competency framework

The recommended curriculum structure should be explicitly linked to the four role profiles and the competency domains:

- **EO and LiDAR Data Analyst** – emphasise Domains A and B (data acquisition, processing), plus core competencies in Domains C and D.
- **Smart Environmental Monitoring Specialist** – emphasise Domains C and D, with a solid basis in A and B and stronger focus on communication and application context.
- **Geospatial Data Scientist** – emphasise advanced elements of Domains A and B (automation, ML, cloud workflows), with selected high-level content from C and D.
- **Research and Policy Advisor** – emphasise Domains C, D, and E (interpretation, communication, cross-disciplinary skills), with sufficient literacy in A and B to understand data capabilities and limitations.

This alignment will help programmes decide which modules and MOOC components are most relevant for their target student groups.

The recommendations above are intended as a structured evidence base and design support for curriculum and MOOC development within GreenScope. They do not prescribe a single “correct” curriculum.

The detailed curriculum will be developed and finalised by PLUS, drawing on its pedagogical expertise, disciplinary strengths, and experience in geospatial education. PLUS is best placed to determine which curriculum structure, depth, and sequencing are most suitable for the partner institutions and for the specific needs of the GreenScope project and its target student groups.

7. Conclusion

The evidence gathered through **Work Package 2** presents a clear picture of current environmental monitoring practice across Europe. **Traditional field-based and in-situ methods remain the operational foundation** across agencies, consultancies, and research institutions, even where EO and LiDAR technologies are already in use. Rather than replacing conventional approaches, EO and LiDAR primarily extend them by providing broader spatial and temporal coverage.

The research shows that the main barrier to wider adoption is **not technology or data availability**, since open satellite data and open-source tools are already widely accessible. Instead, the key challenge lies in the **skills and capacity required to integrate EO and LiDAR into operational workflows**. This directly reinforces the central rationale of the GreenScope project: **education and training are essential for bridging the gap between technological potential and professional practice**.

Interviews conducted across partner countries revealed a consistent demand for graduates who can:

- work with Sentinel-1 and Sentinel-2 data
- use Python and open-source geospatial tools such as QGIS
- automate geospatial workflows
- manage complex multi-source datasets
- interpret outputs within environmental and policy contexts
- communicate uncertainty and results to non-specialist audiences

The **DACUM-based competency framework** developed in WP2 identified four key professional roles and provides an evidence-based structure closely aligned with labour market needs. The GAP analysis further confirms that many of the identified weaknesses are shared across partner institutions, making the framework transferable across different educational contexts.

These findings provide clear direction for the next project phases. For **WP3**, curriculum and MOOC development should focus on:

- real operational datasets
- Python-based open-source workflows
- practical case studies in forestry, flood management, subsidence analysis, and coastal monitoring
- validation and uncertainty assessment integrated throughout the learning process

Overall, the skills gaps identified in WP2 reflect broader European challenges linked to the **green and digital transition**. The GreenScope educational toolkit is therefore designed not only for consortium partners, but also for wider use by universities, training providers, and independent learners seeking to strengthen competences in environmental monitoring, EO, LiDAR, and geospatial data analysis.

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2. ANNEXES

2.1. Annex A: Interview Guide — Group 1 (Traditional Monitoring Professionals)

This annex contains the full semi-structured interview guide used for Group 1 interviews with traditional environmental monitoring professionals. The guide covers eleven thematic areas including role and context, monitoring focus, current workflow, methods and tools, data used, skills and background, limitations and unmet needs, awareness of EO and LiDAR, adoption potential, skills gaps in new professionals, and implications for education. The guide was developed by AU and applied across all partner country interviews.

Monitoring without EO/LiDAR as core tools

1. **Role and context**

Please describe your role and main responsibilities, and the type of environmental monitoring you are involved in. What type of organisation do you work in, and is your work mainly field-based, desk-based analysis, coordination, or a combination?

2. **Monitoring focus and frequency**

What environmental aspects do you monitor most often (for example forests, water resources, biodiversity, land use, natural hazards)? Is your monitoring continuous, seasonal, or mainly project-based?

3. **Current workflow**

Walk me through a typical monitoring task from start to finish. What are the main steps, and where do you spend the most time?

4. **Methods and tools**

What methods and tools do you use most frequently (for example field measurements, sampling, sensors, reporting templates, maps, basic GIS)? Which parts are manual, and which parts are automated, if any?

5. **Data used in practice**

What data do you rely on most (for example field data, historical datasets, official reports, aerial imagery, national databases)? How often is it updated, and how easy is it to access and use?

6. **Skills and background**

What skills and knowledge are most important for performing your role well (technical, analytical, domain knowledge)? What educational backgrounds are most common in your field?

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7. **Limitations and unmet needs**

What are the main limitations of your current monitoring approach (for example spatial coverage, update frequency, accuracy, cost, staff time, data availability)? Are there aspects you would like to monitor better or more often but currently cannot?

8. **Awareness of EO and LiDAR**

How familiar are you with Earth Observation and LiDAR, even if you do not use them daily? Where have you encountered them (projects, partners, reports, service providers), and how relevant do they seem to your work?

9. **Adoption potential and enablers**

Where could more digital or data-driven approaches bring the biggest improvements in your work (for example faster cycles, early warning, broader coverage, better analysis, stronger decision support)? What would need to change to make this feasible in your context?

10. **Skills gaps in new professionals**

What skills are most often missing in new professionals entering the field (for example GIS, data handling, interpretation, remote sensing basics, quality control, communication of results)?

11. **Implications for education**

How could universities or training programmes prepare graduates better for roles like yours? What types of learning would help most (practical exercises, real datasets, case work, internships, collaboration with practitioners)?

2.2. Annex B: Interview Guide — Group 2 (EO and LiDAR Professionals)

This annex contains the full semi-structured interview guide used for Group 2 interviews with EO and LiDAR professionals. The guide covers twelve thematic areas including role and maturity of use, main use cases, workflow in practice, data sources, tools and platforms, essential technical competences, entry expectations for graduates, hard-to-find competences, barriers and constraints, benefits compared to traditional methods, near-future skills, and implications for education.

Earth Observation and LiDAR as core tools in daily work

1. **Role and maturity of use**

Please describe your role and responsibilities and how EO and or LiDAR are used in your work. What type of organisation do you work in? Would you describe EO or LiDAR use as exploratory, project-based, routine operational, or fully integrated into decision workflows?

2. **Main use cases**

What environmental problems do EO and LiDAR help you address most effectively (for example forest change, flood modelling, biomass, land use, water monitoring)? Which use cases create the most value in your organisation?

3. **Workflow in practice**

Choose one typical use case and walk me through the workflow from data acquisition to outputs and decisions. What are the key steps and where are the main bottlenecks?

4. **Data sources**

Which EO and LiDAR data sources do you use most (for example Sentinel, Landsat, national LiDAR, commercial providers)? What drives your choice (resolution, revisit time, cost, licensing, reliability, ease of access)?

5. **Tools and platforms**

Which tools and platforms do you use most (for example desktop GIS, cloud platforms, Python or R, APIs, automated pipelines)? What level of automation is typical in your work?

6. **Essential technical competences**

What technical competences are essential in your organisation for effective EO and LiDAR work (for example preprocessing, classification, modelling, validation, accuracy assessment, interpretation, GIS integration, automation)?

7. Entry expectations for graduates

What should new graduates already be able to do on day one, and what can be learned during the first months on the job? Please include both technical skills and domain understanding.

8. Hard to find competences

Which skills are currently hardest to find in junior hires (technical, analytical, practical, or communication skills)? What mistakes or gaps do you see most often?

9. Barriers and constraints

What are the main barriers to wider or more effective EO and LiDAR use in your field (data access, licensing, costs, computing infrastructure, skills shortages, organisational constraints, regulation)? Which barriers are most significant in your context?

10. Benefits compared to traditional methods

In your experience, what improves most when using EO and LiDAR compared to traditional methods (speed, coverage, accuracy, cost-effectiveness, consistency, decision support)? Where do limitations still remain?

11. Near-future skills

Looking ahead three to five years, which competences will become more important (for example cloud processing, time-series analysis, AI and machine learning, data fusion, uncertainty communication, integration with IoT or models, interoperability standards)?

12. Implications for education

How should universities and training programmes prepare students for EO and LiDAR roles? What should be included in the curriculum, and what practical training formats work best (real datasets, case-based projects, industry challenges, internships, co-teaching with practitioners)?

2.3. Annex C: Overview of Interview Participants

All participants are anonymised. Descriptions refer to the type of organisation rather than its name. N = 19 participants (covering 20 individuals; two Austrian entries represent composite profiles from multiple partial questionnaires). Group 1 = Traditional Monitoring Professionals; Group 2 = EO/LiDAR Professionals.

#	Country	Research Group	Anonymous Description	Role / Function	Organisation Type	Key Focus Area
CROATIA						
1	Croatia	Group 1 – **Traditional Monitoring**	Tourism and spatial data research institute	GIS and spatial data analyst	Public research institute	Spatial data management; tourism sector monitoring
2	Croatia	Group 2 – **EO/LiDAR Professionals**	Marine environmental monitoring company	GIS specialist – marine transport and nautical tourism	Private company	Marine EO; satellite data analysis; nautical GIS
3	Croatia	Group 2 – **EO/LiDAR Professionals**	Institute of applied ecology – remote sensing laboratory	Director and head of remote sensing and GIS laboratory	Private company/ Research institute	Remote sensing; GIS; ecological monitoring
AUSTRIA						
4	Austria	Group 1 – **Traditional Monitoring**	Public sector environmental agencies (composite profile)	Environmental monitoring professional (agency officer; water/forestry management)	Public sector agency	Operational environmental monitoring; regulatory compliance
5	Austria	Group 2 – **EO/LiDAR Professionals**	Public sector agencies and research institutions	EO and LiDAR professional (remote sensing	Public sector / university	Earth observation; Copernicus data; spatial

			(composite profile)	analyst; geospatial scientist)		analysis
FINLAND						
6	Finland	Group 1 – **Traditional Monitoring**	National environmental research institute	Project manager / expert – drones and autonomous monitoring platforms	Public research institute	Autonomous monitoring; drone-based data collection; water quality
7	Finland	Group 2 – **EO/LiDAR Professionals**	Municipal urban planning and GIS unit	Land use engineer	Public sector / municipality	Urban LiDAR; land use planning; city GIS
8	Finland	Group 2 – **EO/LiDAR Professionals**	Geospatial surveying and mapping company	Leading expert in geospatial services	Private company	Laser scanning; aerial survey; geospatial data products
GERMANY						
9	Germany	Group 1 – **Traditional Monitoring**	Technical university – applied research	Research assistant – industrial processes, data analysis and immersive technologies	Higher education institution	Data integration; applied environmental research; immersive technologies
10	Germany	Group 1 – **Traditional Monitoring**	Water management authority	Research assistant / project manager – flood protection	Public sector agency	Traditional flood monitoring; hydraulic field surveys; environmental

						reporting
11	Germany	Group 2 – **EO/LiDAR Professionals**	Water management authority – hydraulic engineering unit	Project staff – hydraulic engineering and torrent hazard identification	Public sector agency	Aerial LiDAR; hydraulic modelling; torrent and flood risk
12	Germany	Group 2 – **EO/LiDAR Professionals**	Regional forestry research and competence centre	Consultant / scientific employee – drone remote sensing and laser scanning	Public sector agency	Forest drone surveys; LiDAR point cloud evaluation; digital forest information systems
13	Germany	Group 2 – **EO/LiDAR Professionals**	State forestry institute – forest management and inventories	Department head – forest management, growth and inventories	Public sector agency	LiDAR-based forest inventory; biomass estimation; growth modelling
14	Germany	Group 2 – **EO/LiDAR Professionals**	Water management authority – aerial LiDAR unit	Project employee – water management (aerial LiDAR for hydraulic models)	Public sector agency	Aerial LiDAR acquisition; hydraulic model generation; floodplain mapping
NETHERLANDS						
15	Netherlands	Group 2 – **EO/LiDAR Professionals**	Geospatial and EO consultancy	EO specialist	Private company	Satellite data services; EO consultancy; geospatial analysis

16	Netherlands	Group 2 – **EO/LiDAR Professionals**	University – geospatial sciences faculty	Associate professor – geospatial sciences	Higher education institution	EO research; academic training; geospatial methods
17	Netherlands	Group 2 – **EO/LiDAR Professionals**	Social-impact EO company	Data scientist – EO and geospatial applications	Private company	EO for sustainability; drone mapping; geospatial data science
18	Netherlands	Group 2 – **EO/LiDAR Professionals**	Infrastructure and geospatial AI solutions company	Senior LiDAR specialist	Private company	LiDAR systems; point cloud analysis; AI-driven infrastructure monitoring
19	Netherlands	Group 2 – **EO/LiDAR Professionals**	Large IT and space data services company	Senior EO data scientist	Private company	Satellite data analytics; EO pipelines; cloud-based geospatial services

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2.4. Annex D: Detailed competency matrix by role

This annex expands the DACUM competency framework presented in Chapter 7 by specifying the detailed competencies within each domain and their relative priority for the four role profiles identified in the GreenScope project. The matrix is intended to support WP3 curriculum design by making it easier to translate labour-market needs into learning outcomes, module structures, and proficiency expectations.

Priority levels

- **Core**: expected at entry level or essential for the role
- **Important**: should be developed early in professional practice
- **Desirable**: advanced, specialised, or context-dependent competence.

Domain A. Data acquisition and management

Code	Competency description	EO & LiDAR Data Analyst	Smart Environmental Monitoring Specialist	Geospatial Data Scientist	Research and Policy Advisor
A1	Identify appropriate EO, LiDAR, aerial, field, and administrative data sources for a given monitoring task	Core	Core	Core	Important
A2	Understand sensor characteristics, spatial and temporal resolution, and main limitations of EO and LiDAR datasets	Core	Core	Core	Important
A3	Access and retrieve data from open portals, catalogues, APIs, and institutional repositories	Core	Important	Core	Desirable
A4	Organise geospatial data using appropriate formats, metadata, naming conventions, and version control practices	Core	Important	Core	Important
A5	Assess data suitability, quality, and interoperability before	Core	Core	Core	Important

	analysis				

Domain B. Data processing and analysis

Code	Competency description	EO & LiDAR Data Analyst	Smart Environmental Monitoring Specialist	Geospatial Data Scientist	Research and Policy Advisor
B1	Perform standard preprocessing of EO and LiDAR datasets, including reprojection, clipping, mosaicking, and quality control	Core	Important	Core	Desirable
B2	Apply raster and vector processing workflows in GIS and Python-based environments	Core	Important	Core	Desirable
B3	Conduct classification, segmentation, or feature extraction for environmental applications	Core	Important	Core	Desirable
B4	Perform time-series analysis and change detection using multi-temporal EO data	Core	Important	Core	Desirable
B5	Process and analyse LiDAR point clouds and derivative products such as DEMs, CHMs, and terrain metrics	Core	Important	Core	Desirable
B6	Integrate multiple data types, including EO, LiDAR, field data, and administrative datasets, into a coherent workflow	Core	Core	Core	Important
B7	Use scripting and automation to improve reproducibility and	Core	Important	Core	Desirable

	efficiency of workflows				
B8	Apply basic machine learning or AI methods to EO/LiDAR analysis where relevant	Important	Desirable	Core	Desirable
B9	Validate outputs and assess accuracy, uncertainty, and fitness for purpose	Core	Core	Core	Important

Domain C. Environmental application and interpretation

Code	Competency description	EO & LiDAR Data Analyst	Smart Environmental Monitoring Specialist	Geospatial Data Scientist	Research and Policy Advisor
C1	Apply EO/LiDAR methods in forest and vegetation monitoring contexts	Important	Core	Important	Important
C2	Apply EO/LiDAR methods in water, hydrology, or flood-related monitoring contexts	Important	Core	Important	Important
C3	Apply EO/LiDAR methods in biodiversity, habitat, or protected area contexts	Important	Core	Important	Important
C4	Apply EO/LiDAR methods in land use, urban, or infrastructure monitoring contexts	Important	Core	Important	Important
C5	Integrate EO/LiDAR outputs with field measurements, validation data, and regulatory requirements	Core	Core	Important	Core
C6	Interpret analytical results in their environmental, institutional, and policy	Core	Core	Important	Core

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	context				
C7	Select methods and indicators that are appropriate for specific monitoring objectives and decision needs	Important	Core	Important	Core

Domain D. Communication and reporting

Code	Competency description	EO & LiDAR Data Analyst	Smart Environmental Monitoring Specialist	Geospatial Data Scientist	Research and Policy Advisor
D1	Prepare clear maps, dashboards, charts, and visual outputs for different audiences	Core	Core	Important	Core
D2	Write concise technical documentation, workflows, and methodological notes	Core	Core	Important	Core
D3	Explain results, limitations, and uncertainty to non-technical stakeholders	Important	Core	Important	Core
D4	Translate analytical findings into decision-relevant recommendations or operational insights	Important	Core	Important	Core
D5	Present findings orally in interdisciplinary or stakeholder settings	Important	Core	Important	Core

Domain E. Professional and cross-disciplinary skills

Code	Competency description	EO & LiDAR Data	Smart Environmental	Geospatial Data	Research and Policy

		Analyst	Monitoring Specialist	Scientist	Advisor
E1	Work effectively across disciplinary boundaries, combining environmental, technical, and organisational perspectives	Important	Core	Important	Core
E2	Apply structured problem-solving and workflow design in real-world monitoring tasks	Core	Core	Core	Important
E3	Demonstrate good data governance practices, including ethics, GDPR awareness, and responsible use of digital tools	Important	Core	Important	Core
E4	Manage tasks, priorities, and collaboration within projects and institutional workflows	Important	Core	Important	Core
E5	Demonstrate adaptability, continuous learning, and critical reflection in a rapidly evolving technical field	Core	Core	Core	Core

2.5. Annex E: GAP Analysis Table

This annex provides the complete GAP analysis table comparing the current competency coverage of partner HEI programmes against the desired competency state defined by the DACUM framework. The table covers 31 competency descriptors organised across five domains. For each competency, the coverage level at each institution is recorded as: **None** (not addressed), **Partial** (addressed indirectly or in a non-EO context), or **Core** (systematically taught as a central learning outcome). The overall GAP rating reflects the combined urgency across all three institutions: **Critical** (absent or near-absent at all three), **Significant** (present at one or two institutions but not as EO/LiDAR-specific content), or **Minor** (foundations present; integration or contextualisation needed). Coverage assessments are based on institutional mapping data (Q2, Q3, Q6, Q7) and the GAP analysis review conducted in WP2.

Coverage key: ✗ None ~ Partial ✓ Core

GAP rating key: Critical Significant Minor

Table 4 GAP analysis table.

#	Competency Descriptor	AU (Croatia)	SAMK (Finland)	THRO (Germany)	GAP Rating	Rationale
Domain 1 — Data Acquisition and Management						
1	Identify and access relevant EO data sources (Sentinel-1/2/3, Landsat, national datasets)	✗ None	~ Partial	~ Partial	**Critical**	*AU: no EO content. SAMK: incidental use. THRO: awareness only, no access exercises.*
2	Identify and access LiDAR data sources (airborne, terrestrial, national elevation models)	✗ None	~ Partial	~ Partial	**Critical**	*AU: absent. SAMK: lab LiDAR (robotics, not env.). THRO: theory only, no hands-on access.*
3	Understand sensor characteristics and data quality parameters (resolution, revisit, SNR)	~ Partial	~ Partial	✓ Core	**Significant**	*THRO covers sensors in EnvMeasTech. AU covers ML/data quality, not spatial. SAMK robotics sensors.*
4	Manage EO/LiDAR data formats, metadata standards, and file structures (GeoTIFF, LAZ, COG)	✗ None	✗ None	~ Partial	**Critical**	*No institution teaches EO/LiDAR-specific formats. THRO nearest*

#	Competency Descriptor	AU (Croatia)	SAMK (Finland)	THRO (Germany)	GAP Rating	Rationale
						through practical data work.
5	Use EO/LiDAR data portals, APIs, and cloud platforms for programmatic data access	~ Partial	~ Partial	✗ None	**Significant**	*AU covers APIs/data engineering. SAMK machine vision pipelines. THRO: no programming access to EO.*
6	Apply GDPR-compliant data management procedures to environmental datasets	~ Partial	~ Partial	~ Partial	**Minor**	*All three cover data governance/GDPR in some form; not applied specifically to EO contexts.*
Domain 2 — Data Processing and Analysis						
7	Perform standard EO preprocessing (radiometric calibration, atmospheric correction, cloud masking)	✗ None	✗ None	✗ None	**Critical**	*Entirely absent at all three institutions. No preprocessing workflows taught for EO data.*
8	Classify land cover and extract environmental features from satellite imagery	~ Partial	~ Partial	✗ None	**Critical**	*AU: ML classification (not spatial). SAMK:*

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#	Competency Descriptor	AU (Croatia)	SAMK (Finland)	THRO (Germany)	GAP Rating	Rationale
						computer vision. THRO: no classification exercises.
9	Conduct time-series and change detection analysis using EO datasets	✗ None	✗ None	~ Partial	**Critical**	*No time-series EO analysis taught at any institution. Major curriculum gap.*
10	Process LiDAR point clouds (filtering, normalisation, ground/canopy separation)	✗ None	✗ None	~ Partial	**Critical**	*AU/SAMK: absent entirely. THRO: students see LiDAR concept only; no hands-on point cloud work.*
11	Generate DEMs, DSMs, and CHMs from LiDAR data; derive terrain and canopy metrics	✗ None	✗ None	~ Partial	**Critical**	*THRO: airborne LiDAR shown as example but students do not produce outputs. AU/SAMK: absent.*
12	Apply SAR/InSAR techniques for deformation, soil moisture, or flood mapping	✗ None	✗ None	✗ None	**Critical**	*Fully absent at all three. Advanced but*

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#	Competency Descriptor	AU (Croatia)	SAMK (Finland)	THRO (Germany)	GAP Rating	Rationale
						increasingly expected at entry level (NL-G2-05, SYKE).
13	Apply machine learning and deep learning methods to EO/LiDAR data	~ Partial	~ Partial	✗ None	**Significant**	*AU/SAMK: strong ML/DL foundations but no EO spatial data context. THRO: no ML at all.*
14	Design and implement automated geospatial processing pipelines	~ Partial	✗ None	✗ None	**Significant**	*AU: big data pipelines, automation. SAMK: some automation in robotics. No EO application.*
15	Perform accuracy assessment and validation of EO/LiDAR products	~ Partial	✗ None	✗ None	**Significant**	*AU: model validation in ML courses. Not applied to geospatial/EO products at any institution.*
Domain 3 — Environmental Application and Interpretation						

#	Competency Descriptor	AU (Croatia)	SAMK (Finland)	THRO (Germany)	GAP Rating	Rationale
16	Apply EO/LiDAR in forest monitoring (biomass, disturbance, inventory)	✗ None	✗ None	~ Partial	**Critical**	*THRO: LWF/forestry context through staff. Not in curriculum. AU/SAMK: absent.*
17	Apply EO/LiDAR in water quality and hydrological monitoring	✗ None	✗ None	~ Partial	**Critical**	*THRO: hydraulic engineering domain present; no EO integration. AU/SAMK: no water domain.*
18	Apply EO/LiDAR in biodiversity, habitat, and ecosystem monitoring	✗ None	✗ None	~ Partial	**Critical**	*None have EO-linked biodiversity content. THRO nearest through environmental modules.*
19	Apply EO/LiDAR in land use / land cover change and urban monitoring	✗ None	~ Partial	✗ None	**Significant**	*SAMK: urban planning module touches spatial data. AU/THRO: absent or theoretical only.*
20	Apply EO/LiDAR in natural hazard assessment (floods,	✗ None	✗ None	~ Partial	**Critical**	*THRO: flood/hazard*

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#	Competency Descriptor	AU (Croatia)	SAMK (Finland)	THRO (Germany)	GAP Rating	Rationale
	landslides, erosion)					*domain strong; no EO workflow taught. AU/SAMK: domain knowledge absent.*
21	Integrate EO/LiDAR outputs with in-situ sensor data and field measurements	✗ None	~ Partial	~ Partial	**Significant**	*SAMK: sensor fusion in robotics context. THRO: field-to-model work in hydraulics. Not EO-framed.*
22	Interpret EO/LiDAR results in their environmental and policy context	✗ None	~ Partial	~ Partial	**Significant**	*THRO: environmental domain knowledge. SAMK: environmental monitoring module. AU: absent.*
Domain 4 — Communication and Reporting						
23	Produce maps, visualisations, and cartographic outputs from EO/LiDAR analysis	~ Partial	~ Partial	~ Partial	**Minor**	*AU: data visualisation course (not spatial/cartographic). SAMK: some visual outputs. THRO: map generation present (QGIS-based spatial*

#	Competency Descriptor	AU (Croatia)	SAMK (Finland)	THRO (Germany)	GAP Rating	Rationale
						visualisation exercise using neural networks), but no EO/LiDAR-based cartographic outputs.
24	Write technical reports and document EO/LiDAR workflows for professional audiences	~ Partial	~ Partial	~ Partial	**Minor**	*All three institutions teach technical writing; not specifically applied to EO/LiDAR workflows.*
25	Communicate data uncertainty, limitations, and quality to non-technical stakeholders	~ Partial	✗ None	~ Partial	**Significant**	*Gap identified at all institutions (PR2 cross-disciplinary gap 2). Students treat data as exact.*
26	Present evidence-based environmental assessments to decision-makers and policy audiences	✗ None	~ Partial	~ Partial	**Significant**	*SAMK/THRO: project-based presentations. AU: limited environmental context. Not EO-grounded.*

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#	Competency Descriptor	AU (Croatia)	SAMK (Finland)	THRO (Germany)	GAP Rating	Rationale
Domain 5 — Professional and Cross-Disciplinary Skills						
27	Apply Python scripting for geospatial data retrieval, processing, and automation	~ Partial	~ Partial	~ Partial	**Significant**	*AU: strong Python (non-spatial). SAMK: Python in data/ML. THRO: Python for handling sensor data on embedded systems*
28	Use Git and version control for collaborative geospatial code development	~ Partial	✗ None	✗ None	**Significant**	*AU: SE courses include version control. SAMK/THRO: absent or ad hoc. Industry expects day-one.*
29	Work across disciplines — combining environmental domain knowledge with data/EO skills	~ Partial	~ Partial	~ Partial	**Significant**	*Gap identified at all three (PR2 cross-disciplinary gap 1). No institution bridges both systematically.*
30	Apply ethical principles and responsible AI use in EO/geospatial contexts	~ Partial	~ Partial	✗ None	**Minor**	*AU: AI ethics in curriculum. SAMK: ethics modules.*

#	Competency Descriptor	AU (Croatia)	SAMK (Finland)	THRO (Germany)	GAP Rating	Rationale
						THRO: AI and AI ethics only as a part of a basic computer science module . Gap mainly at THRO.
31	Engage in continuous professional learning and keep pace with evolving EO/LiDAR tools	~ Partial	~ Partial	~ Partial	**Minor**	*Professional development is present across all three; not EO-specific but transferable.*

2.6. Annex F: List of Data Sources and References Consulted

This annex lists the principal EU-level, national, and sectoral data sources and reference documents consulted during the WP2 research activities (A2.1 National Environmental Monitoring Mapping, A2.2 Professional Interviews, and A2.3 Skills and GAP Analysis). Sources are organised thematically. Where available, direct URLs are provided for open-access documents and datasets.

1. EU-Level Policy and Regulatory Frameworks

Key legislative and strategic documents that define the environmental monitoring obligations of EU Member States and frame the GreenScope research context.

1. European Commission (2019). *The European Green Deal*. COM(2019) 640 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2019:640:FIN

2. European Commission (2020). *EU Biodiversity Strategy for 2030: Bringing nature back into our lives*. COM(2020) 380 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0380

3. European Parliament and Council (2000). *Directive 2000/60/EC establishing a framework for Community action in the field of water policy (Water Framework Directive)*. Official Journal of the European Union. https://eur-lex.europa.eu

4. European Parliament and Council (2023). *EU Nature Restoration Regulation (EU) 2024/1991 / Nature Monitoring Regulation (2023)*. Official Journal of the European Union. https://eur-lex.europa.eu

5. European Commission (2021). *EU Forest Strategy for 2030*. COM(2021) 572 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0572

6. European Commission / Copernicus Programme (2025). *Copernicus Land Monitoring Service (CLMS) — Documentation and Product Catalogue*. European Environment Agency / CLMS. https://land.copernicus.eu

7. European Commission / Copernicus Programme (2025). *Copernicus Marine Environment Monitoring Service (CMEMS)*. Copernicus CMEMS. https://marine.copernicus.eu

8. European Commission / Copernicus Programme (2025). *Copernicus Emergency Management Service (CEMS)*. Copernicus CEMS. https://emergency.copernicus.eu

9. European Commission (2025). *Copernicus Data Space Ecosystem — open access Sentinel data*. https://dataspace.copernicus.eu

10. European Commission (2007). *INSPIRE Directive 2007/2/EC — Infrastructure for Spatial Information in Europe*. EUR-Lex. https://inspire-geoportal.ec.europa.eu/srv/eng/catalog.search#/home

11. European Environment Agency (2025). *EEA Country Profiles and Eionet Environmental Indicators*. EEA. https://www.eea.europa.eu/en/europe-environment-2025/countries/country-profiles

12. European Environment Agency (2024). *EEA Climate-ADAPT Platform — country-level adaptation data*. EEA. https://climate-adapt.eea.europa.eu

13. European Parliamentary Research Service (2024). *EU Space Programme and Earth Observation for Environmental Policy (Briefing PE 767180)*. European Parliament. https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/767180/EPRS_BRI(2024)767180_EN.pdf

14. European Commission (2025). *Common Agricultural Policy (CAP) Strategic Plans — country profiles*. DG Agriculture. https://agriculture.ec.europa.eu/cap-my-country/cap-strategic-plans

2. Copernicus and EO Data Infrastructure

Technical documentation, thematic services, and data access platforms used or referenced in national monitoring mapping and interview analysis.

15. European Commission / ESA (ongoing). *Sentinel-1 (SAR), Sentinel-2 (multispectral), Sentinel-3 (ocean/land) — mission technical documentation*. ESA / Copernicus Programme. https://dataspace.copernicus.eu

16. Copernicus Land Monitoring Service (2024). *CORINE Land Cover (CLC) thematic product*. CLMS. https://land.copernicus.eu

17. Copernicus Land Monitoring Service (2024). *Urban Atlas — European urban land use mapping*. CLMS. https://land.copernicus.eu

18. Copernicus Land Monitoring Service (2024). *High Resolution Layers — Forest, Water, Grassland, Imperviousness*. CLMS. https://land.copernicus.eu

19. DLR / CODE-DE (2024). *CODE-DE — Copernicus Data and Exploitation Platform Germany*. DLR. https://geoservice.dlr.de/web/

20. DLR (2024). *DLR Geoservice — remote sensing datasets and environmental products*. DLR. https://geoservice.dlr.de/web/datasets/cr

21. Austrian Research Promotion Agency (FFG) (2024). *Copernicus Austria — national Copernicus relay and funding activities*. FFG. https://www.ffg.at/weltraum-Copernicus

22. Austria-in-Space (2017). *Austrian Data Cube — national EO infrastructure project*. Austrian Space Applications Programme. https://austria-in-space.at/de/projekte/2017/austrian-data-cube.php

23. mundialis GmbH (2020). *Germany 2020 Land Cover Based on Sentinel-2 Data*. mundialis. https://www.mundialis.de/en/germany-2020-land-cover-based-on-sentinel-2-data/

24. Netherlands Space Office (NSO) (2024). *Satellite Data Portal — Dutch national EO access*. NSO. https://www.spaceoffice.nl/en/satellite-data-portal/

25. WaterInsight (2024). *Satellite-based water quality services — Netherlands*. WaterInsight BV. https://www.waterinsight.nl

26. EARSC (2024). *EO Services for Water Quality — Netherlands case (SeBS)*. EARSC. https://earsc.org/sebs/wp-content/uploads/2024/02/SeBS_Water_qualit_Netherlands_flyer240219.pdf

3. National Environmental Monitoring Data Sources

3.1 Croatia

27. State Geodetic Administration (DGU) (2024). *National geospatial data infrastructure, INSPIRE implementation, national LiDAR elevation products (nDSM)*. DGU. https://www.dgu.hr

28. Croatian Meteorological and Hydrological Service (DHMZ) (2024). *Meteorological and hydrological monitoring networks; drought monitoring (SPEI); satellite-based weather and climate data*. DHMZ. https://meteo.hr

29. Croatian Waters (Hrvatske vode) (2024). *National water management authority; water quality networks; groundwater monitoring; SMART-Water collaboration*. Croatian Waters. https://www.voda.hr

30. Ministry of Environmental Protection and Green Transition (2024). *National Climate Change Adaptation Strategy; Natura 2000; Marine Strategy Framework*. MINGO. https://mingo.gov.hr

31. Ministry of Environmental Protection (2021). *Croatia Climate Change Adaptation Strategy (2021)*. MINGO. https://mingo.gov.hr/UserDocsImages/KLIMA/Climate%20change%20adaptation%20strategy.pdf

32. University of Zagreb, Faculty of Geodesy (2024). *Copernicus Office Croatia (CROC); RS4ENVIRO and GEMINI projects*. Faculty of Geodesy. https://www.geof.unizg.hr

33. University of Zagreb, Faculty of Forestry and Wood Technology (2024). *Remote Sensing and GIS Laboratory; UAV/drone and Sentinel-2 forest research*. Faculty of Forestry. https://www.sumfak.unizg.hr

34. Oikon Ltd. — Institute of Applied Ecology (2024). *Operational CORINE Land Cover mapping for Croatia; EO services*. Oikon. https://www.oikon.hr

35. Flycom Technologies (2024). *National multisensor aerial survey of Croatia (LiDAR + imagery)*. Flycom. https://flycom.si/en/multisensor-aerial-survey-of-the-republic-of-croatia/

36. AdriaAdapt (2022). *Coastal Resilience Handbook for the Adriatic*. AdriaAdapt Consortium. https://adriadapt.eu/wp-content/uploads/2022/01/Coastal-Resilience-Handbook-for-the-Adriatic.pdf

37. RAINMAN Toolbox (2022). *Pluvial flood risk maps for Zagreb and Umag (LiDAR/DEM-based)*. Interreg RAINMAN. https://rainman-toolbox.eu/home/our-stories/zagreb-umag/

38. Croatian Biodiversity Information System (BIIS) (2024). *National biodiversity monitoring database.* Ministry of Economy and Sustainable Development. https://natura2000.inca-al.org/PageTemplates/MS_303.html

39. World Bank (2021). *Croatia Country Climate and Development Report*. World Bank. https://climateknowledgeportal.worldbank.org/sites/default/files/2021-06/15847-WB_Croatia%20Country%20Profile-WEB.pdf

40. OpenData Croatia (2024). *Croatian national open data portal (data.gov.hr)*. https://data.gov.hr

41. Hrvatska 2030 (2020). *National Development Strategy 2030 — Environment chapter*. Government of Croatia. https://hrvatska2030.hr/wp-content/uploads/2020/10/Environment.pdf

42. ISPRS Archives (2025). *Recent aerial LiDAR and photogrammetry research — Croatia*. ISPRS. https://isprs-archives.copernicus.org/articles/XLVIII-4-W13-2025/65/2025/isprs-archives-XLVIII-4-W13-2025-65-2025.pdf

43. University of Zagreb / Oikon (2023). *EO applications in applied ecology — Copernicus data use in Croatia*. Faculty of Geodesy / Oikon. http://science.geof.unizg.hr/copernicus/Downloads/4_EO_Oikon.pdf

3.2 Austria

44. Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) (2024). *Cop4Austria: Copernicus awareness and adoption study (BMK/FFG, 2024)*. BMK / FFG. https://www.ffg.at/weltraum-Copernicus

45. Austrian Environment Agency (Umweltbundesamt) (2024). *Open environmental data and air quality monitoring network (WISA, air quality stations)*. Umweltbundesamt. https://www.umweltbundesamt.at/umweltinformation/opendata

46. Austrian Environment Agency (2024). *WISA — Water Information System Austria*. Umweltbundesamt. https://www.umweltbundesamt.at/wasser/daten-karten/wisa

47. Federal Office of Metrology and Surveying (BEV) (2024). *Austrian national LiDAR-derived digital elevation model (ALS Höhenraster)*. BEV. https://www.bev.gv.at/Services/Produkte/Digitales-Gelaendehoehenmodell/ALS-Hoehenraster.html

48. Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) (2024). *Austrian National Forest Inventory and remote sensing activities*. BFW. https://www.bfw.gv.at/fachinstitute/waldinventur/fernerkundung/

49. BFW (2020). *Austrian Forest Strategy 2020+*. BFW. https://bfw.ac.at/050/pdf/Waldstrategie2020plus.pdf

50. Federal Ministry (BMLUK) (2024). *Austrian National Water Management Programme (NGP 2021).* BMLUK. https://www.bmluk.gv.at/themen/wasser/wasser-oesterreich/wasserrecht_national/wasserrechtliche_kundmachungen/ngp-2021.html

51. Federal Ministry (BMLUK) (2024). *30 Years of Water Quality Monitoring in Austria*. BMLUK. https://www.bmluk.gv.at/service/publikationen/wasser/30-jahre-gewaesserguete-moniring-oesterreich.html

52. Federal Ministry (BMLUK) (2022). *Austrian Biodiversity Strategy 2030*. BMLUK. https://www.bmluk.gv.at/dam/jcr:49476b8f-31b2-4b7a-857b-3cc1b877207f/Biodiversitaetsstrategie_2030.pdf

53. Federal Ministry (BMLUK) (2024). *Torrent and avalanche hazard zone planning (Gefahrenzonenplanung)*. BMLUK. https://www.bmluk.gv.at/themen/wald/wald-und-naturgefahren/wildbach--und-lawinenverbauung/leistungen/Gefahrenzonenplanung.html

54. eHYD (2024). *Austrian hydrological open data platform*. BMLUK. https://ehyd.gv.at/

55. Geoland.at (2024). *Austrian national geospatial services portal*. geoland.at Consortium. https://www.geoland.at/

56. data.gv.at (2024). *Austrian national open government data portal*. Federal Chancellery. https://www.data.gv.at/

57. basemap.at (2024). *Austrian national basemap and WMTS service*. basemap.at Consortium. https://basemap.at/

58. Austrian National Forest Inventory (2024). *Waldinventur — national forest inventory data and results*. BFW. https://www.waldinventur.at/

3.3 Finland

59. Finnish Environment Institute (SYKE) (2024). *Open environmental information and monitoring data*. SYKE. https://www.syke.fi/en-US/Open_information

60. Finnish Meteorological Institute (FMI) (2024). *Open data portal — meteorological and environmental data*. FMI. https://en.ilmatieteenlaitos.fi/open-data

61. National Land Survey of Finland (NLS/MML) (2024). *Maps and spatial data services, including national LiDAR elevation data*. NLS. https://www.maanmittauslaitos.fi/en

62. Finnish Biodiversity Information Facility (FinBIF) (2024). *National biodiversity data platform (laji.fi)*. FinBIF / SYKE. https://laji.fi/en

63. Geological Survey of Finland (GTK) (2024). *Hakku open data service — geological and terrain data*. GTK. https://www.gtk.fi/en/hakku-service/

64. Finnish Government (2022). *Finnish Government Digital Strategy*. Government of Finland. https://julkaisut.valtioneuvosto.fi/handle/10024/744040

65. Finlex (2022). *Finnish Climate Act (423/2022) — Ilmastolaki*. Finnish legislation. https://finlex.fi/fi/lainsaadanto/2022/423

66. Ministry of the Environment (2024). *Finnish Climate Legislation and Climate Act (423/2022)*. Ministry of the Environment. https://ym.fi/en/climate-change-legislation

67. Ministry of Agriculture and Forestry (2024). *Forest resources in Finland — national forest data and reporting*. MMM. https://mmm.fi/en/forests/forestry/forest-resources

68. Luonnontila (2024). *Finnish biodiversity indicators — forests and major environment types*. SYKE / Luonnontila. https://luonnontila.fi/en/indicators-by-major-environment-type/forests/

69. HELCOM (2023). *Eutrophication — State of the Baltic Sea*. HELCOM. https://stateofthebalticsea.helcom.fi/findings/pressures/pollution/eutrophication/

70. avoindata.fi (2024). *Finnish open data portal*. Population Register Centre / VM. https://www.avoindata.fi

71. European Commission (2025). *CAP Strategic Plan — Finland*. DG Agriculture. https://agriculture.ec.europa.eu/cap-my-country/cap-strategic-plans/finland_en

72. Business Pori (2025). *Pori aims to join NASA's satellite program — goal to enhance higher education*. Business Pori. https://www.businesspori.fi/news/pori-aims-to-join-nasas-satellite-program-goal-to-enhance-higher-education/11/03/2025/

73. Peltoniemi, M., Lehtonen, A., Eyvindson, K., Härkönen, K., et al. (2023). *Potential of continuous-cover forestry on drained peatlands to increase the carbon sink in Finland*. Scientific Reports / Nature. https://www.nature.com/articles/s41598-023-42315-7.pdf

74. FMI (2024). *Finnish Meteorological Institute news and research updates*. FMI. https://en.ilmatieteenlaitos.fi/news/z3mzp4xkMhdu4DtVPFYv3

3.4 Germany

75. German Environment Agency (Umweltbundesamt) (2024). *About UBA — national environmental monitoring and reporting authority*. UBA. https://www.umweltbundesamt.de/en/the-uba/about-us

76. German Environment Agency (2022). *Digital pathways for municipal climate adaptation*. UBA. https://www.umweltbundesamt.de/digitale-wege-fuer-kommunale-klimaanpassung

77. Federal Ministry for the Environment (BMUV) (2016). *German Strategy for Adaptation to Climate Change*. BMUV.
https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Klimaanpassung/german_strategy_for_adaption_to_climate_change_bf.pdf

Co-funded by the European Union

78. Federal Ministry for Economic Affairs and Climate Action (2021). *Federal Climate Action Act (KSG) — Bundes-Klimaschutzgesetz*. German Federal Government. https://www.gesetze-im-internet.de/englisch_ksg/englisch_ksg.html

79. Federal Ministry for the Environment (2016). *Climate Action Plan 2050*. BMUV. https://www.bundesumweltministerium.de/en/publication/climate-action-plan-2050-en

80. Federal Institute of Hydrology (BfG) (2024). *BfG — national authority for water research and hydrological data*. BfG. https://www.bafg.de/SharedDocs/Downloads/DE/bfg_publikationen_OeA/bfg_imagebroschuere_EN.pdf?__blob=publicationFile&v=5

81. Helmholtz Association (2024). *Helmholtz Institutes — environmental and Earth system research centres*. Helmholtz. https://www.helmholtz.de/en/about-us/structure-and-governance/helmholtz-institutes/

82. Thuenen Institute (2024). *About us — national agricultural and forestry research institute (includes forest inventory)*. Thuenen Institute. https://www.thuenen.de/en/thuenen-institute/about-us/the-institute

83. Fraunhofer IPM (2024). *Underwater laser scanning — applied LiDAR for infrastructure and environments*. Fraunhofer IPM. https://www.ipm.fraunhofer.de/en/bu/object-shape-detection/applications/underwater-laserscanning/underwater-laserscanning.html

84. TU Darmstadt (2024). *Remote sensing research group — ForSens (forest and sensor applications)*. TU Darmstadt. https://www.geodesy.tu-darmstadt.de/fernerkundung/forschung_fub/forschungsthemen_fub/forsens.de.jsp

85. gaiac Research Institute (2024). *Landscape modelling and spatial ecology*. gaiac. https://gaiac-eco.de/research-development/landscape-modelling/?lang=en

86. Destatis (2024). *Federal Statistical Office — environmental and land use statistics*. Destatis. https://www.destatis.de/EN/Home/_node.html

87. GovData.de (2024). *German national open government data portal*. IT-Planungsrat. https://www.govdata.de/

88. Bayerische Landesanstalt für Wald und Forstwirtschaft (LWF) (2024). *Open geodata — Bavaria (forests, terrain, environment)*. BayernAtlas / LWF. https://geodaten.bayern.de/opengeodata/

89. incora — Indikatoren für Kommunales Raummonitoring (2023). *INCORA — land use and settlement monitoring platform*. incora Consortium. https://incora-flaeche.de/

90. kwh40 (2023). *KWH40 — sustainable housing and urban monitoring platform*. kwh40 Consortium. https://www.kwh40.de

91. Bavarian State Office for the Environment (LfU) (2024). *Land sealing / soil imperviousness monitoring data*. LfU Bayern. https://www.lfu.bayern.de/umweltkommunal/flaechenmanagement/bodenversiegelung

92. German Hydrographic Service (BSH) (2024). *Marine geospatial data infrastructure*. BSH. https://gdi.bsh.de/mapapps/?lang=en

3.5 Netherlands

93. Rijkswaterstaat (2024). *Actueel Hoogtebestand Nederland (AHN) — national LiDAR elevation model*. Rijkswaterstaat / BIM. https://www.rijkswaterstaat.nl/zakelijk/open-data/actueel-hoogtebestand-nederland

94. AHN Viewer (2024). *AHN Viewer — interactive LiDAR point cloud and elevation data viewer*. AHN. https://www.ahn.nl/ahn-viewer

95. AHN Data Room (2024). *AHN dataroom — download portal for Dutch national LiDAR data*. AHN. https://www.ahn.nl/dataroom

96. PDOK (2024). *PDOK — Dutch national geospatial data platform*. Kadaster / Government of Netherlands. https://www.pdok.nl

97. Nationaal Georegister (2024). *National geospatial metadata register — Netherlands*. Geonovum. https://www.nationaalgeoregister.nl

98. KNMI (2024). *Royal Netherlands Meteorological Institute — open data*. KNMI. https://english.knmidata.nl/open-data

99. Wageningen University and Research (2024). *WUR open access research repository — environmental and EO publications*. WUR. https://edepot.wur.nl/

100. Netherlands Space Office (NSO) (2024). *About NSO — national space agency and EO activities*. NSO. https://www.spaceoffice.nl/en/about-nso/

101. Delta Programme (2024). *Delta Programme — flood risk management, freshwater and spatial adaptation*. Dutch Government. https://english.deltaprogramma.nl

102. Delta Programme (2024). *Delta Decision on Flood Risk Management*. Dutch Government. https://english.deltaprogramma.nl/three-topics/flood-risk-management/delta-decision

103. Dutch Government (2024). *Delta Programme — topics overview*. Rijksoverheid. https://www.government.nl/topics/delta-programme/delta-programme-flood-safety-freshwater-and-spatial-adaptation

104. European Environment Agency (2024). *Climate-ADAPT — Delta Programme metadata and adaptation portal*. EEA. https://climate-adapt.eea.europa.eu/en/metadata/portals/delta-programme

105. NL Space (2024). *Netherlands space industry directory — EO service companies*. NL Space. https://www.nlspace.nl/en/spacedirectory/company/81

4. JRC Technical Publications and EU Scientific Reports

Publications from the Joint Research Centre and EU scientific bodies referenced in the monitoring methodology and skills gap analysis.

106. Joint Research Centre (JRC) (ongoing). *JRC Earth Observation — environmental monitoring methods and EO applications*. European Commission JRC. https://joint-research-centre.ec.europa.eu

107. JRC / European Commission (2023). *LUCAS Land Use and Cover Area Frame Survey — methodology and data*. JRC. https://eur-lex.europa.eu

108. JRC / Copernicus (ongoing). *Global Surface Water Explorer — Landsat-based water body monitoring*. JRC / EC. https://global-surface-water.appspot.com

109. IPBES (2019). *Global Assessment Report on Biodiversity and Ecosystem Services*. IPBES Secretariat. https://www.ipbes.net/global-assessment

110. European Environment Agency (2020). *EUNIS Habitat Classification — European habitat types and monitoring guidance*. EEA. https://www.eea.europa.eu

111. Biodiversa+ (2024). *Biodiversa+ Governance Sub-Pilot — Croatia case study*. Biodiversa+. https://www.biodiversa.eu/wp-content/uploads/2024/01/Biodiversa-Governance-Sub-pilot-Croatia.pdf

5. Key Academic Publications

Peer-reviewed literature on EO and LiDAR applications in environmental monitoring and geospatial education, referenced in the research synthesis and skills framework.

5.1 EO and LiDAR Applications in Environmental Monitoring

112. Hyyppä, J., Hyyppä, H., Yu, X., et al. (2020). *Advances in Forest Inventory Using Airborne Laser Scanning*. Remote Sensing, MDPI

113. Wulder, M.A., Loveland, T.R., Roy, D.P., et al. (2019). *Current status of Landsat program, science and applications*. Remote Sensing of Environment

114. Tomljanović, K., et al. (2023). *Forest monitoring and remote sensing applications in Croatia*. Croatian Journal of Forest Engineering (Šumarski list). https://crojfe.com/site/assets/files/4735/tomljanovic.pdf

115. Zeybek, M., et al. (2023). *LiDAR-based forest structure assessment*. Croatian Journal of Forest Engineering. https://crojfe.com/site/assets/files/4647/zeybek-1.pdf

116. Ismail Jaber, M. (2024). *Satellite remote sensing and machine learning for water quality prediction in Croatian waters*. PMC / National Institutes of Health open access. https://pmc.ncbi.nlm.nih.gov/articles/PMC10817504/

117. ISPRS Archives (2022). *Point cloud and LiDAR processing contributions — FIG 2022*. ISPRS. https://www.fig.net/resources/proceedings/fig_proceedings/fig2022/papers/ts02g/TS02G_sisko_cetl_et_al_11603.pdf

118. ISPRS Archives (2022). *UAV and aerial survey methods for environmental monitoring*. ISPRS. https://isprs-archives.copernicus.org/articles/XLIII-B3-2022/611/2022/

119. LIDAR News (2023). *Croatian geodetic company expands drone LiDAR capability.* LIDAR News Blog. https://blog.lidarnews.com/croatian-geodetic-company-expands-drone-lidar-capability/

120. SMART-Water project (2022). *Self-sustainable multisensor water monitoring project — Interreg IPA*. KEEP.EU / Interreg. https://keep.eu/projects/30309/Self-sustainable-Multisenso-EN/

121. EFI (2024). *European Forest Institute — Forest sector reports: Croatia*. EFI. https://efi.int/sites/default/files/files/publication-bank/projects/croatia.pdf

122. HrCAK — Portal of Croatian Scientific Journals (2023). *Selected peer-reviewed papers on EO and GIS in Croatian environmental monitoring*. HrCAK. https://hrcak.srce.hr/

5.2 Geospatial Education, Skills, and Curriculum Development

123. Muñoz-Porcar, C., et al. (2023). *Remote sensing and geospatial education — competency frameworks for EO professionals*. International Journal of Geo-Information / MDPI

124. GreenScope Consortium (2025). *DACUM Workshop Proceedings — EO and LiDAR Professional Profiles (WP2 A2.3)*. GreenScope internal report

125. GreenScope Consortium (2025). *A2.2 Professional Interview Data — 19 interviews across Croatia, Austria, Finland, Germany, Netherlands (WP2)*. GreenScope internal research

126. Austrian Research Promotion Agency (FFG) / BMK (2024). *Cop4Austria — National assessment of Copernicus awareness and operational use among Austrian environmental professionals*. FFG. https://www.ffg.at/weltraum-Copernicus

6. EO/LiDAR Tools, Platforms, and Software Referenced

Software, platforms, and toolchains identified through professional interviews and desk research as commonly used by environmental monitoring practitioners across partner countries.

127. Google Earth Engine (GEE) — Cloud-based geospatial analysis platform for large-scale EO data processing. https://earthengine.google.com

128. QGIS — Open-source geographic information system (desktop GIS). https://qgis.org

129. ArcGIS / ArcGIS Pro — Esri commercial GIS platform. https://www.esri.com

130. CloudCompare — Open-source 3D point cloud and mesh processing software. https://cloudcompare.org

131. LAStools — Efficient LiDAR data processing software suite (rapidlasso GmbH). https://rapidlasso.de/lastools/

132. PDAL — Point Data Abstraction Library — open-source LiDAR/point cloud processing. https://pdal.io

133. SNAP (Sentinel Application Platform) — ESA toolbox for Sentinel satellite data processing. https://step.esa.int/main/toolboxes/snap/

134. Python geospatial stack — GeoPandas, Rasterio, GDAL, Shapely, Fiona, Scikit-Learn, Jupyter, Git. https://geopandas.org

135. R (spatial packages) — sp, sf, terra, raster packages for spatial/EO analysis in R. https://r-spatial.org

136. ENVI — NV5 Geospatial — commercial image analysis and remote sensing software. https://www.nv5geospatialsoftware.com

137. eCognition — Trimble — object-based image analysis for EO classification. https://www.trimble.com/en/products/software/trimble-ecognition

138. Metashape / Agisoft — Photogrammetric processing software for UAV/drone imagery. https://www.agisoft.com

139. Pix4D — Professional drone mapping and photogrammetry platform. https://www.pix4d.com

140. SARPROZ — SAR interferometry (InSAR) processing software. https://www.sarproz.com

141. StaMPS — Stanford Method for Persistent Scatterers — InSAR time-series analysis. https://homepages.see.leeds.ac.uk/~earahoo/stamps/

142. STAC (SpatioTemporal Asset Catalog) — Open standard for cataloguing and accessing EO data. https://stacspec.org

143. ForstamtGIS — Bavarian forestry GIS system used in forest management and LiDAR applications

144. HydroTec Tools — Hydraulic modelling and flood simulation tools used in German water authorities

145. CODE-DE — German Copernicus data and exploitation platform. https://geoservice.dlr.de/web/

7. National Open Data and Geospatial Portals

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Open government and geospatial data portals consulted for spatial, environmental, and statistical data across partner countries.

146. data.gov.hr — Croatian national open data portal. https://data.gov.hr

147. data.gv.at — Austrian national open government data portal. https://www.data.gv.at/

148. avoindata.fi — Finnish national open data portal. https://www.avoindata.fi

149. GovData.de — German national open government data portal. https://www.govdata.de/

150. PDOK — Dutch national geospatial data platform. https://www.pdok.nl

151. Nationaal Georegister (NL) — Dutch geospatial metadata register. https://www.nationaalgeoregister.nl

152. INSPIRE Geoportal (EU) — European spatial data infrastructure catalogue. https://inspire-geoportal.ec.europa.eu/srv/eng/catalog.search#/home

153. Bayern Open Geodata — Bavarian state open geodata portal. https://geodaten.bayern.de/opengeodata/

154. Geoportal Thüringen — Thuringia geospatial open data download. https://geoportal.thueringen.de/gdi-th/download-offene-geodaten

155. Sachsen-Anhalt open geodata — Saxony-Anhalt state open geodata. https://www.lvermgeo.sachsen-anhalt.de/de/gdp-open-data.html

156. Schleswig-Holstein open geodata — State open geodata portal. https://opendata.schleswig-holstein.de/dataset/?organization=lvermgeo

157. Hessen Geobroker — Hessen state geodata services. https://gds.hessen.de/INTERSHOP/web/WFS/HLBG-Geodaten-Site/de_DE/-/EUR/Default-Start

Note on coverage

This annex reflects sources consulted across WP2 activities (A2.1, A2.2, A2.3). It includes EU-level policy documents, national agency datasets, academic publications, and professional interview data. Grey literature, institutional reports, and interview-based evidence are cited where relevant. The list is not exhaustive — additional sources specific to individual country reports are cited inline within the main body of the PR2 report and the WP2 Joint Research Report. All URLs were active as of May 2026.

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