EARTH OBSERVATION DATA MANAGEMENT AND APPLICATIONS IN SUSTAINABLE URBAN DEVELOPMENT

- COURSE OUTLINE -

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Course Outline and Competence Development

The proposed curriculum presents a progressive and feasible framework for developing competencies at the intersection of Earth Observation (EO), geospatial data science, and urban planning and development. Designed in alignment with vocational training needs, it strikes a deliberate balance between theoretical understanding, tool-based practice, and applied learning through real-world case studies. The curriculum emphasizes inclusivity and accessibility by integrating low-threshold EO tools and open data resources, enabling diverse learners to actively engage in EO-driven urban planning and decision-making.

The course connects geodata science with urban development applications, particularly through the use of Copernicus EO data and UDENE tools. It builds learners' capacity to interpret, analyze, and apply EO-derived insights to sustainable urban development challenges. Learning outcomes blend technical competencies, such as EO data handling and geospatial modelling, with applied skills, including problem interpretation and the formulation of practical, evidence-based solutions.

Course Structure and Estimated Workload

The syllabus consists of five modules:

1. **Theoretical Foundations**: Fundamentals of Remote Sensing, EO products, Copernicus services, urban applications and the UDENE framework.
2. **EO Data Management and Applications in Sustainable Urban Development**: The role of EO data in sustainable urban development through spatial analysis and evidence-based decision-making, with the focus on integrating Copernicus services in analytical workflows.
3. **UDENE Tools in Practice**: Introduction to UDENE framework, Data Cube concept, natural experiment concept, Exploration Tool for urban simulations and scenario-building for informed decision making, Matchmaking Tool to connect with potential service providers.
4. **Case Study Applications**: Guided real-world urban use case development, demonstrating each step of the workflow for evidence-based decision making. At least three case studies related to urban development challenges will be covered using Copernicus EO solutions and UDENE tools.
5. **Individual Assignments**: Assessment of technical and analytical competencies through problem identification, tool use, interpretation, and solution reporting.

Together, these modules provide a coherent, inclusive, and practice-oriented curriculum that equips learners with technically robust and professionally applicable skills for modern urban and regional planning contexts.

The curriculum will be implemented as a one-semester course, combining lectures and practical exercises in the computer laboratory. The share between lectures and practical exercises will be either 50–50% or 40–60%, depending on the available resources and instructional needs. This will ensure that assignments consume at least half of the study time either through guided tool-based exercises and hands-on practice or individual assignments intended for assessment of acquired knowledge and skills.

Estimated workload:

1. **Theoretical Foundations**:
    a. 12–15 study hours (including lectures and exercises).
    b. Assessment: participation and discussion (60%), theoretical quiz (40%). Self-assessment quizzes and reflective logs will support continuous progress tracking.
2. **EO Data Management and Applications in sustainable urban development**:
    a. 15–18 study hours (including lectures, tool-based exercises, and one integrative case study).
    b. Assessment: Practical EO analysis report (60%), theoretical quiz (20%), participation and discussion (20%). Self-assessment quizzes and reflective logs will support continuous progress tracking.
3. **UDENE Tools in Practice:**
    a. 12–15 study hours (including lectures, tool-based exercises, and case study analysis).
    b. Assessment: Practical platform utilization (60%), theoretical quiz (20%), participation and discussion (20%). Self-assessment quizzes and reflective logs will support continuous progress tracking.
4. **Use Case Applications**:
    a. Estimated Workload: 30–45 study hours (including lectures, tool-based exercises, and three integrative use cases). At least three use cases covering more than 50% of the course workload will be included.
    b. Assessment: Continuous progress tracking in each phase of the workflow.
5. **Individual Assignments**:
    a. Estimated Workload: 8–12 working hours (individual integrative use case).
    b. Assessment: Data and preprocessing - 25%, Analysis - 25%, Maps - 20%, Interpretation - 15%, Report - 15%

Target Audience and Course Prerequisites

This course is designed for undergraduate students enrolled in Geodesy and Geoinformatics, Architecture and Urbanism, Computing and Automation, Environmental Protection and similar study programmes. It is also intended for practitioners and professionals involved in urban planning, environmental protection, smart cities application development and related fields.

Although not required, prior completion of foundational courses in GIS and Remote Sensing is recommended. Learners may also benefit from existing knowledge in the fields of urban planning and environmental protection. Depending on the learners' background and knowledge, the course can be adapted in several directions. Although primarily intended for advanced and expert learners (e.g., students in the final year of Bachelor studies or the first year of Master studies), the course can be adapted to accommodate learners at more introductory levels. In that case core competencies can be prioritized, the number of case studies reduced from three to less, and advanced topics moved to optional materials or supplementary workshops. Furthermore, depending on the interests of the target group, case studies may be tailored to place greater emphasis on specific subject areas. While the case studies are designed to encompass multiple application domains, in practice a single area of interest may be selected and prioritized.

Skill Development and Competence Assessment

Upon completing the "Earth observation data management and applications in sustainable urban development" course, the learner will acquire a structured set of competencies that align with the EWF qualification framework. The table below outlines the expected knowledge, skills, and levels of autonomy and responsibility achieved at each proficiency level.

Table 1. EWF System skill descriptor

FIELD OF ACTIVITY		EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
UDENE COMPETENCES	EO–GIS–URBAN DEVELOPMENT	**EXPERT**	• Highly advanced knowledge of Earth Observation systems, Copernicus services, Sentinel missions and EO data architecture. • In-depth understanding of Data Cube concepts, integration of EO, socio-economic and in-situ data. • Advanced understanding of modelling, simulations, scenario building and natural experiment approaches. • Comprehensive knowledge of urban development, climate adaptation, UHI dynamics, air quality, mobility and green infrastructure.	• Ability to design complex EO-GIS simulations, natural experiment analyses and multi-criteria planning workflows. • Integration of S1–S6 data for advanced assessments including hazards, LST, air pollution and urban indicators. • Development of advanced what-if scenarios (infrastructure changes, green system redesign, risk mitigation). • Creation of fully customised EO-GIS analytical pipelines.	• Leads high-level strategic projects combining EO, planning tools and simulation frameworks. • Takes full responsibility for methodological design, validation and data interpretation for policy-relevant outputs. • Fully autonomous in defining analytical standards and producing expert recommendations.
		ADVANCED	• Deep understanding of EO data processing, spectral indices (NDVI, NDWI, NDBI, LST) and Copernicus Core Services. • Strong knowledge of EO applications for urban heat, air quality, green infrastructure, mobility and climate risks. • Solid understanding of integrating EO data with urban indicators and planning layers.	• Executes advanced processing: reprojection, atmospheric correction, mosaicking, temporal analysis, S1–S6 usage. • Performs independent analyses of UHI, air quality (NO_2, CO, SO_2), vegetation, urban form and risks. • Applies UDENE tools for scenario comparison and evidence-based policy assessments.	• Plans and performs complex EO-GIS analyses with minimal supervision. • Responsible for analytical quality and methodological accuracy. • Provides specialist input to multidisciplinary teams and urban planners.
		SPECIALIZED	• Solid knowledge of EO fundamentals and Sentinel missions. • Understanding of key EO products (NDVI, NDWI, NDBI, LST). • Knowledge of EO applications in UHI, pollution, green infrastructure, mobility and risk mapping.	• Performs EO processing, index calculation and thematic mapping following established methodologies. • Uses UDENE Exploration and Matchmaking tools within predefined workflows. • Conducts standard analyses such as vegetation change, surface temperature, flood susceptibility, land cover detection.	• Works independently on well-defined tasks and subtasks. • Takes responsibility for parts of EO-GIS workflows, while seeking guidance for complex interpretation. • Identifies data limitations and issues appropriately.

		INDEPENDENT	• Understanding of basic EO concepts: electromagnetic spectrum, spatial/spectral/temporal resolution, active vs passive sensors. • Basic knowledge of Sentinel-1, Sentinel-2 and Sentinel-3 missions. • Understanding basic urban indicators (vegetation, water bodies, built-up areas, land surface temperature).	• Downloads and organises EO data (e.g., S2 L2A, S1 RTC). • Computes basic indices (NDVI, NDWI, NDBI) and creates simple thematic layers. • Performs preprocessing steps (cloud masking, mosaicking) following instructions.	• Performs routine EO tasks under guidance. • Responsible for data preparation and basic map outputs. • Not responsible for final interpretation or strategic recommendations.
		BASIC	• Basic EO concepts: types of satellite data, resolution, active/passive principles. • Basic understanding of the Copernicus programme and Sentinel satellites.	• Opens, views and performs simple interpretation of EO imagery (RGB composites). • Uses basic GIS tools for layer display and visual comparison.	• Works under close supervision. • Completes clearly defined tasks in data display and observation.
		ELEMENTARY	• Elementary understanding of satellite images and simple EO concepts.	• Performs very basic operations such as opening imagery, identifying locations and recognising major features.	• Works only under direct supervision.

Course Feasibility

Feasibility is ensured through compliance with Erasmus Quality Standards, corresponding to 3 ECTS (75–90 study hours), with at least half of the learning time dedicated to tool-based assignments and hands-on practice. The modular design integrates lectures, computer-based exercises, and case studies that anchor theory in real-world urban contexts. This approach supports progressive learning and ensures achievable yet challenging outcomes that demand sustained learner engagement and critical thinking.

Needs Analysis

The curriculum responds to a growing demand for professionals capable of integrating Earth Observation (EO), geospatial data science, and sustainable urban development practices. Modern cities increasingly rely on satellite-derived intelligence to address challenges related to climate change, heat stress, environmental degradation, mobility pressures, sustainable urban planning and evidence-based decision making. However, these competencies remain underdeveloped within many higher-education and vocational training programmes.

The course directly addresses this gap by combining Copernicus (and other) data, UDENE tools, and applied geospatial analysis into a coherent learning framework. It meets the needs of undergraduate students in geomatics, architecture, environmental science, and computing, as well as urban planning practitioners seeking upskilling in EO-driven approaches. The curriculum is aligned with EU priorities on digital skills, sustainability, and EO utilisation, ensuring high relevance for both academic and professional contexts.

Resources and Capacities

The implementation of the curriculum is feasible due to the availability of robust human, technical, and infrastructural resources:

Human Resources

The programme relies on a team of experts in Earth Observation, GIS, sustainable urban development, and UDENE tools, supported by teaching staff with extensive experience in remote sensing, spatial analysis, and scenario modelling. In addition, dedicated technical support ensures smooth access to data, effective use of platforms, and timely troubleshooting of software-related issues.

Technical and Material Resources

Students have access to Copernicus datasets and Sentinel missions (S1–S6), as well as UDENE tools including the Exploration Tool, Matchmaking Tool, and the Data Cube environment. The curriculum also relies on both open-source and institutional software such as QGIS, SNAP, and various cloud-based EO platforms. Learning activities are supported by computer laboratories with sufficient processing capacity for raster analysis, along with reliable internet connectivity necessary for accessing cloud-hosted datasets and services.

Financial Resources

The curriculum leverages free and open Copernicus resources and provides educational access to UDENE tools, which together help minimize operational costs. Its implementation is further supported by existing institutional infrastructure and Erasmus-aligned funding mechanisms, ensuring that the programme can be delivered efficiently and sustainably.

Given these resources, the curriculum can be delivered reliably and sustainably within diverse academic institutions.

Feasibility Assessment

The curriculum demonstrates strong feasibility across multiple dimensions:

Pedagogical Feasibility

The modular structure supports progressive learning from theoretical foundations to advanced EO-based simulations. Case studies and individual assignments ensure deep application of knowledge in realistic scenarios. The alignment with EWF skill levels provides clear learning progression.

Technical Feasibility

While some tools used in the course, such as Copernicus datasets and open-source GIS software, are freely accessible, UDENE tools might operate under specific access conditions. However, it is anticipated that students will be provided with the opportunity to use UDENE platforms for educational purposes. If this is not the case, other geospatial open-source or proprietary solutions may be used as a substitute. This ensures that all required tools remain available for hands-on exercises, and the Copernicus services continue to provide stable and scalable data infrastructures suitable for student projects and practical coursework.

Organizational Feasibility

The workload distribution (3 ECTS, 75–90 hours) fits the structure of standard university courses. The balance of lectures, hands-on exercises, and applied case studies is aligned with Erasmus Quality Standards.

Financial Feasibility

Since core resources such as Copernicus EO data and open-source geospatial software are freely available, the financial requirements for implementing the curriculum remain relatively low. Although UDENE tools might not be entirely free, educational or project-based access can possibly be provided to students at no additional cost, which reduces institutional expenses. With these arrangements, the curriculum remains financially viable and cost-efficient for academic institutions. Overall, the programme is highly implementable, offering substantial educational value with manageable financial commitments.

Risk Analysis

The curriculum presents several potential risks that may affect its implementation. Students with limited prior experience in GIS or Earth Observation may find advanced analytical workflows challenging, which can be mitigated through introductory tutorials, step-by-step guidance, and structured self-assessment materials. Another risk relates to variability in institutional digital infrastructure, as some institutions may lack high-performance computers or stable internet connectivity; this can be addressed by relying on cloud-based platforms such as DIAS or the UDENE Data Cube and by tailoring exercises to run efficiently on moderate-capacity systems. Additionally, the large volume and complexity of EO datasets may overwhelm beginners, making it essential to provide pre-processed subsets, annual composites, or lower-resolution products during initial learning stages. Overreliance on external services and online data availability also poses a risk, as temporary outages could disrupt planned activities; offering backup datasets and offline resources ensures continuity of learning. Furthermore, scenario modelling and simulation tasks may require more time than the standard workload allows, so structured exercises and optional extended project time are recommended to support deeper exploration and skill development. Finally, one of the major risks is the heavy dependence on UDENE Tools. If access is restricted or the platform evolves, course continuity may be affected. In this case it is necessary to use alternative platforms (e.g. Google Earth Engine, Copernicus Browser, QGIS/SNAP) and prepare backup workflows, and maintain downloadable datasets for offline work.

Course Sustainability

Long-Term Relevance and Future Needs

The curriculum addresses long-term trends in Earth Observation, digital transformation, and sustainable urban development. Its relevance is expected to grow as cities increasingly rely on EO-based tools for climate action, environmental monitoring, and evidence-based planning. The skills developed in the course remain essential as international policies (EU Green Deal, Digital Europe, Mission "Climate-Neutral and Smart Cities") prioritize geospatial competencies for the coming decades.

Organisational Sustainability

The programme can be delivered sustainably over multiple years due to stable institutional structures, the availability of qualified teaching staff, and the possibility of continuous professional development. The modular design allows easy integration into existing curricula and supports long-term adaptability. Since the course relies on open-source and cloud-based tools, institutions can maintain the programme without significant future investments.

Financial Sustainability

Long-term costs remain relatively low because the curriculum is built around free and open EO datasets (such as Copernicus) and widely available open-source software like QGIS. Although UDENE tools might not be fully free or available, they might provide options for educational or project-based access, or substituted by a set of related geospatial tools, allowing institutions to integrate them into teaching without incurring substantial recurring expenses. This reduces the overall operational burden and supports sustainable programme delivery. Future updates or expansions of the curriculum can be financed through institutional budgets, Erasmus+ cooperation frameworks, or research grants, ensuring that the programme remains financially viable over time.

Technological Sustainability

The course relies on widely adopted EO technologies and standards that are expected to remain stable and supported long-term. The use of open standards and cloud-based geospatial environments ensures that the curriculum can adapt to technological changes without requiring major redevelopment. If certain tools evolve or are replaced, the modular structure allows for smooth substitution with updated platforms.

Pedagogical Sustainability

The learning units are designed to be updated regularly in response to new datasets, tools, or policy frameworks. The curriculum promotes competencies, data literacy, spatial reasoning, environmental modelling, that remain foundational regardless of technological change. The inclusion of case-based learning ensures lasting pedagogical relevance and flexibility.

Environmental and Social Sustainability

The curriculum directly supports sustainability principles by promoting responsible use of EO data, awareness of environmental impacts, and skills relevant for climate-resilient urban planning. It encourages inclusive access to learning by using free tools and cloud-based platforms that reduce barriers for institutions with limited resources. The programme contributes to creating a workforce capable of addressing environmental and societal challenges.

Sustainability Risks

Several long-term risks may affect the sustainability of the curriculum. The rapid evolution of EO technologies may require frequent updates to learning materials, while dependence on external platforms such as cloud services introduces uncertainty if access policies change over time. Sustainability may also be challenged by insufficient long-term staff training, particularly if institutions do not invest in continuous professional development. In addition, variability in institutional digital infrastructure can impact the consistent and equitable delivery of the curriculum across different learning environments.

Recommendations for Long-Term Sustainability

To support long-term sustainability, the curriculum should undergo periodic updates that reflect advancements in Earth Observation and urban sustainability. Strengthening partnerships with EO organisations, universities, and industry will help secure ongoing expertise and ensure relevance. Continuous training for teaching staff—facilitated through Erasmus+ mobility and professional development—will maintain institutional capacity, while an agile curriculum structure will enable the rapid integration of new datasets, platforms, and case studies as they emerge.

Module: 1. Theoretical Foundations

Topic: Introduction to Earth Observation (EO) principles and the European Copernicus programme as foundational pillars for the UDENE (Urban Data-Enhanced Environmental Network for Europe) framework. Emphasis on understanding EO data, products, and services relevant to sustainable urban development and environmental monitoring.

A. Objectives

- Introduce the theoretical foundations of Earth Observation and remote sensing.
- Familiarize students with EO data types, processing levels, and core Copernicus services.
- Explain the structure and purpose of the UDENE framework in integrating EO data for decision-making.
- Build understanding of how EO products support environmental analysis, urban sustainability, and data-driven governance

B. Learning Outcomes

When completing this module, the learner is expected to be able to:

1. Describe fundamental EO concepts (radiation, sensors, resolution).
2. Identify and classify EO data types (optical, radar, thermal).
3. Distinguish between Copernicus Core Services and their applications.
4. Explain how the UDENE framework integrates EO data into urban environmental management.
5. Interpret basic EO products (e.g. NDVI, LST, urban extent) in the context of urban monitoring.
6. Evaluate the role of EO and Copernicus services in supporting SDGs and climate resilience policies.

C. Learning Units / Concepts

UNIT 1 - Fundamentals of Earth Observation	
Content	Electromagnetic spectrum (gamma rays and X-rays, ultraviolet, visible, near-infrared (NIR), shortwave infrared (SWIR), thermal infrared (TIR), microwave), remote sensing principles (interaction of electromagnetic energy with the atmosphere and terrestrial targets, the processes of energy emission, reflection, absorption, and detection), active vs. passive sensors, resolutions (spatial, spectral, radiometric, temporal), satellite orbits (geostationary, sun-synchronous, polar trajectories)
Exercises	Identify different regions of the electromagnetic spectrum and their relevance to Earth Observation; distinguish between active and passive sensors based on their energy sources, explore how spatial, spectral, temporal, and radiometric resolutions affect image interpretation and data quality; match sensors to spectral

	ranges; interpret example satellite images; analyse the impact of various orbital types such as geostationary and polar orbit on data acquisition
Self-assessment	Multiple-choice questions, short-answer tasks, labelling tasks, image interpretation exercises, simple calculations
Solutions/Answers for self-assessment	Solutions and answer keys in a structured format

UNIT 2 - EO Data and Products	
Content	Raw imagery, preprocessing (georeferencing, atmospheric correction), derived indices (NDVI, NDWI, NDBI, EVI, LST…), classification levels
Exercises	Understanding data types, sensors, metadata, and file formats Preparing EO data for analysis (georeferencing) Derived indices, vegetation, water, thermal, build indicators derived from EO data (NDVI, NDWI, NDBI, EVI, LST…) Thematic mapping, levels of generalization, land cover vs. land use
Self-assessment	Practical data analysis tasks, short calculations, and interpretation questions based on satellite imagery and derived indices. Learners may also complete multiple-choice or matching exercises to review preprocessing steps and classification concepts.
Solutions/Answers for self-assessment	Answer keys, data visualization and interpretation, worked examples, calculation results, reference classifications

UNIT 3 – Applications of EO products and Case Studies	
Content	Introduction to EO-based urban planning and sustainable development, evidence-based decision making, natural experiments, green infrastructure mapping, air quality monitoring, climate adaptation strategies, risks and hazards, smart and resilient cities
Exercises	Applying EO concepts to urban planning and sustainable development challenges. Analysing the role of EO data for evidence-based decision making. Introducing examples of natural experiments. Understanding the role of spatial information to identify and assess urban challenges such as green infrastructure improvements, air quality patterns, and climate adaptation strategies. Engaging in scenario-based reflections focused on risk and hazard management and the development of smart and resilient cities. Analysing the role of EO-derived indicators to evaluate urban sustainability and resilience.
Self-assessment	Case-based questions, short written reflections, and map interpretation tasks where learners analyze EO data applications in urban planning and sustainability contexts. Multiple-choice or matching questions may also be used to review key concepts such as resilience, adaptation, and evidence-based decision making.
Solutions/Answers for self-assessment	Answer keys, solutions and answers, provided as model responses, annotated maps, and key concept summaries

UNIT 4 - Copernicus Programme Overview	
Content	Sentinel satellite families (S1–S6), Copernicus Core Services (Land, Marine, Atmosphere, Climate Change, Emergency, Security)
Exercises	Fundamentals of the Sentinel satellite families, understand each mission's purpose, sensing capabilities, and key data products. Explore the Copernicus Core Services—Land, Marine, Atmosphere, Climate Change, Emergency, and Security—to see how Sentinel data supports real-world environmental monitoring, risk management, and decision-making across diverse applications.
Self-assessment	Check understanding of Sentinel missions and Copernicus Core Services by recalling key satellite functions, identifying appropriate data sources, and recognizing which service supports specific environmental or management tasks.
Solutions/Answers for self-assessment	Answer keys, data visualization and interpretation

UNIT 5 - Introduction to UDENE Framework	
Content	Overview of the UDENE initiative, objectives, natural experiments, Data Cube, Matchmaking Tool, Exploration Tool, data integration pipeline, interoperability, use cases (urban heat island and linked parks, mapping air quality, earthquake preparedness)
Exercises	Introduce learners to the UDENE initiative by exploring its objectives, the concept of natural experiments, and the roles of the Data Cube, Matchmaking Tool, and Exploration Tool.
Self-assessment	Verify general understanding of UDENE's purpose, tools, and workflows.
Solutions/Answers for self-assessment	Answer keys

C1. Learning Units / Detailed Overview

UNIT 1 - Fundamentals of Earth Observation

The goal of Unit 1 is to develop a comprehensive understanding of the fundamental concepts that underpin Earth Observation (EO) and its scientific basis. This unit introduces learners to the electromagnetic spectrum, exploring the full range of wavelengths from gamma rays and X-rays through ultraviolet, visible, near-infrared (NIR), shortwave infrared (SWIR), thermal infrared (TIR), and microwave regions, emphasizing their relevance in detecting and analysing features on Earth's surface. It further explains the principles of remote sensing, including the interaction of electromagnetic energy with the atmosphere and terrestrial targets, and the processes of energy emission, reflection, absorption, and detection. The distinction between active and passive sensors is examined to illustrate how different EO instruments acquire data, either by emitting their own energy or by relying on external sources such as sunlight. The unit also explores the concept of resolutions—spatial, spectral, radiometric, and temporal—demonstrating how they determine the level of detail, sensitivity, and frequency of EO data acquisition. Finally, learners will gain insight into satellite orbits, including geostationary, sun-synchronous, and polar trajectories, to understand how orbital characteristics influence coverage, temporal repeatability, and observation geometry. Through this integrated approach, the unit establishes the scientific and technical foundation necessary for interpreting and applying remote sensing data in environmental monitoring and Earth system analysis.

The exercises in this unit are designed to strengthen understanding of the electromagnetic spectrum, remote sensing principles, sensor types, resolutions, and satellite orbits through a combination of conceptual and applied tasks. Learners will identify different regions of the electromagnetic spectrum and their relevance to Earth Observation, distinguish between active and passive sensors based on their energy sources, and explore how spatial, spectral, temporal, and radiometric resolutions affect image interpretation and data quality. Practical activities include matching sensors to spectral ranges, interpreting example satellite images, and analysing the impact of various orbital types, such as geostationary and polar orbits, on data acquisition. Through these exercises, students gain a solid foundation in the physical and technical principles that underpin remote sensing and satellite observation.

Self-assessment can include multiple-choice questions, short-answer tasks, image interpretation exercises, and simple calculations to test conceptual understanding and practical application. Learners can complete these independently after each lesson to evaluate their grasp of key concepts. Solutions and answer keys are provided in a structured format, either as a separate answer sheet or as model answers at the end of the worksheet, allowing students to compare their responses, identify gaps, and reinforce learning through self-correction.

UNIT 2 - EO DATA AND PRODUCTS

The goal of Unit 2 is to provide a thorough understanding of the fundamental concepts that define EO data and products, focusing on the processes that transform raw satellite imagery into meaningful information for analysis and decision-making. The unit begins with an introduction to raw imagery, explaining how data captured by satellite sensors represent the Earth's surface in different spectral bands and how this imagery serves as the foundation for all subsequent analysis. Learners will then explore essential preprocessing techniques, including georeferencing, which aligns imagery to real-world geographic coordinates, and atmospheric correction, which removes distortions caused by the atmosphere to retrieve accurate surface reflectance values. Building upon this foundation, the unit introduces derived indices such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Normalized Difference Built-up Index (NDBI) and Land Surface Temperature (LST), demonstrating how spectral combinations can be used to monitor vegetation health, water content, built-up areas and thermal characteristics of the land surface. Finally, students will examine classification levels, understanding how EO data are grouped into hierarchical land cover and land use categories that vary in thematic detail depending on application needs. Through these topics, Unit 2 equips learners with both theoretical knowledge and practical insight into how EO data are processed, refined, and interpreted to support environmental monitoring, urban planning, agriculture, and other geospatial applications.

The exercises in this unit focus on developing practical skills in working with EO data and products, guiding learners through each stage from raw imagery to classified outputs. Activities include identifying key characteristics of raw satellite images, applying preprocessing techniques such as georeferencing and atmospheric correction, and calculating derived indices like NDVI, NDWI, NDBI, EVI, and LST to assess vegetation, water, urban areas, and temperature patterns. Learners will also explore different classification levels, distinguishing between land cover and land use categories and designing simple classification schemes for specific applications. These exercises combine conceptual understanding with hands-on data interpretation, preparing students to transform EO data into meaningful, analysis-ready information.

Self-assessment for this unit can include practical data analysis tasks, short calculations, and interpretation questions based on satellite imagery and derived indices. Learners may also complete multiple-choice or matching exercises to review preprocessing steps and classification concepts. Solutions and answers are provided as worked examples, calculation results, and reference classifications at the end of the worksheet, enabling learners to verify their results and reflect on potential errors or alternative interpretations.

UNIT 3 – APPLICATIONS OF EO PRODUCTS AND CASE STUDIES

The goal of Unit 3 is to develop a general understanding of how Earth Observation EO supports urban planning and sustainable development by providing spatially explicit, objective, and timely data for evidence-based decision-making. This unit emphasizes the integration of EO technologies in addressing complex urban and environmental challenges through data-driven insights and monitoring frameworks. Learners will explore how EO data enable natural experiments, allowing researchers and planners to observe real-world changes over time and assess the impact of policies or interventions on urban systems. A particular focus will be placed on green infrastructure mapping, which involves identifying and assessing vegetation, parks, and ecological corridors that enhance urban resilience, as well as air quality monitoring, where satellite-derived observations of pollutants contribute to understanding spatial patterns of air pollution and their health implications. The unit also examines the role of EO in climate adaptation strategies, helping cities anticipate and mitigate the effects of heat islands, flooding, and other climate-related risks. Additionally, learners will study EO applications in hazard management, including flood mapping, earthquake impact assessment, and post-disaster recovery monitoring. The overarching theme of Unit 3 is to link EO-based analyses with the broader vision of smart and resilient cities, where remote sensing, geospatial intelligence, and sustainability planning converge to create data-informed policies that foster environmental quality, social well-being, and adaptive urban growth.

The exercises in this unit are designed to help learners apply EO concepts to urban planning and sustainable development challenges. Activities include interpreting EO data for evidence-based decision making, analysing examples of natural experiments, and using spatial information to identify and assess urban challenges related to urban heat, green infrastructure, air quality, etc. Learners will also engage in scenario-based reflections focused on risk and hazard management and the development of smart and resilient cities, integrating EO-derived indicators to evaluate urban sustainability and resilience. These exercises combine theoretical understanding with applied geospatial analysis, encouraging critical thinking and data-informed problem solving.

Self-assessment for this unit can include case-based questions, short written reflections, and map interpretation tasks where learners analyse EO data applications in urban planning and sustainability contexts. Multiple-choice or matching questions may also be used to review key concepts such as resilience, adaptation, and evidence-based decision making. Solutions and answers are provided as model responses, annotated maps, and key concept summaries at the end of the worksheet to guide self-evaluation and reinforce understanding.

UNIT 4 - COPERNICUS PROGRAMME OVERVIEW

The goal of Unit 4 is to develop a general understanding of the Sentinel satellite families and the Copernicus Core Services, which together form the backbone of Europe's Earth Observation capacity. This unit introduces the Sentinel missions, each designed to deliver specific types of environmental data: Sentinel-1 for all-weather radar imaging, Sentinel-2 for high-resolution multispectral optical imagery, Sentinel-3 for ocean and land surface monitoring, Sentinel-4 and Sentinel-5 for atmospheric composition, and Sentinel-6 for precise sea-level measurements. Learners will explore how these complementary satellites operate within the Copernicus Programme, providing free and open data to support environmental management, climate monitoring, and disaster response. The unit also delves into the Copernicus Core Services, which translate raw Sentinel data into actionable information for users across multiple domains. The Land Service focuses on land cover, vegetation, and urban dynamics; the Marine Service monitors sea surface conditions and marine ecosystems; the Atmosphere Service tracks air quality, greenhouse gases, and ozone levels; and the Climate Change Service provides long-term data records for understanding and mitigating climate impacts. In addition, the Emergency Management Service supports rapid mapping and situational awareness during natural disasters, while the Security Service contributes to border surveillance, maritime safety, and crisis prevention. Through these topics, Unit 4 emphasizes how the synergy between the Sentinel satellites and Copernicus services enables continuous, reliable, and scientifically robust monitoring of the Earth system, supporting research, innovation, and informed decision-making at global, regional, and local levels.

The exercises in this unit guide students through the fundamentals of the Sentinel satellite families (S1–S6), helping them understand each mission's purpose, sensing capabilities, and key data products. Learners will also explore the Copernicus Core Services—Land, Marine, Atmosphere, Climate Change, Emergency, and Security—to see how Sentinel data supports real-world environmental monitoring, risk management, and decision-making across diverse applications.

Self-assessment for this unit includes questions that allow learners to check their understanding of Sentinel missions and Copernicus Core Services by recalling key satellite functions, identifying appropriate data sources, and recognizing which service supports specific environmental or management tasks. The answers provide brief explanations linking each Sentinel mission to its primary sensing technology and application and match each Copernicus Core Service with the types of datasets and real-world uses it supports, helping learners verify and reinforce essential concepts.

UNIT 5 – INTRODUCTION TO UDENE FRAMEWORK

The goal of Unit 5 is to provide a general understanding of the UDENE Tools and their purpose within the broader UDENE initiative, which aims to enhance the use of Earth Observation for data-driven urban planning, environmental monitoring, and sustainable development through innovative analytical frameworks. The unit begins with an overview of the UDENE initiative and its core objectives—promoting evidence-based decision-making by integrating EO data with socio-environmental information to support natural experiments, or real-world analyses of urban and environmental changes over time. Learners will explore the key components of the UDENE platform, starting with the Data Cube, a powerful system that organizes and manages multi-dimensional EO data for efficient storage, retrieval, and temporal-spatial analysis. The Exploration Tool will be introduced as a virtual environment where users can integrate EO and in-situ data to simulate, visualize, and analyse urban scenarios under varying environmental, social, and hazard conditions. It enables planners to assess the potential impacts of proposed interventions, guided by insights from comparable real-world examples. Complementing this, the Matchmaking Tool connects users with relevant EO products, processing services, and technical expertise tailored to their specific urban planning challenges. The unit also examines the data integration pipeline, which ensures that diverse EO and non-EO datasets can be processed, harmonized, and made interoperable allowing for seamless use across different analytical environments. Finally, practical use cases such as analysing urban heat islands and linked parks, mapping air quality, and enhancing earthquake preparedness will demonstrate how UDENE tools support applied research and real-world problem solving. By the end of this unit, learners will understand how UDENE Tools bridge scientific data and practical decision-making, fostering collaboration among researchers, planners, and policymakers to create smarter, more resilient, and sustainable urban environments.

The exercises in this unit introduce learners to the UDENE initiative by exploring its objectives, the concept of natural experiments, and the roles of the Data Cube, Matchmaking Tool, and Exploration Tool. Students will practice understanding the data integration pipeline, interoperability principles, and examine real use cases such as urban heat islands and linked parks, air-quality mapping, and earthquake preparedness to see how UDENE tools support evidence-based urban planning.

Self-assessment for this unit includes questions that help learners verify their understanding of UDENE's purpose, tools, and workflows by reflecting on how the Data Cube, Matchmaking Tool, and Exploration Tool support natural experiments, data integration, and interoperability across different urban scenarios. The answers briefly clarify the roles of each UDENE component and explain how they contribute to analysing real use cases, such as urban heat mitigation, air-quality mapping, infrastructure changes and earthquake preparedness, allowing learners to confirm and strengthen their grasp of key concepts.

D. Glossary

- **Earth Observation (EO):** The collection of information about Earth's physical, chemical, and biological systems using satellite or airborne sensors.
- **Remote Sensing:** A method of acquiring information about objects or areas from a distance, typically through satellites or aircraft, without physical contact.

- **Electromagnetic Spectrum:** The full range of wavelengths (from gamma rays to microwaves) used in EO to detect and analyse features on the Earth's surface.
- **Active Sensor:** A sensor that emits its own energy (e.g., radar) and measures the return signal from the Earth.
- **Passive Sensor:** A sensor that measures natural energy reflected or emitted from the Earth, usually sunlight.
- **Spatial Resolution:** The size of the smallest observable feature in an image, typically expressed as pixel size.
- **Temporal Resolution:** The frequency with which a satellite revisits and acquires data over the same location.
- **Spectral Resolution:** The number and width of spectral bands a sensor can capture.
- **Radiometric Resolution:** The sensitivity of a sensor to detect small differences in energy (brightness levels).
- **Copernicus Programme:** The European Union's Earth Observation programme providing free and open data from Sentinel satellites and thematic services for environmental monitoring, security, and climate services.
- **Sentinel Satellites (S1–S6):** A series of satellites within the Copernicus programme designed for radar imaging, multispectral optical imaging, land/ocean monitoring, atmospheric composition, and sea-level measurements.
- **Copernicus Core Services:** Operational services providing processed EO data for thematic domains: Land, Marine, Atmosphere, Climate Change, Emergency, and Security.
- **UDENE Framework:** Urban Data-Enhanced Environmental Network for Europe — a platform integrating EO, in-situ, and socioeconomic data to support evidence-based urban development.
- **EO Data Cube (UDENE):** A multidimensional data structure that stores spatial and temporal EO data for efficient access, analysis, and time-series modelling.
- **Matchmaking Tool (UDENE):** A tool connecting datasets, EO products, and analytical workflows with user needs and planning challenges.
- **Exploration Tool (UDENE):** An interactive platform for visualizing, analysing, and simulating urban scenarios using EO and in-situ data.
- **Natural Experiment:** An observational study using real-world changes (e.g., new infrastructure) to analyse cause–effect relationships without controlled experiments.
- **NDVI (Normalized Difference Vegetation Index):** A vegetation health indicator derived from red and near-infrared spectral bands.
- **NDWI (Normalized Difference Water Index):** An index used to detect water bodies or assess surface moisture.
- **NDBI (Normalized Difference Built-up Index):** An index used to identify built-up or urbanized areas.
- **LST (Land Surface Temperature):** A thermal parameter derived from EO imagery used to evaluate Urban Heat Islands (UHIs).
- **Urban Heat Island (UHI):** A phenomenon where urban areas exhibit higher surface or air temperatures than surrounding rural areas due to human activities and built-up surfaces.
- **Interoperability:** The ability of different datasets, systems, or tools to work together seamlessly through standard formats and interfaces.

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Module: 2. EO data management and applications in sustainable urban development

Topic: This module explores how Earth Observation (EO) data supports sustainable urban planning and management through spatial analysis and evidence-based decision-making. Students will learn to acquire, manage, and process EO datasets relevant to urban dynamics—including land use, Urban Heat Island (UHI) effects, green infrastructure, air quality, transportation systems, and natural hazards. The special focus of this module is placed on integrating Copernicus data and services with analytical workflows to inform policies and design solutions that enhance urban resilience, liveability, and sustainability.

A. Objectives

- To develop technical proficiency in accessing, managing, and pre-processing EO data for urban applications.
- To link EO-derived indicators with urban sustainability challenges such as heat mitigation, air quality improvement, and green space connectivity.
- To foster the ability to interpret EO-based analyses for decision-making in urban and regional planning.
- To encourage critical thinking about the role of EO in supporting sustainable, inclusive, and data-driven urban development.
- To understand the role of Copernicus Core Services in supporting integrated urban monitoring and management.

B. Learning Outcomes

Upon successful completion of this module, learners will be able to:

1. Identify and describe major EO data sources, including Copernicus Core Services and Sentinel missions.
2. Acquire and manage EO data relevant to urban areas, ensuring quality and usability for planning applications.
3. Preprocess and analyse EO data to extract geospatial indicators (land cover, surface temperature, vegetation, air quality).
4. Apply EO tools and techniques to assess UHI effects, green corridors, transportation dynamics, and environmental risks.
5. Integrate EO-derived insights into sustainable urban development strategies and spatial planning scenarios.
6. Communicate EO-based analytical results effectively through maps, dashboards, and policy-oriented storytelling.

C. Learning Units / Concepts

UNIT 1 - Introduction to EO in Urban Planning	
Content	Introduction to the Copernicus Programme and Sentinel missions: Sentinel-1 (SAR): land deformation, flood mapping, infrastructure monitoring, Sentinel-2 (Optical): vegetation, land cover, urban

	mapping, Sentinel-3 (Radiometer): temperature and color of land and oceans, Sentinel-4 (Geostationary Atmospheric): air quality and gas monitoring, Sentinel-5 and 5P (Atmospheric): air quality, pollution detection, Sentinel-6 (Altimetry): sea level, ocean and coastal monitoring; EO relevance to urban sustainability and SDG monitoring (SDG 11- Sustainable Cities and Communities, 13-Climate Action).
Exercises	Identify Sentinel missions and their applications in urban areas; Compare active (S1) and passive (S2, S3) sensors; Explore EO examples related to SDG 11 – Sustainable Cities.
Self-assessment	Match Sentinel mission and their main use; Multiple-choice questions on EO and Copernicus. Navigate Copernicus Browser to visualize Sentinel imagery for an urban area.
Solutions/Answers for self-assessment	Answer key for quizzes and matching; Quick reference table of Sentinel missions and their domains.

UNIT 2 - EO Data Access and Management	
Content	Accessing open EO data: Copernicus Open Access Hub, DIAS platforms; Overview of Sentinel data types and formats (SAFE, GeoTIFF, NetCDF); Data pre-processing: reprojection, mosaicking, atmospheric correction, cloud masking, temporal compositing; Quality control, metadata interpretation, and data organization; Using Sentinel-1 to 6 data for different analytical needs.
Exercises	Download Sentinel-2 scene from Copernicus Hub; Apply reprojection and cloud masking using SNAP/QGIS; Mosaic multi-temporal images and compare data quality; Interpret metadata of Sentinel-1 vs. Sentinel-2 data. Integrate multiple Sentinel datasets (S1 and S2) into a single analysis-ready layer.
Self-assessment	True/false and matching questions on data access and pre-processing; Selecting appropriate Sentinel dataset for a given task; Explain differences between Level-1 and Level-2 products.
Solutions/Answers for self-assessment	Key answers and brief justifications; Example metadata and pre-processing workflow; Table comparing Sentinel data levels and formats.

UNIT 3 - EO Analysis for Urban Heat and Air Quality	
Content	Application of Sentinel-1 to -6 data for urban heat and air quality analysis: S1-surface roughness, flooding, infrastructure monitoring, S2-urban land cover, vegetation indices (NDVI, NDBI), S3-Land Surface Temperature (LST), thermal anomalies, S4-monitoring air pollutants over Europe (NO_2, O_3), S5/5P-global air quality mapping, trace gases (CO, SO_2), S6-elevation and coastal water level support for climate analysis; Copernicus Core Services: Land, Atmosphere, Marine, Climate Change, Emergency, Security; EO-based urban heat and air quality indicators.

Exercises	Extract and map LST using Sentinel-3 data; Visualize NO_2 concentration maps from Sentinel-5P; Compare seasonal variations in LST and air quality in selected cities. Correlate EO-derived LST with in-situ air temperature data.
Self-assessment	Multiple-choice questions on Sentinel sensors and environmental indicators; Calculation of average LST from thermal raster; Linking EO air quality data with SDG 11 and 13.
Solutions/Answers for self-assessment	Computed examples and graphs; Interpretation keys for air quality maps; Example workflow for combining Sentinel-3 and Sentinel-5P data.

UNIT 4 – EO-based Green Infrastructure and Connectivity Mapping	
Content	EO for mapping urban green infrastructure and ecosystem connectivity; EO-based indicators for urban biodiversity and ecosystem services assessment, Sentinel-2 and Sentinel-3 data for vegetation and water indices (NDVI, NDWI); Integration with Copernicus Land and Climate Change Services; Landscape metrics for connectivity and fragmentation analysis; EO contributions to nature-based solutions and urban resilience.
Exercises	Compute NDVI and NDWI using Sentinel-2 data; Generate green infrastructure map from Copernicus Land Service layers; Analyse connectivity between urban green areas using GIS tools. Perform change detection of green infrastructure over time using Sentinel-2 composites.
Self-assessment	Matching EO index and environmental variable; Selecting Sentinel data for vegetation and water mapping.
Solutions/Answers for self-assessment	Example NDVI/NDWI maps and interpretation notes; Answer key and reference images.

UNIT 5 - EO Applications for Urban Mobility and Risk Management	
Content	Integration of EO-based environmental and infrastructure indicators for comprehensive urban risk and mobility assessment; Monitoring urban mobility, traffic corridors, and built-up areas using Sentinel-1 and Sentinel-2; Green infrastructure, air quality, and liveability indicators; Climate adaptation, flood risk mapping, and disaster management with Copernicus Emergency and Climate Change Services; Integration of Sentinel-1 and Sentinel-2 for hazard assessment; Role of Sentinel-3-6 in long-term climate and sea-level monitoring relevant for urban resilience.
Exercises	Identify flood-prone zones using Sentinel-1 backscatter data; Map transport networks and impervious surfaces from Sentinel-2 data; Develop a workflow for EO-based risk assessment in an urban area; Interpret EO indicators supporting mobility and resilience planning. Analyse Sentinel-3 and Sentinel-5P data to evaluate climate-related risks affecting transport infrastructure.
Self-assessment	Choose appropriate Sentinel data for a given risk scenario; Explore EO for smart and resilient cities; Multiple-choice questions on EO-based adaptation and mobility strategies.

Solutions/Answers for self-assesment	Example flood and infrastructure maps; Annotated risk management workflows; Answer keys for quizzes.

C1. Learning Units / Detailed Overview

UNIT 1 - INTRODUCTION TO EO IN URBAN PLANNING

The goal of this unit is to provide learners with a foundational understanding of Earth Observation (EO) principles and their relevance to urban planning and sustainable development. Special emphasis is placed on the Copernicus Programme and the family of Sentinel missions, highlighting their complementary roles in observing and analysing urban environments.

Through this unit, students will explore how active sensors (e.g., Sentinel-1 Synthetic Aperture Radar) and passive sensors (e.g., Sentinel-2 optical and Sentinel-3 radiometric instruments) provide essential data for understanding urban dynamics such as land cover change, infrastructure monitoring, flood risk, air quality, and climate impacts.

By linking EO technologies to the United Nations Sustainable Development Goals (SDGs)—particularly SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action)—students will gain insight into how satellite data support evidence-based decision-making in urban management, environmental monitoring, and resilience planning.

The unit aims to build a conceptual and practical foundation for subsequent modules that apply EO data and analytics to real-world urban challenges.

Table 2. Comparison of Copernicus Services

Service	Focus	Key Datasets / Products	Main Applications	Access Portal
CAMS – Atmosphere Monitoring Service	Atmosphere, air quality, emissions	Global forecasts of pollutants & greenhouse gases, European regional air quality, fire emissions (GFAS), UV radiation, solar radiation	Air quality management, renewable energy, health impact studies, climate policy	ADS
C3S – Climate Change Service	Climate variability & change	ERA5 reanalysis, seasonal forecasts, climate projections (CMIP/IPCC), Essential Climate Variables (ECVs)	Climate studies, adaptation strategies, agriculture, energy, water management	CDS
CMEMS – Marine Environment	Oceans & seas	Sea surface temp., salinity, currents, sea level, waves, ice	Maritime safety, fisheries, marine energy, coastal	Marine Data Store

Monitoring Service		cover, chlorophyll, oxygen, nutrients	monitoring, climate research	
CLMS – Land Monitoring Service	Land cover/use, vegetation, soil, ground motion	CORINE Land Cover (CLC), High-Resolution Layers (HRL), European Ground Motion Service (EGMS), vegetation indices, global land cover maps	Urban planning, agriculture, forestry, biodiversity, natural hazards	CLMS Portal
CEMS – Emergency Management Service	Disasters, hazards, early warning	Rapid Mapping (earthquakes, floods, wildfires), Risk & Recovery maps, EFAS (floods), EFFIS (forest fires), GloFAS (global floods)	Civil protection, humanitarian aid, crisis response, risk management	CEMS Portal
Security Service	Border/maritime security, external action	Border & maritime surveillance data, crisis monitoring	Border control, maritime safety, security operations	Restricted (authorized users only)

UNIT 2 - EO DATA ACQUISITION AND MANAGEMENT

The goal of this unit is to equip learners with the skills and knowledge needed to acquire, manage, and preprocess EO data for urban analysis. The unit introduces open-access EO data platforms such as the Copernicus Open Access Hub and DIAS, focusing on data discovery, download, and organization.

Students will gain practical experience in EO data preprocessing workflows, including reprojection, mosaicking, atmospheric correction, cloud masking, and temporal compositing, to prepare datasets for analytical tasks. Emphasis is placed on ensuring data quality and consistency for multi-temporal and multi-sensor analysis in urban contexts.

This unit builds a bridge between theoretical EO understanding and technical competence in managing large-scale satellite datasets for urban applications.

UNIT 3 - EO ANALYSIS FOR URBAN HEAT AND AIR QUALITY

The goal of this unit is to develop learners' ability to apply EO data and tools to analyse environmental conditions affecting urban areas, particularly urban heat and air quality. The unit focuses on data products derived from Sentinel-3 (thermal and radiometric) and Sentinel-5P (atmospheric composition) missions, as well as complementary information from Sentinel-1 and Sentinel-2.

Students will learn to extract and interpret indicators such as Land Surface Temperature (LST), air pollutants (NO_2, SO_2, CO), and particulate matter concentrations using Copernicus data services. The unit also introduces methods for correlating EO-derived environmental data with urban land cover, built-up density, and vegetation distribution.

By the end of this unit, learners will understand how EO contributes to urban environmental monitoring, heat island mitigation strategies, and air quality management within sustainable city planning frameworks.

UNIT 4 – EO-based Green Infrastructure and Connectivity Mapping

The goal of this unit is to teach students how to use EO data to map and evaluate green infrastructure and ecological connectivity in urban and peri-urban environments. The unit emphasizes the role of Sentinel-2 optical imagery and Copernicus Land Monitoring Services in identifying vegetation, open spaces, and landscape corridors that contribute to ecosystem services and climate resilience.

Students will apply spectral indices (e.g., NDVI, NDWI) and classification techniques to distinguish vegetation types, assess green space quality, and analyse connectivity between ecological patches. The unit also explores how EO supports urban greening strategies, biodiversity protection, and the integration of natural assets into spatial planning.

By the end of this unit, learners will be able to produce and interpret EO-based maps that inform sustainable land use and urban design decisions.

UNIT 5 - EO Applications for Urban Mobility and Risk Management

The goal of this unit is to integrate EO data into applied analyses of urban mobility, infrastructure, and risk management. Learners will explore how Sentinel-1 radar and Sentinel-2 optical data can be used to map transport networks, impervious surfaces, and land cover dynamics relevant to mobility planning and hazard assessment.

The unit introduces methods for flood detection, deformation monitoring, and urban expansion mapping, demonstrating how EO supports resilience planning, infrastructure maintenance, and disaster risk reduction. Students will also analyse EO data in relation to transportation corridors and urban sprawl to identify vulnerabilities and opportunities for sustainable mobility solutions.

By the end of this unit, learners will have a comprehensive understanding of how EO contributes to urban risk assessment, smart mobility, and climate adaptation strategies, supporting data-driven urban management.

D. Glossary

- **EO (Earth Observation):** The collection of information about Earth's physical, chemical, and biological systems via remote sensing technologies.
- **Copernicus Programme:** The European Union's Earth observation initiative providing free and open EO data for environmental monitoring.

- **Copernicus Core Services**: Thematic services providing processed EO data on land, atmosphere, marine, climate, emergency, and security domains.
- **Sentinel Missions:** A series of satellites (Sentinel-1 to -6) providing radar, optical, and atmospheric data for Copernicus.
- **UHI (Urban Heat Island):** A phenomenon where urban areas experience higher temperatures than surrounding rural areas due to human activities and surface materials.
- **NDVI (Normalized Difference Vegetation Index):** A spectral index indicating vegetation health and density.
- **DIAS (Data and Information Access Services):** Platforms providing cloud-based access to Copernicus data and processing tools.
- **Geospatial Modelling:** The use of spatial data and analytical models to simulate and interpret geographic phenomena.
- **Green Corridors:** Linear green spaces that connect parks and natural areas, promoting ecological connectivity and urban cooling.
- **Raster/Vector Data:** Two primary types of spatial data—continuous surfaces (raster) and discrete features (vector).
- **Spatial Resolution:** The smallest object detectable in an EO image, often measured in meters per pixel.
- **Atmospheric Correction**: The process of removing atmospheric effects from satellite imagery to obtain true surface reflectance.

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Module: 3. UDENE Tools in Practice

Topic: This module introduces learners to the UDENE platform, and its suite of tools designed for interactive visualization, spatial simulation, and urban scenario-building. Participants will explore how Earth Observation (EO) data and geospatial models can be integrated with UDENE to test hypotheses, conduct "natural experiments," and evaluate planning strategies under different environmental and socio-economic conditions. The focus is on developing data-driven decision-support skills using real-world urban datasets and EO-based indicators to assess sustainability, resilience, and policy outcomes.

A. Objectives

- To familiarize learners with the UDENE environment and its core analytical and visualization functionalities.
- To develop the ability to construct and interpret spatial simulations of urban change using EO and geospatial data.
- To train learners to build and compare urban development scenarios through interactive mapping, dashboards, and analytical workflows.
- To promote understanding of "natural experiments" as a method to evaluate policy and planning interventions using observational EO data.
- To strengthen the link between scientific modelling, stakeholder engagement, and sustainable urban decision-making.

B. Learning Outcomes

Upon completing this module, learners will be able to:

1. Navigate and use UDENE tools for EO data visualization, overlay analysis, and indicator display.
2. Design and run spatial simulations related to urban dynamics (e.g., land-use change, green infrastructure evolution, environmental improvements, hazard exposure).
3. Build and evaluate multiple "what-if" scenarios for sustainable urban planning.
4. Integrate EO data with socio-economic and environmental datasets for evidence-based analysis.
5. Apply natural experiment logic to assess the effects of real-world policies or events (e.g., new infrastructure, zoning changes, hazard mitigation).
6. Communicate analytical results through interactive maps, reports, and visual dashboards suitable for stakeholder engagement.

C. Learning Units / Concepts

UNIT 1 - Natural Experiments and EO-Based Evidence	
Content	This unit introduces the concept of a natural experiment and explains how EO products can be used to generate evidence for informed, data-driven decision making. Learners explore how real-world environmental changes, observed through satellite data,

	support analysis, evaluation of interventions, and development of effective policies.
Exercises	Explore how real-world variations in environmental or urban conditions can serve as natural experiments to test hypotheses about urban planning impacts. By analysing EO-derived datasets, participants will practice deriving quantitative evidence to support decisions in sustainable urban planning, resource management, and environmental policy.
Self-assessment	Reflect on understanding of the concept of natural experiment and the application of EO data in evidence-based decision making. Evaluate how effectively learners can identify suitable EO datasets, interpret spatial patterns, and derive conclusions that inform real-world planning or policy scenarios.
Solutions/Answers for self-assessment	Guidance and sample outputs for each exercise, illustrating correct analytical approaches, expected data interpretations, and reasoning steps.

UNIT 2 - Introduction to UDENE Environment, its Tools and Architecture	
Content	Introduction to UDENE environment and its architecture, Data Cube concept, Exploration tool and Matchmaking tool. Introduction to components of the user interface: login page, landing page, the menu, datasets (in situ dataset tab, global datasets tab), experiments (automatic, manual), and use cases.
Exercises	Introduce the UDENE Tools and Architecture, focusing on how the platform integrates various components for urban data exploration and analysis. Participants will practice using the login interface, landing page, and menu navigation to access different functionalities within the system. Explore the Data Cube concept for managing spatiotemporal EO data and work with both in situ and global datasets, run experiments and identify matched services through Exploration tool and Matchmaking tool.
Self-assessment	Evaluate ability to navigate and use the UDENE tools effectively. Understand the concept of Data Cube its architecture and available tools.
Solutions/Answers for self-assessment	Examples of correct procedures and interpretations for each activity, allowing learners to verify their results, identify areas for improvement, and deepen their understanding of UDENE’s integrated data and analysis environment.

UNIT 3 – Data Visualization and Interpretation	
Content	Explains the key datasets, required inputs, and expected outcomes used in geospatial analysis, and shows how these elements are organised, accessed, and managed within the Data Cube repository to support efficient, integrated EO-based workflows.
Exercises	Guide learners in exploring the Datasets (global, in-situ), Inputs, Outcomes, and Data Cube Repository within the UDENE framework. Participants will work hands-on with different dataset

	types, including EO imagery, in situ measurements, and socio-environmental data, to understand how they are integrated and analysed. Practice identifying data inputs, interpreting analytical outputs, and navigating the Data Cube repository to retrieve, visualize, and manage datasets relevant to urban analysis.
Self-assessment	Allows learners to evaluate how well they understand the relationships between datasets, inputs, and outcomes within the UDENE Data Cube framework. It encourages reflection on their ability to identify dataset types, interpret analytical results, and effectively use the Data Cube repository for visualization and data management.
Solutions/Answers for self-assessment	Examples of correct relationships between datasets, inputs, and outcomes.

UNIT 4 - Simulation and Urban Dynamics through Natural Experiments	
Content	Covers how to design, configure, and execute (run) experiments in the analysis environment, including both automatic workflows and manually controlled setups. Learners understand how to structure experiments, select parameters based on the developed understanding of their relationships, run analyses, and interpret results efficiently.
Exercises	Focus on applying the UDENE platform to design, execute, and evaluate simulations and experiments. Practice setting up and running both automatic and manual experiments. Explore how different parameters influence urban processes. By interpreting simulation outputs, gain insight into how EO-based evidence supports scenario analysis and decision-making.
Self-assessment	Reflect on ability to design, run, and interpret simulations of urban dynamics using the UDENE platform. Evaluate how effectively learners selected parameters, executed experiments, and analysed resulting patterns related to urban processes.
Solutions/Answers for self-assessment	Examples of well-structured simulations, expected outputs, and correct interpretations.

UNIT 5 – Use Case Driven Scenario-Building for Sustainable Development	
Content	Demonstration of the default use cases available in the platform, showing how EO data supports urban and environmental analysis on the examples of assessing how linked parks reduce heat load, evaluating high-rise districts for earthquake preparedness, and examining how a new ring road affects air quality.
Exercises	Engage in scenario-building for sustainable urban development using EO-based data and the UDENE tools. Test default urban development scenarios (use cases) offered by the framework, such as evaluating the cooling effects of linked park systems, assessing earthquake resilience in high-rise areas, or analysing the air quality impacts of new transport infrastructure.
Self-assessment	Allows learners to evaluate their ability to analyse urban development scenarios and encourages reflection on how

	effectively they can interpret simulation results and link outcomes to real-world planning decisions.
Solutions/Answers for self-assessment	Sample default scenarios, expected results, and guidance on correct analytical approaches.

C1. Learning Units / Detailed Overview

UNIT 1 - Natural Experiments and EO-Based Evidence

The learning goal of Unit 1 is to enable learners to understand how EO data can be used to conduct natural experiments for analysing and improving urban development processes. A natural experiment in scientific research is a study design where the researcher takes advantage of naturally occurring events or circumstances to examine causal relationships. Unlike controlled experiments, where the researcher actively manipulates variables, natural experiments rely on real-world conditions that create variations in exposure to a potential causal factor. These variations are typically beyond the direct control of the researcher and occur due to external factors such as policies, environmental changes, or historical events.

By the end of this unit, learners will be able to understand the concept of natural experiments and EO-based evidence to assess urban dynamics through simulations and scenario building, as well as data-driven, evidence-based decision-making for sustainable, resilient, and inclusive urban planning. The workflow may be complemented with other relevant processing and analysis tools and open data repositories, such as qGIS or ArcGIS, Google Earth Engine, statistical tools, Copernicus Services, etc.

Exercises in unit 1 will focus on applying natural experiments and evidence-based decision-making using EO products. Learners will explore how real-world variations in environmental or urban conditions can serve as natural experiments to test hypotheses about urban development, land use changes, or policy impacts. By analysing EO-derived datasets, such as satellite imagery, land cover maps, or climate indicators, participants will practice deriving evidence to support decisions in sustainable urban planning, resource management, and environmental policy.

The self-assessment encourages learners to reflect on their understanding of natural experiments and the application of EO data in evidence-based decision making. It helps them evaluate how effectively they can identify suitable EO datasets, interpret spatial patterns, and derive conclusions that inform real-world planning or policy scenarios. The Solutions/Answers section provides guidance and sample outputs for each exercise, illustrating correct analytical approaches, expected data interpretations, and reasoning steps. This enables learners to compare their work with reference solutions, identify gaps in understanding, and reinforce key concepts through feedback-based learning.

UNIT 2 - INTRODUCTION TO UDENE ENVIRONMENT, ITS TOOLS AND ARCHITECTURE

The learning goal of Unit 2 is to familiarize learners with the overall structure, components, and functionality of the UDENE platform. By the end of this unit, learners will understand the Data Cube concept for managing EO data, and be able to navigate the platform's login process, landing page, and menu structure to access different datasets, including in situ and global data sources, to access different use cases, run experiments and identify matched services through Exploration tool and Matchmaking tool. The focus is to get acquainted with the platform and its overall functionalities, while in-depth understanding of conducting experiments and relationships among available datasets, inputs and outcomes is the main goal of the following units.

The UDENE Data Cube is a comprehensive platform that integrates raster, vector, textual, and external data sources into a single environment for advanced geospatial analysis. It supports tasks such as image classification, object detection, spatial modelling, change detection, and predictive modelling making it valuable tool for urban planning, environmental monitoring, land-use assessment, and disaster management. The Exploration Tool builds on this foundation by providing a virtual laboratory where urban planners can test development scenarios using Earth Observation and local datasets. Through simulations, natural experiments, and causal analysis, it helps evaluate the impacts of interventions in areas such as transport, energy, and infrastructure. Its user-centred, iterative design and advanced visualizations offer clear, evidence-based insights into relationships between urban form and outcomes like air quality, congestion, or sustainability. The Matchmaking Tool complements these capabilities by linking planners with Earth Observation service providers that can help implement their development ideas. Using AI-driven NLP and similarity algorithms, it identifies relevant EO services from the eoMALL platform, supports collaboration between planners and EO experts, and strengthens decision-making through provider profiles.

Exercises in this unit introduce learners to the UDENE Tools and Architecture, focusing on how the platform integrates various components for urban data exploration and analysis. Participants will practice using the login interface, landing page, and menu navigation to access different functionalities within the system. They will explore the Data Cube concept for managing spatiotemporal EO data and work with both in situ and global datasets. Through the Exploration tool and Matchmaking tool, learners will run automatic and manual experiments related to real-world use cases such as linked parks, urban heat islands, air quality monitoring, gaining hands-on experience in data-driven urban analysis. UDENE tools may be compared to the traditional geospatial metadata catalogues and WebGIS solutions.

The self-assessment for these exercises enables learners to evaluate their ability to navigate and use the UDENE tools effectively, understand the Data Cube architecture, and apply different datasets and experiment types. It helps them reflect on how well they can perform tasks such as accessing datasets, running automatic or manual experiments, and interpreting outputs from the exploration and matchmaking tools. The Solutions/Answers section provides examples of correct procedures, expected outputs, and interpretations for each activity, allowing learners to verify their results, identify areas for improvement, and deepen their understanding of UDENE's integrated data and analysis environment.

UNIT 3 – DATA VISUALIZATION AND INTERPRETATION

The learning goal of Unit 3 is to enable learners to understand how different types of datasets are collected, organized, and utilized within the UDENE Data Cube framework. By the end of this unit, learners will be able to identify and distinguish between various input datasets (such as EO imagery, in situ data, and socio-environmental information), interpret derived outcomes from analytical processes, and navigate the Data Cube repository to access, visualize, and manage data. This unit aims to build a solid understanding of how integrated datasets support urban analysis, natural experiments, and evidence-based planning.

Exercises will guide learners in exploring the available Datasets (Table 3), Inputs (Table 5) and Outcomes (Table 4) in Data Cube Repository within the UDENE framework. Participants will work hands-on with different dataset types, including EO imagery, in situ measurements, and socio-environmental data, to understand how they are integrated and analysed. They will practice identifying data inputs, interpreting analytical outputs, and navigating the Data Cube repository to retrieve, visualize, and manage datasets relevant to urban analysis. Through these tasks, learners will strengthen their ability to link data sources with real-world applications in urban planning, natural experiments, and evidence-based decision making.

The self-assessment for these exercises allows learners to evaluate how well they understand the relationships between datasets, inputs, and outcomes within the UDENE Data Cube framework. It encourages reflection on their ability to identify dataset types, interpret analytical results, and effectively use the Data Cube repository for visualization and data management. The Solutions/Answers section provides examples of correct datasets, inputs, and expected outcomes. By comparing their work with these reference solutions, learners can assess their accuracy, reinforce key concepts, and improve their competence in applying integrated data for urban and environmental analysis.

Table 3. Available datasets

Abbreviation / Code	Dataset	Description & Potential Applications
Alos PALSAR Mosaic	Alos PALSAR Mosaic	Radar mosaic from the Japanese ALOS satellite (L-band SAR). L-band penetrates vegetation and is sensitive to forest structure, soil moisture, and surface roughness. Used for forest mapping, deforestation monitoring, land cover change detection, topography studies, and flood monitoring.
Biosens Sentinel 2AB	Biosens Sentinel 2AB	Multispectral optical imagery from Sentinel-2 A/B, covering visible to shortwave infrared bands. Useful for vegetation indices (NDVI, SAVI), built-up indices (NDBI), water indices (NDWI), soil indices (BSI), crop monitoring, urban expansion, and land cover mapping.
CCI Landcover	CCI Landcover	ESA Climate Change Initiative global land cover product. Supports long-term land cover monitoring, change detection, ecosystem assessments, carbon stock modeling, and climate studies.

CGLS Landcover	CGLS Landcover	Copernicus Global Land Service land cover maps. Applied for vegetation monitoring, urbanization studies, land classification, agriculture planning, and environmental modeling.
Crop Mask	Crop Mask (all regional variants)	Masks identifying cropland areas per region. Used for agricultural statistics, crop monitoring, irrigation planning, yield estimation, food security, and policy-making.
DEM SRTM	DEM SRTM	Digital Elevation Model from SRTM (~30 m). Useful for topography, hydrology, flood modeling, slope/aspect calculation, erosion modeling, and infrastructure planning.
DEM SRTM Deriv	DEM SRTM Derivatives	Derived products such as slope, aspect, hillshade, and contour lines. Applied in hydrology, geomorphology, landslide studies, erosion assessment, and road/infrastructure planning.
FC LS	FC LS / FC LS Summary Annual	Fractional cover from Landsat measuring green vegetation, non-photosynthetic vegetation, and bare soil. Useful for land degradation assessment, vegetation monitoring, desertification studies, and agriculture.
GM LS5 LS7 Annual	GM LS5 / LS7 Annual / Lowres	Gap-filled Landsat 5 and 7 annual composites. Applied in long-term vegetation monitoring, land cover changes, urbanization, and NDVI analysis. Lowres versions suitable for large-area studies.
GM LS8 Annual	GM LS8 Annual / Lowres	Gap-filled Landsat 8 annual composites. Useful for vegetation, urban growth, land monitoring. Lowres reduces data volume.
GM LS8 LS9 Annual	GM LS8 + LS9 Annual / Lowres	Combined Landsat 8 and 9 annual composites for recent years. Applied in vegetation monitoring, urbanization, and land cover analysis. Lowres speeds up processing.
GM S2 Annual	GM S2 Annual / Lowres / Rolling / Semiannual	Gap-filled Sentinel-2 composites, annual or semiannual. Cloud-free imagery suitable for NDVI, SAVI, NDBI, NDWI, BSI. Used for vegetation monitoring, urbanization, soil analysis, land cover classification, and temporal change detection.
GMW	GMW	Global Mangrove Watch. Provides mangrove extent and change maps. Useful for coastal vegetation monitoring, mangrove conservation, ecosystem assessment, and sea-level rise impact studies.
IO LULC	IO LULC / IO LULC v2	Land cover datasets for the Indian Ocean region. Used for environmental monitoring, urbanization studies, agriculture assessment, and climate research.
ISDA Soil Bedrock Depth	ISDA Soil Datasets (Bedrock Depth, Bulk Density, Carbon Total, Clay, Sand, Silt)	Soil properties datasets derived from field measurements and remote sensing. Applied in crop yield modeling, soil fertility assessment, hydrological modeling, carbon stock estimation, land degradation, and climate impact studies.
JERS SAR Mosaic	JERS SAR Mosaic	Mosaic from Japanese L-band radar satellite JERS. Useful for forest mapping, biomass estimation, soil moisture, flood detection, and urban monitoring. SAR allows cloud-penetrating observations.
Landsat C2L2 AR	Landsat C2L2 AR	Landsat Collection 2 Level 2 Surface Reflectance. Applied for NDVI, NDBI, NDWI calculations, land cover mapping, vegetation health assessment, and climate research.
LS5 SR	LS5 / LS7 / LS8 / LS9 SR / ST	Landsat Surface Reflectance (SR) and Surface Temperature (ST). SR used for vegetation, NDVI/NDBI, urban monitoring; ST used for land surface temperature, urban heat, and climate studies.
Maxar Morocco Earthquake 4 Bands	Maxar Morocco Earthquake 4/8 Bands	High-resolution Maxar imagery post-earthquake. Useful for damage assessment, disaster response, urban infrastructure analysis, and recovery planning.

NDVI Anomaly	NDVI Anomaly	Maps NDVI deviations from long-term averages. Used to detect drought, vegetation stress, seasonal or interannual changes, and land degradation.
NDVI Climatology LS	NDVI Climatology LS	Long-term NDVI climatology from Landsat. Supports vegetation trend analysis, climate studies, phenology research, and agriculture planning.
NIK Sentinel 2AB	NIK Sentinel 2AB / Tunsa Sentinel 2AB	Processed Sentinel-2 cloud-free mosaics. Applied for vegetation monitoring, urban expansion, land cover classification, soil and water studies, environmental change detection.
PC LS8 Annual	PC LS8 Annual / PC S2 Annual	Principal Component (PC) products from Landsat 8 or Sentinel-2 annual composites. Useful for dimensionality reduction, change detection, land cover classification, highlighting spectral variation for environmental monitoring.
Rainfall CHIRPS Daily	Rainfall CHIRPS Daily / Monthly	CHIRPS precipitation dataset. Applied in drought monitoring, hydrological modeling, agriculture planning, water resource management, and climate studies.
S1 Monthly Mosaic	S1 Monthly Mosaic / S1 RTC	Sentinel-1 SAR monthly mosaics and Radiometrically Terrain Corrected (RTC) products. Used for flood monitoring, soil moisture mapping, urban mapping, and surface structure analysis. SAR works day/night and through clouds.
S2 L2A	S2 L2A / S2 L2A C1	Sentinel-2 Level 2A surface reflectance products. Useful for NDVI, SAVI, NDBI, NDWI, BSI calculations, urban, agricultural, and environmental monitoring.
S3 OL 2 WFR NRT	S3 OL 2 WFR NRT	Sentinel-3 Ocean & Land Colour near-real-time imagery. Applied in ocean color, chlorophyll monitoring, vegetation health, water quality, and environmental change detection.
WOFS LS	WOFS LS / WOFS LS Summary Alltime / Annual / Annual v2	Water Observations from Space (Landsat). Used to monitor surface water extent, flood events, seasonal water dynamics, and long-term hydrological changes.
WSF 2015	WSF 2015 / 2019 / Evolution	World Settlement Footprint datasets. Provide global urban extent for different years and evolution over time. Applied for urban growth monitoring, infrastructure planning, land use change analysis, and studying settlement patterns.

Table 4. Outcomes

Outcome	**Description**	**Application**
UHI	Urban Heat Island effect representing areas in cities warmer than surrounding rural areas.	Urban planning, climate adaptation, energy demand analysis, identification of urban hotspots.
Nitrogen Dioxide (NO2) emissions	Measures NO2 concentration in the atmosphere, often from traffic, industrial activity, and urban sources.	Air quality monitoring, pollution control, health impact assessment, regulatory compliance.
Particle Matter (PM2.5 and PM10) emissions	Measures fine (PM2.5) and coarse (PM10) particulate matter in the air.	Air quality assessment, health risk analysis, urban pollution management, epidemiology studies.
Carbon Monoxide (CO) emissions	Tracks CO levels in urban and industrial areas.	Air quality monitoring, traffic-related pollution studies, public health assessment.

Sulfur Dioxide (SO2) emissions	Measures SO2 emissions from industrial sources and fossil fuel burning.	Environmental monitoring, health impact studies, regulatory policy evaluation.
Average integration of the transportation network	A network analysis metric showing how well locations are connected to the rest of the network.	Urban accessibility analysis, transport planning, mobility optimization.
Average choice of the transportation network	Measures the frequency of network paths being chosen in shortest-path analyses.	Traffic modeling, congestion analysis, route optimization, urban mobility studies.
Normalized choice of the transportation network	Similar to average choice, but scaled to a normalized range for comparisons between networks.	Transport efficiency evaluation, accessibility studies, planning for infrastructure improvements.
Surface Urban Heat Islands (SUHI)	Satellite-derived mapping of urban heat differences at the surface level.	Identifying urban hotspots, assessing mitigation strategies, planning green infrastructure.
Heat Load	Quantifies thermal energy or intensity over urban areas, integrating surface temperature and urban morphology.	Energy demand estimation, urban design, environmental impact studies, heat risk management.
EO base data portraying gridded damaged buildings with different levels of sophistication and their economic losses due to high-rise effect in the context of land use	Remote sensing datasets mapping building damage after disasters, including economic losses.	Disaster risk assessment, post-event recovery planning, insurance studies, urban resilience analysis.
EO base data portraying gridded undamaged buildings having low and mid-rise	Remote sensing building inventory for undamaged structures.	Urban planning, infrastructure assessment, disaster preparedness, zoning and development studies.
LST	Land Surface Temperature measuring the temperature of the land surface as seen from satellites.	UHI studies, climate monitoring, agricultural stress detection, energy balance modeling, environmental monitoring.

Table 5. Inputs

Input	Description	Applications
Average integration (or closeness) of the transportation network	Measures how easily a node or location can be reached from other nodes in the transport network.	Urban accessibility studies, transport planning, traffic optimization, emergency response routing.
Average choice (or betweenness) of the transportation network	Measures how often a node or link is part of the shortest paths in the network.	Traffic flow modeling, congestion analysis, infrastructure prioritization, urban mobility studies.
Normalized choice of the transportation network	Scaled measure of network betweenness to allow comparisons between networks of different sizes.	Transportation efficiency analysis, urban planning, comparison of accessibility across regions.
Average traffic lane occupancy	Average proportion of road lane usage by vehicles.	Traffic monitoring, congestion management, road capacity planning.

Average vehicle speed	Mean speed of vehicles in a given road section or network.	Traffic performance evaluation, congestion analysis, transport safety studies.
Traffic volume	Number of vehicles passing through a road segment in a given time.	Traffic monitoring, infrastructure planning, urban mobility studies.
Average number of bicycles	Average count of bicycles in a given area or network segment.	Urban mobility planning, sustainable transport assessment, bicycle lane design.
Average number of motorcycles	Average count of motorcycles in a given area or road segment.	Traffic monitoring, urban mobility planning, emission estimation.
Average number of cars	Average count of cars in a given road segment or area.	Traffic analysis, parking demand, urban planning, emissions assessment.
Average number of buses	Average count of buses in the network or area.	Public transport planning, transit efficiency, emission monitoring.
Average number of light cargo vehicles	Average count of light trucks/vans.	Urban logistics planning, freight traffic analysis, emissions estimation.
Average number of medium cargo vehicles	Average count of medium trucks.	Freight management, congestion and road wear analysis, emission estimation.
Average number of heavy cargo vehicles	Average count of heavy trucks.	Freight planning, urban traffic safety, road maintenance planning, air quality modeling.
Average number of car transporters	Average count of car transport trucks.	Logistics planning, road safety assessment, heavy vehicle traffic analysis.
Average number of tractors	Average number of tractors in the area.	Agricultural traffic monitoring, rural-urban interface planning, road safety assessment.
Wind speed	Speed of wind at a location.	Air quality dispersion modeling, urban ventilation, environmental risk assessment.
Dew point	Temperature at which air becomes saturated with moisture.	Weather modeling, humidity assessment, climate analysis, HVAC planning.
Humidity	Moisture content of the air.	Weather impact studies, urban climate modeling, health risk assessment.
Distribution of vehicle types per district	Spatial distribution of different vehicle types in city districts.	Urban traffic management, emissions inventory, mobility planning.
Education levels per household per district	Socioeconomic indicator describing education attainment.	Demographic studies, urban planning, health and economic policy analysis.
Occupation distribution per district	Employment type distribution in a given area.	Socioeconomic planning, urban mobility studies, risk assessment for disasters.
Historical city population	Population records over time for the city.	Urban growth modeling, infrastructure planning, disaster risk analysis.
Nitrogen dioxide ($NO2$) emissions	$NO2$ concentration in urban or industrial areas.	Air quality assessment, pollution control, health impact studies.
Carbon monoxide (CO) emissions	CO levels in urban environments.	Traffic pollution monitoring, air quality studies, health risk assessment.
Sulfur dioxide ($SO2$) emissions	$SO2$ concentration from industrial or combustion sources.	Environmental monitoring, industrial impact assessment, health studies.

Building type	Classification of buildings (residential, commercial, industrial, etc.).	Urban planning, disaster risk modeling, vulnerability assessment.
Building density	Number of buildings per area unit.	Urbanization studies, land use planning, hazard exposure assessment.
Urban spectral indices (NDBI, BUI, ASI, ENDISI)	Satellite-derived indices highlighting built-up areas and urban features.	Urban expansion monitoring, land cover classification, impervious surface mapping.
Land cover land use (LCLU)	Classification of land into types such as vegetation, water, urban, etc.	Land management, urban planning, environmental monitoring, agriculture assessment.
Human settlement - Built-up	Mapping of built structures in an area.	Urban growth monitoring, infrastructure planning, disaster exposure assessment.
Human settlement - Population	Population estimates associated with settlements.	Demographic studies, urban planning, risk assessment, resource allocation.
Population density	Number of people per area unit.	Urban planning, hazard modeling, infrastructure design, service allocation.
Vegetation cover	Fraction or presence of vegetation in an area.	Environmental monitoring, urban green space planning, heat mitigation studies.
Land surface temperature (LST)	Temperature of the Earth's surface derived from satellite imagery.	UHI studies, climate monitoring, energy demand analysis, agricultural stress monitoring.
Rainfall	Precipitation amounts in a location.	Flood modeling, agriculture planning, climate studies, hydrology.
Water surface spectral indices (MNDWI…)	Satellite indices highlighting water bodies.	Surface water mapping, flood monitoring, wetland management.
Wind direction and speed	Vector of wind flow in an area.	Pollution dispersion modeling, urban climate studies, hazard assessment.
Magnitude	Earthquake magnitude measurement.	Seismic risk assessment, disaster planning, infrastructure safety analysis.
Epicentral coordinates	Geographic location of earthquake epicenter.	Earthquake hazard modeling, emergency response planning, urban risk assessment.
Focal depth	Depth at which an earthquake originates.	Seismic risk assessment, building vulnerability studies, hazard mapping.
Fault line rupture	Information about active fault rupture during an earthquake.	Seismic hazard analysis, land-use planning, disaster preparedness.
V30 Shear Wave Velocity	Average shear wave velocity of top 30 m of soil.	Seismic site characterization, earthquake engineering, building design standards.
Building types	Categories of buildings (residential, commercial, industrial).	Urban planning, disaster vulnerability modeling, land use management.
Number of buildings (population related) and number of stories	Count of buildings, including their height in stories.	Exposure modeling, disaster risk assessment, urban growth monitoring.
Age of buildings	Year of construction or age of structures.	Structural vulnerability assessment, heritage preservation, urban planning.
Building heights	Vertical extent of buildings.	Urban morphology studies, UHI modeling, disaster impact analysis.

Building cost	Construction or replacement cost of buildings.	Economic loss modeling, insurance assessment, disaster recovery planning.
Demographic data	Population characteristics: age, sex, income, household size.	Urban planning, risk assessment, resource allocation, policy design.
Global fault line information	Worldwide fault line locations and characteristics.	Seismic hazard assessment, land-use planning, infrastructure risk studies.
Global population distribution	Spatial distribution of people worldwide.	Disaster risk modeling, urban planning, resource allocation.
Direct economic loss	Monetary value of damages due to disasters.	Disaster impact assessment, insurance studies, recovery planning, urban resilience analysis.
NDVI (Normalized Difference Vegetation Index)	Satellite-derived index measuring vegetation health and density.	Agriculture monitoring, urban greenness analysis, land degradation studies.
NDBI (Normalized Difference Built-up Index)	Satellite-derived index highlighting built-up areas.	Urban expansion monitoring, impervious surface mapping, land use analysis.
NDWI (Normalized Difference Water Index)	Satellite index highlighting water bodies.	Surface water mapping, flood monitoring, wetland management.
SAVI (Soil-adjusted Vegetation Index)	Vegetation index adjusted for soil brightness.	Agriculture monitoring, vegetation health assessment, land degradation studies.
IBI (Index-based Built-up Index)	Combined index to identify built-up areas.	Urban mapping, land use classification, impervious surface detection.
EVI (Enhanced Vegetation Index)	Improved vegetation index reducing atmospheric and canopy effects.	Crop monitoring, vegetation health assessment, forest monitoring, urban greenness studies.

UNIT 4 - SIMULATION AND URBAN DYNAMICS THROUGH NATURAL EXPERIMENTS

The learning goal of Unit 4 is to develop learners' ability to use the UDENE platform to model and analyse urban processes through simulations and experiments. By the end of this unit, learners will understand how to set up and run both automatic and manual experiments, interpret their outputs, and apply them to study urban dynamics such as land-use change, environmental impacts, or infrastructure development. This unit equips learners with practical skills to design data-driven simulations, explore scenario outcomes, and apply EO-based evidence in urban planning and decision-making contexts.

Exercises focus on applying the UDENE platform to model and analyse urban dynamics through data-driven simulations and experiments. Learners will practice setting up and running both automatic and manual experiments, interpreting outputs from the exploration and matchmaking tools and exploring how different parameters influence urban processes such as land-use change, environmental impact, and infrastructure development. By interpreting simulation outputs, participants will gain insight into how EO-based evidence supports scenario analysis and decision-making. Through these hands-on tasks, learners will strengthen their ability to design, execute, and evaluate simulations that inform sustainable urban planning strategies.

The self-assessment for these exercises helps learners reflect on their ability to design, run, and interpret simulations of urban dynamics using the UDENE platform. It encourages them to evaluate how effectively they selected parameters, executed experiments, and analyzed resulting patterns related to land-use change, environmental impact, or infrastructure development. The Solutions/Answers section provides reference examples of well-structured simulations, expected outputs, and correct interpretations. By comparing their work to these examples, learners can identify strengths and areas for improvement, deepening their understanding of simulation-based analysis and evidence-supported urban planning.

UNIT 5 - Use Case Driven Scenario-Building for Sustainable Development

The learning goal of Unit 5 is to enable learners to apply EO-based data and UDENE tools to design, test, and evaluate urban development scenarios that address sustainability challenges. This unit mainly focuses on the already developed use cases that are available on the platform and are accessible through navigation bar as example cases. Their purpose is to show use case driven scenario building and evidence-based decision making and reporting and prepare learners for the independent use case developments that will follow in the next modules.

By the end of this unit, learners will be able to construct and analyse scenarios related to the effect of linked park systems on urban heat load, the impact of high-rise districts on earthquake preparedness, and the influence of new transport infrastructure on air quality. This unit aims to strengthen learners' capacity to use spatial evidence and simulations to assess trade-offs, anticipate outcomes, and support informed, sustainable urban planning decisions.

Exercises will engage learners in scenario-building for sustainable urban development using EO-based data and the UDENE tools. Participants will test various urban development scenarios, such as evaluating the cooling effects of linked park systems, assessing earthquake resilience in high-rise areas, or analysing the air quality impacts of new transport infrastructure, that are already available in the Use cases tab on the platform (Figure 1). Through hands-on experimentation and data interpretation, learners will practice using spatial evidence and simulations to explore sustainability trade-offs, predict urban outcomes, and propose data-driven strategies that support informed urban planning decisions.

The self-assessment for these exercises allows learners to evaluate their ability to design, implement, and analyse urban development scenarios using UDENE tools and EO-based data. It encourages reflection on how effectively they can assess trade-offs, interpret simulation results, and link outcomes to real-world planning decisions. The Solutions/Answers section provides already available sample scenarios, expected results, and guidance on correct analytical approaches. By comparing their work to these references, learners can identify strengths, address gaps in understanding, and reinforce skills in evidence-based, sustainability-focused urban scenario planning.

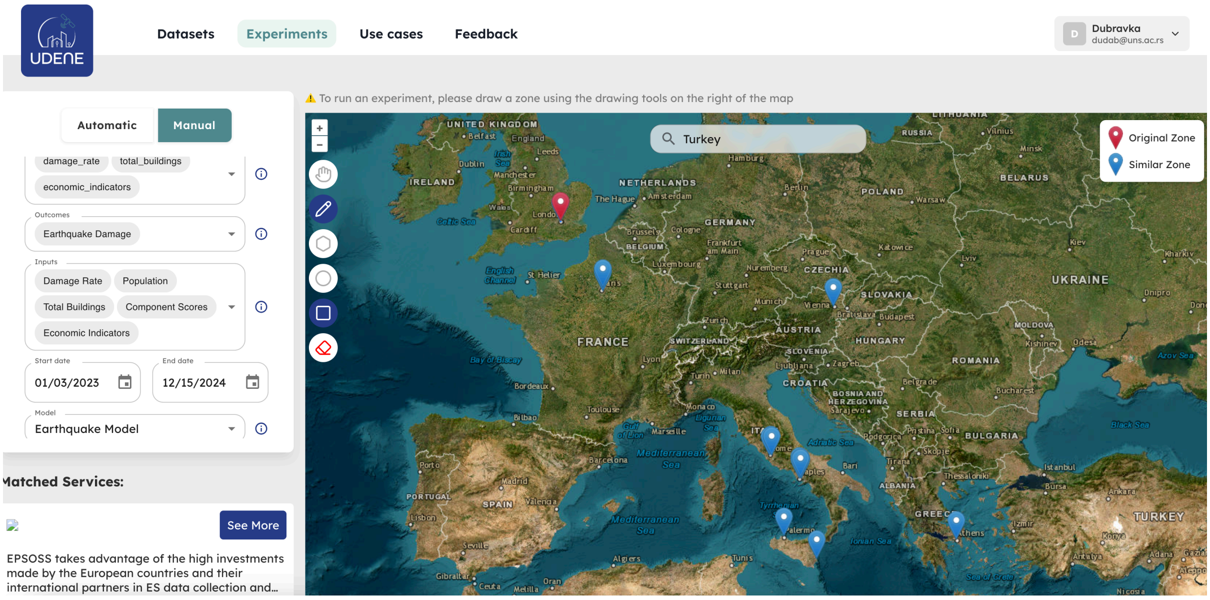

Figure 1. Use case analysis available by the platform

D. Glossary

- **UDENE Platform**: A geospatial decision-support environment integrating EO data and analytical tools for urban sustainability applications.
- **Decision-Support System (DSS)**: A digital platform combining data, analysis, and visualization to inform planning and policy decisions.
- **Data Cube**: A multidimensional data structure allowing efficient storage, retrieval, and analysis of EO and geospatial time-series datasets.
- **Exploration Tool**: A UDENE component enabling visualization, analysis, and simulation of urban processes using EO data and integrated datasets.
- **Matchmaking Tool**: A UDENE service that links planners with EO providers and relevant EO-based services using AI-supported matching.
- **Earth Observation (EO)**: Satellite- or airborne-based measurements used to monitor land, climate, and environmental processes.
- **Natural Experiment**: An observational study where external events or policy changes create conditions similar to an experiment, allowing for impact assessment.
- **Indicator**: A quantified variable (e.g., NDVI, PM2.5, LST) used to describe environmental or socio-economic conditions.
- **Land Surface Temperature (LST)**: Satellite-derived surface temperature used to study urban heat islands and environmental processes.
- **Urban Heat Island (UHI)**: The phenomenon where urban areas are significantly warmer than their rural surroundings due to built-up surfaces and limited vegetation.
- **Surface Urban Heat Island (SUHI)**: EO-derived surface-level measurement of UHI intensity using thermal imagery.
- **Scenario-Building**: The creation and evaluation of alternative future urban conditions to support planning decisions.
- **Simulation**: Computational modeling of real-world urban processes (e.g., traffic, land use, heat load, seismic effects, urban growth, environmental change) to explore potential outcomes under varying conditions.

- **Visualization**: The graphical representation of data and models to facilitate interpretation and communication.
- **Indicator Dashboard**: A visual interface summarizing EO-derived and socio-environmental indicators for decision support.
- **Geospatial Analysis**: Analytical methods used to study spatial patterns, relationships, and processes.
- **Input Data**: Datasets used to run simuselations, experiments, or scenario models (e.g., building height, traffic volumes, vegetation indices).
- **Outcomes**: Outputs of analysis or simulation such as UHI maps, pollutant concentrations, damage estimates, or heat load.
- **In Situ Data**: Ground-based measurements collected locally (e.g., air quality sensors, traffic counters) used to complement EO data.
- **Raster Data**: Grid-based spatial data (e.g., satellite imagery, digital elevation models).
- **Vector Data**: Spatial data represented by points, lines, and polygons (e.g., roads, buildings, administrative boundaries).

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Module: 4. Case Study Applications

Topic: This module applies the previously acquired knowledge to the practical urban applications presented through three case studies. It focuses on using EO products, Copernicus services, urban and other data, and scenario-based modelling to examine how cities respond to key environmental and infrastructural challenges. Through three integrated themes – urban heat mitigation, energy-efficiency impacts on winter air quality, and mobility and land-use dynamics along the Fruška Gora Corridor – the module explores how climate, energy, and transport systems interact to shape urban sustainability. Learners investigate how EO-derived indicators, ground data, and socioeconomic information can be combined to assess past and present conditions, model future scenarios, and support evidence-based planning. The overarching topic integrates climate adaptation, air-quality improvement, and human-centred mobility to highlight data-driven pathways toward resilient urban development.

A. Objectives

By the end of this module, learners will be able to:

- Analyse urban environmental challenges using EO data by identifying UHI hotspots, winter air pollution patterns, and transport-induced land-use changes in Novi Sad and the Fruška Gora corridor.
- Interpret and integrate multi-source datasets (EO, meteorological, socioeconomic, mobility, urban morphology) to understand drivers of heat load, air quality deterioration, and mobility shifts.
- Apply scenario-based modelling to evaluate the effects of greening strategies, energy-efficiency improvements, renewable heating transitions, and sustainable transport/land-use planning.
- Assess the impacts of infrastructure and urban interventions on climate resilience, air quality, mobility, accessibility, and ecological integrity.
- Use UDENE tools (Data Cube, Exploration Tool, Matchmaking Tool) to conduct natural experiments, visualise multi-temporal data, and evaluate mitigation or optimisation strategies.
- Develop evidence-based urban planning recommendations that balance human comfort, energy efficiency, mobility needs, and environmental protection.

B. Learning Outcomes

When completing this module, the learner is expected to be able to:

1. Identify spatial patterns and drivers of UHI, winter air pollution, and transport-related land-use change using EO-derived indicators such as LST, NDVI, NDBI, pollutant concentrations, and settlement extent.
2. Perform multi-temporal analyses using historical EO data, real-time monitoring, and projected scenarios to quantify urban environmental trends.

3. Evaluate mitigation strategies including greening (trees, corridors, green roofs), reflective surfaces, ventilation corridors, building retrofits, and clean heating transitions.
4. Assess mobility and accessibility changes induced by major transport infrastructure and link them to environmental, urban expansion, and socio-economic outcomes.
5. Interpret EO-based modelling results (e.g., heat load reduction, pollution dispersion, land-use change rates, habitat fragmentation) and validate them against in-situ and socioeconomic data.
6. Produce integrated, spatially explicit recommendations that support climate adaptation, sustainable energy use, improved air quality, and human-centred mobility planning.
7. Communicate findings effectively through maps, scenario outputs, and evidence-based reports aligned with real-world urban planning needs.

C. Learning Units / Concepts

UNIT 1 – Case Study 1: Enhancing Urban Green Spaces to Mitigate Urban Heat Islands in Novi Sad	
Content	Objective: Identify and mitigate UHI hotspots through greening strategies. Inverse: prioritise reflective surfaces/ventilation due to space constraints. Study area: Novi Sad; high density, limited green cover. Temporal scope: 10-year historical analysis.
Exercises	Exercises guide learners through the process of identifying UHI hotspots and evaluating mitigation options tailored to the dense urban fabric and limited green space. Participants will analyse spatial and temporal patterns of surface temperatures, map priority hotspots, and design greening interventions such as targeted tree planting or micro-green spaces. They will also explore the inverse scenario, where spatial constraints require alternative solutions—like reflective materials, cool roofs, or improved ventilation corridors—to reduce heat accumulation. Through this practical workflow, learners develop skills in data-driven urban climate assessment and scenario-based planning for sustainable heat mitigation.
Self-assessment	Learners complete a brief set of questions to check their understanding of identifying UHI hotspots, interpreting 10-year spatial patterns, and selecting suitable mitigation strategies—either greening or alternative reflective/ventilation measures.
Solutions/Answers for self-assessment	A concise answer key provides correct interpretations of UHI patterns, justification for chosen mitigation options, and examples of appropriate interventions, allowing learners to verify their reasoning and fill any knowledge gaps.

UNIT 2 – Case study 2: Assessing the Impact of Building Energy Efficiency on Urban Air Quality	
Content	Objective: Assess impact of energy efficiency improvements on winter air pollution caused by individual household heating and district power plant. Inverse: Optimise heating system reducing the use of solid and oil fuel and promoting transition to renewables. Study area: Novi Sad, focusing on high-density residential areas

	with older building stock and suburbs with individual heating facilities. Temporal scope: 10-year historical, real-time monitoring, projections.
Exercises	These exercises guide learners in analysing winter air pollution in Novi Sad by examining emissions from individual household heating and the district power plant across a 10-year dataset, real-time monitoring, and future projections. Learners identify pollution peaks, map affected high-density and suburban areas and assess how energy efficiency improvements, such as insulation upgrades or system retrofits, reduce emissions. They also explore the inverse scenario, evaluating options to optimise the heating system by shifting away from solid and oil fuels toward cleaner and renewable energy sources.
Self-assessment	A short set of questions checks learners' understanding of pollution drivers, the impact of energy efficiency on winter emissions, and the potential benefits of transitioning to cleaner heating systems.
Solutions/Answers for self-assessment	Brief model answers provide correct interpretations of emission trends, explain the effects of energy efficiency measures, and outline suitable renewable-based or cleaner heating strategies, enabling learners to validate their conclusions.

UNIT 3 – Case study 3: Analysing the Impact of the Fruška gora Corridor on Mobility Patterns in Novi Sad and Surrounding Areas	
Content	Objective: Analyse effects of new transport corridor on mobility, traffic, land use, and environment. Inverse: optimise patterns and land-use for human-centred development. Study area: Novi Sad–Ruma corridor, including Fruška gora National Park and surrounding settlements. Temporal scope: 10 years pre- and post-completion.
Exercises	These exercises lead learners through analysing how the new Novi Sad–Ruma transport corridor affects mobility, traffic patterns, land-use change, and environmental conditions across a 10-year period before and after construction. Learners map shifts in accessibility, identify development pressures near settlements and Fruška gora National Park, and evaluate impacts on congestion and ecological areas. They also explore the inverse scenario—optimising land-use and mobility patterns to support human-centred, sustainable development around the corridor.
Self-assessment	A short set of questions checks learners' understanding of corridor-induced changes in mobility, land use, and environmental conditions, as well as strategies for shaping more human-centred development outcomes.
Solutions/Answers for self-assessment	Brief model answers summarise expected mobility and land-use impacts, highlight key environmental considerations, and outline suitable planning strategies for sustainable, human-centred development, helping learners verify their reasoning.

C1. Learning Units / Detailed Overview

UNIT 1 – CASE STUDY 1: ENHANCING URBAN GREEN SPACES TO MITIGATE URBAN HEAT ISLANDS IN NOVI SAD

Use Case Title	**Enhancing Urban Green Spaces to Mitigate Urban Heat Islands in Novi Sad, Serbia**
Use Case Idea	Novi Sad experiences rising summer temperatures due to urban expansion and climate change, exacerbating urban heat islands (UHI). This use case focuses on identifying and mitigating UHI hotspots in Novi Sad by optimizing green infrastructure and vegetation cover. By integrating EO data, land surface temperature mapping, and urban morphology parameters, it aims to propose effective greening interventions such as tree planting, park expansion, and green roofs. The analysis supports sustainable urban cooling strategies, climate adaptation planning, and health risk reduction. This use case can also explore creating interconnected green corridors (e.g., expanding parks along the Danube River and linking them to urban forests) to provide shading, improve air flow, and reduce surface temperatures, addressing environmental degradation and public health risks.
Objective	Objective is to assess spatial patterns and drivers of Urban Heat Islands in Novi Sad using EO-based indicators and to evaluate the cooling potential of different green space enhancement strategies. The goal is to support urban planners in prioritizing interventions that reduce urban heat load, improve thermal comfort, and enhance environmental quality in high-density zones. Furthermore, assess heat load reduction using Local Climate Zones (LCZs); evaluate the cooling efficiency of green corridors; model spatial and temporal variations in temperature to inform urban greening policies.
Inverse Use Case	Where greening is spatially constrained (e.g. densely built areas, water-scarce zones), prioritize reflective urban surfaces (e.g., cool roofs and pavements), ventilation corridors, and surface albedo optimization to reduce surface heat load through passive cooling approaches and urban design adaptations.
Use Case Study Area	Novi Sad, Serbia (45°15′15″N 19°50′33″E), population ~369,000; temperate continental climate with hot summers; high urban density with limited green cover (~20% of area), particularly in newly built residential areas. Focus will be on dense urban cores (e.g., Liman, Grbavica, etc.), industrial and commercial zones (with high impervious surface fraction), peripheral and suburban neighbourhoods with limited green cover and the Danube riverfront.
Study Area Characteristic Variables	Climate (high summer LST >30°C); Population density and exposure (urban core >7,000/km²); Environmental risks (UHI, heatwaves); Land cover/land use composition (built-up vs. vegetated vs. water surfaces); Building density, height, and roof type; Street geometry and ventilation potential; Soil sealing and imperviousness; Surface temperature gradients; Availability and connectivity of urban green spaces.

Temporal Scope	Historical analysis: 10-year period (2015–2025) for temporal UHI trends Seasonal analysis: Focus on summer and early autumn peak heat periods Future projections: Optional climate scenarios (2025–2035) to assess mitigation benefits
Input Predictor Variables	Vegetation indices: NDVI, SAVI, EVI (Sentinel-2/Landsat 8/9); Built-up indices: NDBI, BUI, IBI (Sentinel 2); Water indices: NDWI, MNDWI (Sentinel-2/Landsat 8/9); Land Surface Temperature – LST (Copernicus C3S, Landsat 8/9 TIRS); Land cover and land use – LCLU (Copernicus CLMS Urban Atlas); Impervious surface fraction – ISF (Copernicus High-Resolution Imperviousness Layer); Population density; for measuring exposure (GHS-POP, Eurostat GEOSTAT); Meteorological variables: wind speed, wind direction, humidity, temperature, rainfall (Copernicus C3S); Surface albedo and reflectivity (Sentinel 2/Landsat); Urban geometry: building height, density, orientation, type (OSM, EU DEM, Copernicus Urban Atlas, Copernicus HRL, local LiDAR data, etc.); Inverse: Add albedo factors from building materials.
Outcome Variables	Primary outcomes: • Land Surface Temperature (LST), predicted • Surface Urban Heat Island (SUHI) intensity and spatial extent; SUHI reduction (temperature drop in °C) • Urban Heat Island (UHI) • Heat load (thermal energy in MJ/m²) Derived outcomes (optional): • Cooling effect of vegetation (NDVI–LST correlation) • Heat Load Index (combined LST + built-up density) • Potential cooling zones for greening interventions • Urban comfort index (temperature + green ratio) • Potential impact on PM2.5 (requires external air-quality modelling) Inverse: Similar outcomes but focused on non-vegetative cooling.
Input Dataset/s	Landsat LS8 / LS9 SR and ST - surface reflectance and temperature, long-term UHI trend analysis; Sentinel-2 L2A / GM S2 Annual - NDVI, NDBI, BSI calculations, urban green mapping; WSF 2015 / 2019 / Evolution – urban extent and built-up density, urban growth, imperviousness; CGLS Landcover / CCI Landcover - land cover classification, vegetation, impervious, and water mapping; DEM SRTM and derivatives – elevation, slope, aspect, ventilation potential and heat accumulation; NDVI Climatology LS / NDVI Anomaly – long-term vegetation trends, and deviations from long-term averages, seasonal and interannual vegetation changes;

	Rainfall CHIRPS, Wind speed, - climate data, correlating LST with weather conditions; Population density data (GHSL, WorldPop) – human exposure metrics, urban vulnerability mapping; In-situ weather stations; OSM road/land use data; Local urban planning, cadastral data sets…
Methodology	1. Input datasets collection for LST and vegetation index calculation. Possible integration in UDENE Data Cube. 2. Run natural experiments using UDENE exploration and matchmaking tools to find places with similar characteristics. 3. UHI detection: Compute and map LST anomalies to identify persistent heat hotspots. 4. Urban morphology analysis: Combine WSF, DEM, and building density data to assess structural drivers of UHI. 5. Correlation analysis: Quantify relationships between NDVI, NDBI, and LST to determine cooling effects of green cover. Sensitivity analysis for green coverage variations. 6. Scenario modeling: o Greening scenario: Increase vegetation cover (by e.g. 10–30%) to simulate potential LST reduction. o Reflective/ventilation scenario: Replace impervious surfaces or optimize wind corridors. 7. Validation: Compare EO-derived LST with in-situ temperature and weather station data. 8. Visualization: Generate UHI and mitigation maps for decision-making support. Visualize UHI intensity maps, vegetation trends, and scenario outcomes. Visualize priority zones for greening or albedo-based interventions. Interactive layer comparison (e.g., LST vs. NDVI vs. NDBI). 9. Reporting and evidence-based decision making.
Use Case Integration with UDENE's Data Cube and Exploration Tools	Data Cube: Use available datasets (Sentinel, Landsat, NDVI, WSF, DEM) or combine with external datasets; multi-temporal UHI and vegetation indices. Exploration Tool: Run natural experiments in Exploration Tool to find similar locations. Use appropriate datasets, inputs and outcomes. Matchmaking Tool: connect with other EO providers for high-resolution vegetation monitoring services. Scenario Engine: Evaluate different mitigation strategies (greening, reflective materials, ventilation) and quantify thermal benefits.
Challenges/Risks and Mitigation	Unavailable or incomplete data – adapt scenario to available datasets for the AOI; Cloud contamination in optical EO data - use temporal composites; Mixed land-cover pixels in dense urban cores - apply sub-pixel analysis or high-resolution EO data; Validation data scarcity - integrate ground temperature and meteorological stations;

	Model uncertainty – Cross-validate with in-situ data.
Planning	Phase 1: Data collection, preprocessing, and baseline UHI mapping. Phase 2: Vegetation and urban morphology correlation analysis. Phase 3: Scenario modelling of greening and reflective surface interventions, running natural experiments. Phase 4: Visualization and interactive assessment, evidence-based reporting.
Final Notes	This use case contributes directly to Novi Sad's climate resilience planning by providing EO-driven evidence for designing effective UHI mitigation strategies. By leveraging UDENE's Data Cube and Exploration and Matchmaking Tools, it enables spatial prioritization of green interventions and supports co-benefits for biodiversity, air quality, and liveability. The methodology is adaptable for replication in other medium-sized European cities with similar climatic and urban density conditions.

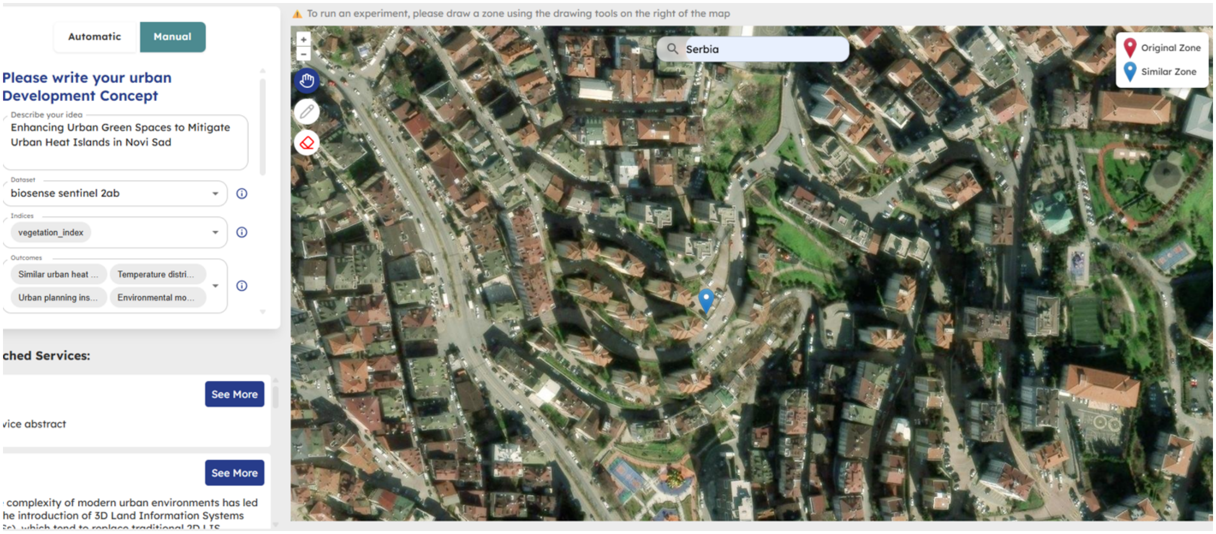

Figure 2. Setting up datasets, inputs, outcomes for the first use case development concept

Example 1

The maps (Figure 3) represent Land Surface Temperature (LST) and the resulting Urban Heat Island (UHI) intensity for the city of Novi Sad, calculated for the summer period of 2023 (June–September). The LST values were derived from Landsat 8 and Landsat 9 Level-2 thermal data, using the ST_B10 thermal infrared band, which was converted to radiance and then to temperature in degrees Celsius. A seasonal median composite was used to reduce cloud contamination and stabilize temperature variability.

The UHI intensity was computed as the difference between the urban LST and the 20th percentile of LST values within the study area, which serves as an approximation of the local rural baseline temperature. This method highlights zones where the urban fabric significantly increases surface temperature relative to nearby rural surroundings.

All data were processed and analysed using publicly available datasets from the USGS Landsat Collection 2 (Level-2) surface temperature products. The spatial resolution of the final LST and UHI maps is 30 meters, enabling fine-scale detection of heat hotspots across the city.

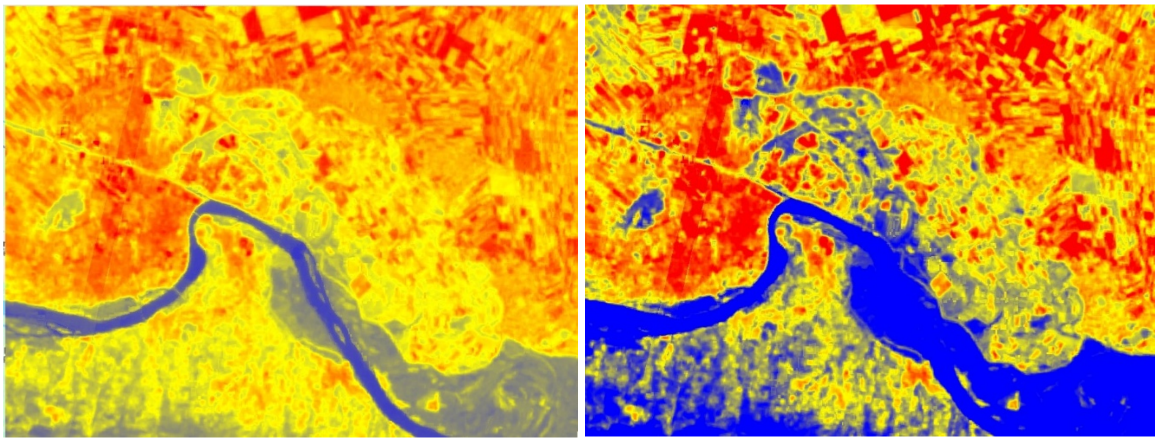

Figure 3. LST Novi Sad 30m (left); UHI Novi Sad 30m (right)

EXAMPLE 2

This analysis simulates the potential cooling effect of a proposed small park in Novi Sad using Landsat 8/9 Level-2 surface temperature data (ST_B10) for the summer period of June–September 2023. The median land surface temperature (LST) for the city was calculated, and a small area representing the future park was artificially cooled by 2°C. The new LST layer retains original temperatures outside the park, allowing comparison of the original and simulated LST (Figure 4). Urban Heat Island (UHI) maps were generated for both scenarios using the 20th percentile of LST as a reference for cooler ("rural") areas, and the cooling impact of the park is visualized through difference maps (ΔLST and ΔUHI).

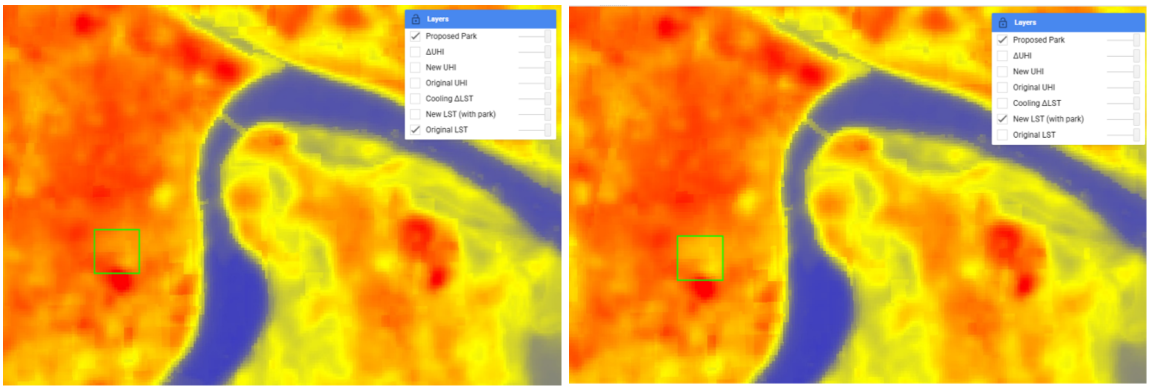

Figure 4. Original LST (left); New LST (right)

UNIT 2 – Case study 2: Assessing the Impact of Building Energy Efficiency on Urban Air Quality

Use Case Title	**Assessing the Impact of Building Energy Efficiency on Urban Air Quality**
Use Case Idea	This use case examines how improvements in building energy efficiency influence winter air pollution in Novi Sad, particularly focusing on emissions from individual household heating and district power plants. The goal is to understand the relationship between energy use patterns, fuel types, and urban air quality to support policies promoting cleaner energy and retrofitting older buildings.
Objective	To evaluate the impact of enhancing building energy efficiency (e.g., insulation, heating system upgrades) on reducing air pollutants such as NO_2, SO_2, CO, $PM_{2.5}$, and PM_{10} during winter seasons, and to identify key urban areas where interventions yield the most air quality benefits.
Inverse Use Case	To optimize the city's heating system by minimizing reliance on solid and oil-based fuels and supporting the transition to renewable and district heating sources, while maintaining or improving indoor comfort and energy performance.
Use Case Study Area	City of Novi Sad, Serbia — focusing on: • High-density residential zones with older building stock (e.g., Liman, Detelinara) • Suburban and peri-urban areas relying on individual heating systems (e.g., Futog, Veternik, Klisa)
Study Area Characteristic Variables	Building type and age; building density and height; heating system type and fuel usage; population density and socio-economic status; urban morphology (street width, openness, ventilation corridors); land cover (built-up vs. green cover); topography and meteorological variables (wind speed/direction, temperature inversions)
Temporal Scope	10-year historical analysis (2015–2025) using EO and ground-based data. Real-time monitoring of air pollutants and meteorological conditions using ground sensors. Scenario-based projections to 2035 for renewable transition and retrofit effects.
Input Predictor Variables	Building-related: age, type, density, height, insulation level (proxy via building age); Energy-related: heating fuel type, district vs. individual heating, energy consumption; Meteorological: wind speed and direction, temperature, humidity, dew point; Urban structure: NDVI, NDBI, BUI, LCLU, surface albedo, impervious surface fraction; Population and transport: population density, traffic volume, vehicle type distribution.
Outcome Variables	Air quality indicators: NO_2, SO_2, $PM_{2.5}$, PM_{10}, CO concentrations; Surface temperature: Land Surface Temperature (LST);

	Derived: Pollution dispersion patterns, winter inversion maps, heat load variation; Indirect outcomes: Energy demand reduction, emission intensity change per district.
Input Dataset/s	Sentinel-2 L2A / GM S2 Annual: NDBI, NDVI, BSI, impervious surfaces; Landsat C2L2 AR / LS8 SR and ST: Land Surface Temperature, built-up indices; WSF 2015–2019 / Evolution: Urban extent and density; CGLS / CCI Landcover: Land cover classification; DEM SRTM and derivatives: elevation, slope (air stagnation modeling); Rainfall CHIRPS / wind speed datasets: Meteorological context; Air quality datasets (local or Copernicus CAMS): NO_2, SO_2, $PM_{2.5}$, PM_{10}, CO; Building database (local cadastral, national mapping agency): age, height, usage type; Urban Atlas: land-use categories, functional zones; Socioeconomic data: population density, heating source mix per district
Methodology	Data collection, integration and preprocessing: harmonize EO, in-situ, and socio-economic data. Spatial analysis: map built-up areas, green cover, and LST to identify heat and emission hotspots. Air quality modelling: combine EO-derived surface data with meteorological dispersion modelling. Scenario modeling: Simulate effects of energy efficiency retrofits (e.g., 20% improved insulation, 50% heating system conversion to renewables). Validation: Use ground-based pollution stations and compare with modelled outputs. Visualization: temporal trends, spatial patterns, scenario comparisons. Reporting and evidence-based decision making.
Use Case Integration with UDENE's Data Cube and Exploration Tools	Data Cube: For multi-temporal EO integration (Sentinel, Landsat, WSF, DEM) and computation of indices (NDVI, NDBI, LST). Exploration Tool: Run natural experiments in Exploration Tool to find similar locations. Use appropriate datasets, inputs and outcomes. Interactive visualization of pollutant concentrations, urban structure, and simulation outcomes. Matchmaking Tool: connect with other EO providers for complementary solutions. Scenario Engine: Testing energy retrofit and heating system transition effects on urban air quality and heat load.
Challenges/Risks and Mitigation	Incomplete building energy data - use building age/type as energy performance proxy Limited temporal air quality data - use EO data and proxies Meteorological uncertainty - apply ensemble models for dispersion scenarios Validation data scarcity - use citizen-sensing or national air quality datasets

Planning	Phase 1: Data collection and preprocessing (EO, building energy data, air quality, socioeconomic). Phase 2: Baseline mapping of air quality and heating-related emissions. Phase 3: Scenario modelling for energy efficiency improvements. Phase 4: Visualization and interactive assessment, evidence-based reporting.
Final Notes	This use case aligns with Novi Sad's sustainable urban development and energy transition goals. By integrating EO-based monitoring with socio-technical data, it enables evidence-based decision-making for improving air quality and reducing carbon intensity in the building sector. It also provides a transferable framework for other Central and Eastern European cities with similar heating-related pollution challenges.

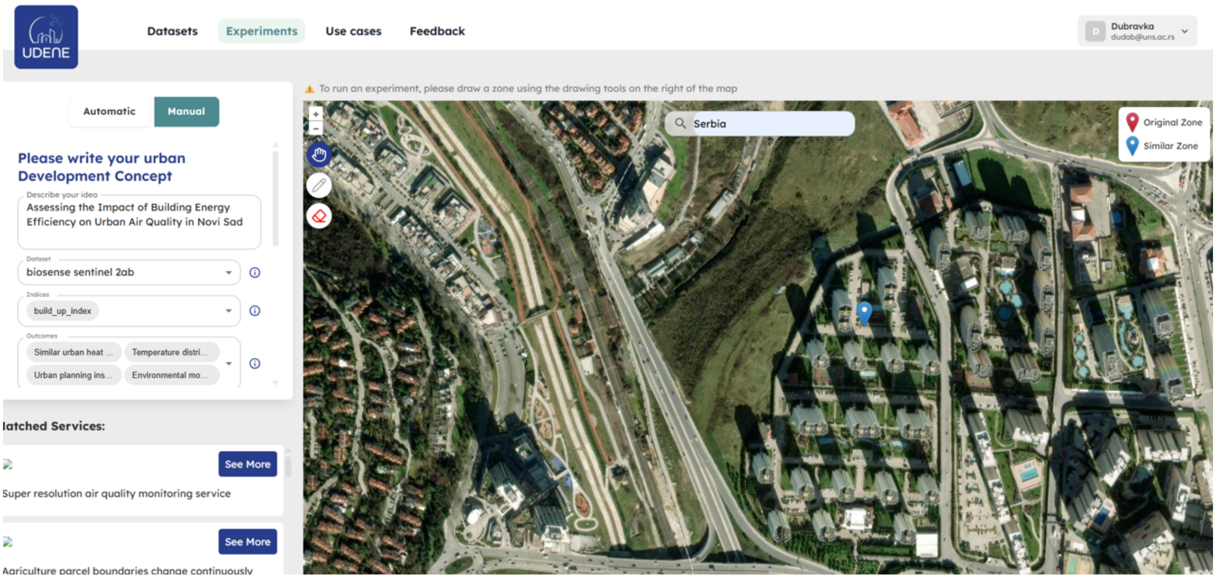

Figure 5. Setting up datasets, inputs, outcomes for the second use case development concept

EXAMPLE

In this analysis, a proxy map for NO_2 concentrations in Novi Sad (Figure 6) was created using Sentinel-2 NDVI data, where areas with higher vegetation were assumed to have lower NO_2. A "what-if" scenario was simulated by defining a specific neighborhood (Klisa) and reducing the proxy NO_2 values by 30 % within that area to represent potential air quality improvements, for example through energy-efficient retrofits or increased green spaces. The resulting maps show the original proxy NO_2, the adjusted NO_2 after improvements, and the difference (ΔNO_2), while values outside the selected neighborhood remain unchanged.

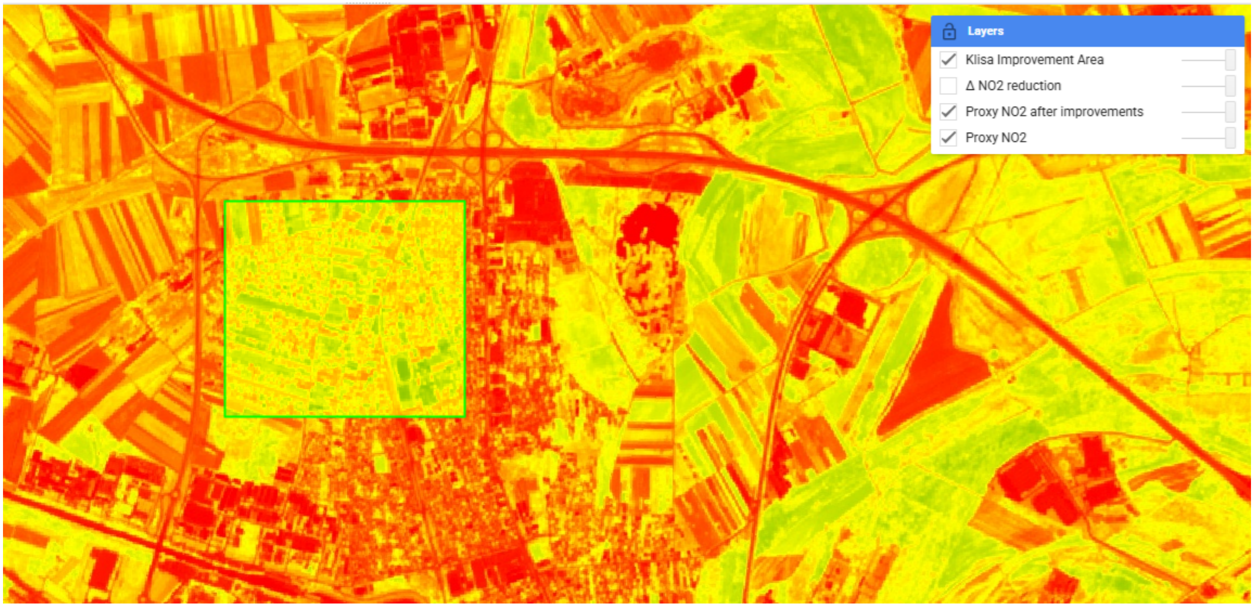

Figure 6. Proxy map for NO_2 concentrations in Novi Sad

UNIT 3 – CASE STUDY 3: ANALYSING THE IMPACT OF THE FRUŠKA GORA CORRIDOR ON MOBILITY PATTERNS IN NOVI SAD AND SURROUNDING AREAS

Use Case Title	**Analysing the Impact of the Fruška gora Corridor on Mobility Patterns in Novi Sad and Surrounding Areas**
Use Case Idea	This use case investigates how the construction and operation of the Fruška Gora Corridor, a major transport route connecting Novi Sad and Ruma, affect regional mobility patterns, traffic distribution, land-use dynamics, and environmental quality. The analysis combines EO data, transport metrics, and socioeconomic indicators to quantify both direct (traffic, accessibility) and indirect (urban sprawl, habitat fragmentation, emissions) effects.
Objective	To assess the spatial and temporal impacts of the Fruška Gora Corridor on mobility flows, accessibility, land-use change, and environmental conditions in Novi Sad and the surrounding municipalities, including Fruška Gora National Park. The aim is to inform integrated transport and land-use planning for sustainable regional development.
Inverse Use Case	To optimize transport patterns, land-use distribution, and environmental protection in the Novi Sad–Ruma region by promoting human-centred and low-carbon mobility strategies, ensuring the corridor supports balanced development rather than uncontrolled urban expansion or ecological degradation.
Use Case Study Area	Primary corridor: Novi Sad – Fruška Gora – Ruma axis; Extent: Urban and peri-urban zones of Novi Sad, Petrovaradin, Irig, and Ruma; Key environmental zone: Fruška Gora National Park (sensitive ecosystem affected by construction and traffic emissions); Transport connections: Existing road networks, future highway and tunnels, surrounding settlements;

Study Area Characteristic Variables	Transport network structure (roads, tunnels, intersections); Population density and commuting patterns; Land cover/land use (urban, rural, forest); Terrain and topography (elevation, slope); Green infrastructure and protected areas; Traffic intensity and vehicle type distribution; Emission and noise levels; Urban expansion dynamics and settlement evolution.
Temporal Scope	Pre-construction baseline: 10 years before completion (approx. 2015–2025) Post-construction monitoring: 10 years after opening (2025–2035, projected) Phased analysis: construction phase (disruption effects), operational phase (long-term mobility and land-use change)
Input Predictor Variables	Transport-related: Traffic volume, average speed, vehicle type distribution; Network integration, choice, and connectivity metrics; Average lane occupancy and road accessibility indices; Socioeconomic: Population density, occupation distribution per district; Education level, income (for mobility behaviour); Environmental: Land cover (urban, agricultural, forest); NDVI, NDBI, NDWI, BUI — vegetation and built-up indices; LST (land surface temperature) as a proxy for surface heat and energy use; Air quality indicators (NO_2, SO_2, $PM_{2.5}$, CO); Terrain slope and aspect (from DEM SRTM).
Outcome Variables	Mobility outcomes: Changes in average travel time, vehicle speed, and traffic volume per segment; Shift in modal distribution (car, bus, truck, bicycle); Accessibility improvements between Novi Sad and Ruma; Spatial and land-use outcomes: Land-use change (urban expansion, agricultural conversion, forest loss) Settlement density and morphology evolution (using WSF datasets) Environmental outcomes: Changes in NO_2, PM, CO concentrations along the corridor NDVI reduction (vegetation stress) and LST increase near infrastructure Habitat fragmentation metrics within Fruška Gora National Park
Input Dataset/s	Sentinel-2 L2A / GM S2 Annual: NDVI, NDBI, NDWI, BUI, impervious surface mapping; Landsat C2L2 AR / LS8 SR and ST: land surface temperature, land cover monitoring; WSF 2015–2019 / Evolution: settlement growth and urban expansion CGLS Landcover / CCI Landcover: regional land cover and land-use trends;

	DEM SRTM + derivatives: elevation, slope, terrain constraints for infrastructure and corridor planning; S1 Monthly Mosaic: SAR-based monitoring of land surface change and construction progress; Rainfall CHIRPS, Wind speed: Environmental and dispersion modeling; Traffic and socioeconomic data: average vehicle count, population distribution, employment, education (local or open datasets); Air quality datasets (Sentinel-5P TROPOMI, CAMS): NO_2, SO_2, CO, $PM_{2.5}$ trends.
Methodology	Baseline creation: map pre-construction land cover, road network, and air quality (using EO and transport data). Change detection: Compare post-construction EO images (Sentinel-2, Landsat, SAR) to detect land-use and vegetation changes. Mobility modelling: use network analysis (integration, choice, closeness) to model accessibility improvements and route shifts. Emission modelling: estimate transport-related pollution changes using vehicle mix and emission factors. Environmental impact: assess deforestation, vegetation stress (NDVI trends), and heat load near the corridor. Scenario analysis: project future land-use and traffic scenarios under different urban planning strategies (e.g., compact vs. dispersed growth). Validation: validate with in-situ traffic and air quality data. Visualization: temporal trends, spatial patterns, scenario comparisons. Reporting and evidence-based decision making.
Use Case Integration with UDENE's Data Cube and Exploration Tools	UDENE Data Cube: Stores EO time series for pre- and post-construction monitoring (Sentinel, Landsat, WSF, DEM). Exploration Tool: Run natural experiments in Exploration Tool to find similar locations. Use appropriate datasets, inputs and outcomes. Interactive visualization of mobility and environmental change (e.g., traffic flow vs. land-use change). Matchmaking Tool: connect with other EO providers for complementary solutions. Scenario Engine: Simulate development alternatives, helping policymakers evaluate mobility–land-use trade-offs and environmental impacts.
Challenges/Risks and Mitigation	Limited ground mobility data - use EO-derived and model-based accessibility metrics Seasonal or cloud interference - integrate multi-source data (SAR + optical) Complex topography (tunnels, slopes) - use DEM derivatives for accurate modelling Environmental sensitivity of Fruška Gora NP - combine NDVI and land cover change alerts for impact detection Post-construction data lag - implement continuous monitoring via near-real-time Sentinel data
Planning	Phase 1: Collect EO, traffic, and socioeconomic data (baseline setup) Phase 2: Conduct change detection and accessibility analysis (pre/post comparison)

	Phase 3: Integrate emissions and land-use models Phase 4: Scenario development for sustainable corridor integration Phase 5: Visualization and interactive assessment, evidence-based reporting.
Final Notes	This use case supports data-driven regional planning by linking infrastructure development with environmental and mobility outcomes. By leveraging EO-based indicators and transport network analysis within UDENE's Data Cube, decision-makers can assess whether the Fruška Gora Corridor fosters sustainable mobility or accelerates urban sprawl. The approach provides a replicable framework for similar large-scale transport projects in the Western Balkans.

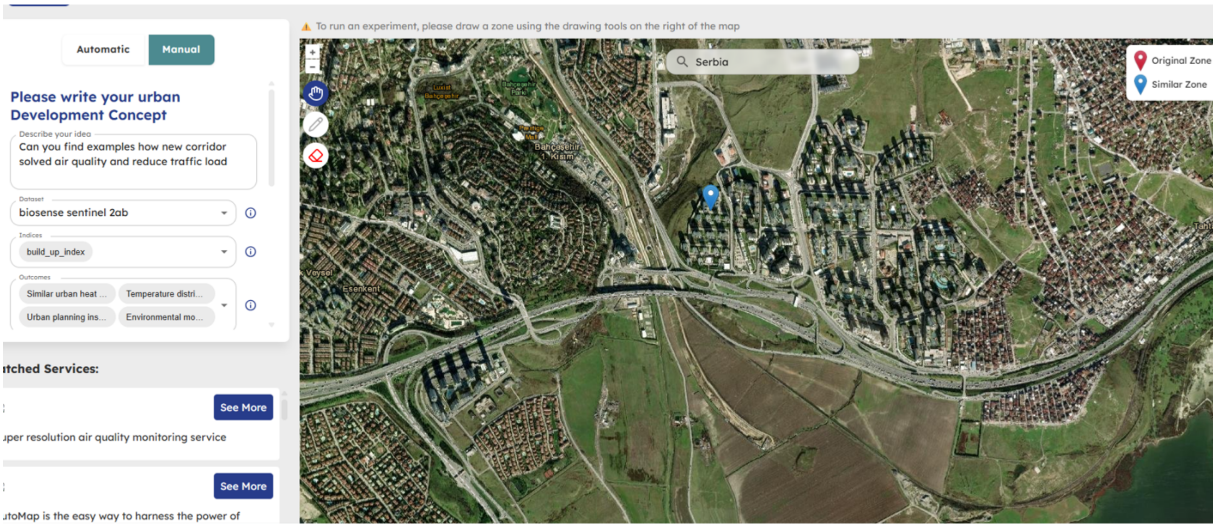

Figure 7. Setting up datasets, inputs, outcomes for the third use case development concept

EXAMPLE

In this analysis, a Fruška Gora corridor passing near Irig was defined as a narrow polygon to represent a potential mobility route. Nighttime Lights (VIIRS) were used as a proxy for mobility patterns across Novi Sad and surrounding areas. A "what-if" scenario was simulated by increasing mobility by 20 % within the corridor polygon, while values outside remained unchanged. The resulting maps display the original mobility proxy, the projected mobility after corridor improvements, and the difference (ΔMobility), allowing visualization of the corridor's potential impact on urban and regional movement.

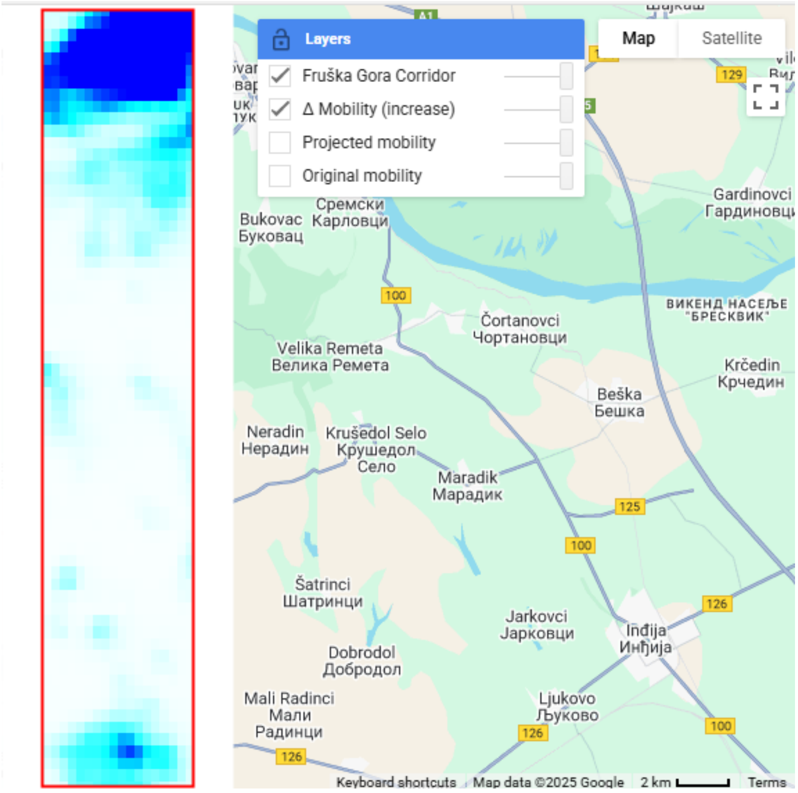

Figure 8. Mobility patterns of newly developed corridor

D. Glossary

- **Urban Heat Island (UHI):** Local temperature increase in cities caused by built-up surfaces, reduced vegetation, and heat-absorbing materials.
- **SUHI (Surface Urban Heat Island):** Temperature contrast derived from surface temperature (LST) rather than air temperature.
- **Land Surface Temperature (LST):** Temperature of the Earth's surface measured using thermal EO sensors.
- **NDVI (Normalized Difference Vegetation Index):** An index for assessing vegetation greenness and health.
- **NDBI (Normalized Difference Built-up Index):** EO-derived index indicating density of built-up surfaces.
- **Impervious Surface Fraction (ISF):** Percentage of land covered by sealed surfaces like asphalt and concrete.
- **Building energy efficiency:** Degree to which buildings use less energy for heating or cooling due to insulation, materials, and technical systems.
- **$PM_{2.5}$ / PM_{10}:** Fine particulate matter pollutants, harmful to human health.
- **Inversion (temperature inversion):** Meteorological condition trapping pollutants near ground level during winter.
- **Accessibility analysis:** Evaluation of how easily people and goods move between locations, often using network models.
- **Habitat fragmentation:** Breaking up of ecosystems by development, reducing ecological connectivity.

- **Scenario analysis:** Simulation of potential future conditions under specific intervention or planning strategies.
- **UDENE Data Cube:** A multidimensional data structure that stores spatial and temporal EO data for efficient access, analysis, and time-series modelling.
- **Exploration Tool**: A UDENE component enabling visualization, analysis, and simulation of urban processes using EO data and integrated datasets.
- **Matchmaking Tool**: A UDENE service that links planners with EO providers and relevant EO-based services using AI-supported matching.
- **Scenario building:** Testing urban planning or environmental interventions and predicting outcomes.

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- Urban Planning Institute of Novi Sad — urban planning datasets. Available at: https://www.nsurbanizam.rs/
- Public Enterprise Roads of Serbia — transport project documentation. Available at: https://www.putevi-srbije.rs/
- GeoSrbija - cadastral datasets; transport networks; INSPIRE data themes. Available at: https://www.rgz.gov.rs/geo-srbija
- Geofabrik, Available at: https://www.geofabrik.de/

Module 5. Individual assignments assessing competencies

Topic: This module focuses on applying geospatial analysis skills through a set of individual, real-world assignments. Students identify environmental or urban problems, select and use appropriate GIS and remote-sensing tools, interpret spatial patterns and risk factors, and communicate their findings through clear, solution-oriented reports. The module emphasizes independent problem-solving, methodological justification, and the production of actionable maps and indicators that support planning and decision-making. Students will be able to choose one or more assignments from the module, depending on their interests and the competencies they wish to demonstrate.

A. Objectives

Enable students to independently solve urban related problems such as:

- Understand key environmental and urban processes influencing heat, pollution, seismic risk, and flooding.
- Interpret satellite imagery, GIS datasets, and derived indices used in urban and environmental analysis.
- Analyse spatial patterns of risk (heat, pollution, seismic, flood) using multi-criteria GIS methods.
- Evaluate the relationships between environmental variables, built structures, and human vulnerability.
- Create actionable maps, indicators, and reports that support urban planning and risk mitigation.

B. Learning Outcomes

When completing this module, the learner is expected to be able to independently:

1. Collect, preprocess, and integrate remote sensing and geospatial datasets from multiple sources.
2. Compute and apply key spatial indicators (NDVI, LST, density metrics, hydrological indices, and vulnerability scores).
3. Produce thematic maps showing susceptibility to heat, pollution, earthquakes, and floods using GIS analysis.
4. Assess and justify the relevance of predictors (terrain, soil, land cover, building attributes) in different risk models.
5. Communicate and recommend evidence-based mitigation measures through structured reports and cartographic outputs.

C. Learning Units / Concepts

UNIT 1 – Assignment 1 - Mapping Urban Heat Islands (UHI) in Niš, Serbia	
Description	Detect UHI hotspots in Niš and relate them to vegetation cover and built-up density.
Learning objective	Understand spatial patterns of UHI and link them to urban structure.

Task Breakdown	• Define study area using bounding box • Compute LST for two summer dates (students choose). • Calculate NDVI and NDBI • Map UHI hotspots (LST > city average) • Identify which variables drive the hotspots • Students propose 3 mitigation measures • Produce a short report that compiles methods, results, maps, and conclusions.
Data Requirements	**Required:** LST, NDVI **Students identify:** Built-up density metrics, imperviousness, population exposure.
Output Requirements	**Required:** UHI hotspot map. **Students identify:** Which derived indicators best show UHI cause (e.g., NDVI–LST correlation)
Recommended Datasets	Sentinel-2 L2A, Landsat 8/9 LST, Copernicus HRL Imperviousness, OSM Buildings.
Expected workload	**10–15 hours** total: • Independent data acquisition and preprocessing: 3–4 hours • Remote-sensing processing (LST, NDVI, NDBI): 3–5 hours • Spatial analysis and hotspot extraction: 2–3 hours • Interpretation and identifying drivers of UHI: 1–2 hours • Report writing and map preparation: 2–3 hours
Scoring (100% total)	**Data and preprocessing -25%** • Valid data sources, clear metadata, reproducible preprocessing. **Analysis - 25%** • Correct LST/index calculations, thresholds, and method justification. **Maps - 20%** • Clear cartography, correct legends/units, proper georeferencing. **Interpretation - 15%** • Reasonable conclusions, correlations, and limitations. **Report - 15%** • Good structure, concise findings, three well-justified recommendations**.**

UNIT 2 - Assignment 2 - Identifying Low-Vegetation and High-Heat Zones in Central Belgrade for Greening Planning	
Description	Locate blocks in Belgrade where lack of green spaces contributes to overheating.
Learning objective	Evaluate where greening interventions have highest cooling potential.
Task Breakdown	• Compute NDVI across municipality boundaries. • Detect blocks <10% vegetation. • Overlay LST and identify “high-heat, low-green” areas. • Rank 5 priority zones for greening. • Define which morphological variables matter (height, density…). • Produce a short report that compiles methods, results, maps, and conclusions.
Data Requirements	**Required:** NDVI, LST. **Students identify:** Morphological predictors (building height, density, orientation).

Output Requirements	**Required:** Priority map. **Students identify:** Greening potential indicators (e.g., predicted °C reduction).
Recommended Datasets	Sentinel-2, Copernicus Urban Atlas, EU DEM/DSM, OSM Buildings
Expected workload	**8–11** hours total: • GIS preprocessing: 2–3 hours • Index calculations (NDVI, LST): 1–2 hours • Spatial analysis and overlays: 2 hours • Ranking of priority zones: 1 hour • Report writing and map layout: 2–3 hours
Scoring (100% total)	**Data and preprocessing - 25%** • Correct NDVI/LST extraction, clean inputs, reproducible workflow. **Analysis - 25%** • Accurate vegetation thresholding, overlays, and ranking logic. **Maps - 20%** • Clear priority map, readable symbology, consistent units/legends. **Interpretation - 15%** • Reasoned explanation of low-green/high-heat patterns and morphology links. **Report - 15%** • Well-structured summary with methods, maps, findings, and top 5 recommendations.

UNIT 3 - Assignment 3 - Detecting Old and Energy-Inefficient Buildings in Novi Sad	
Description	Identify where old building stock correlates with winter pollution.
Learning objective	Map energy-inefficient districts and evaluate their contribution to winter pollution.
Task Breakdown	• Load building footprints. • Assign age categories (students choose thresholds). • Map areas with highest density of old buildings. • Overlay winter NO_2/$PM_{2.5}$. • Propose a simple indicator (a formula or score) that shows which buildings or districts most urgently need energy renovation. • Identify zones with highest retrofit effect. • Produce a short report that compiles methods, results, maps, and conclusions.
Data Requirements	**Required:** Building age proxy. **Students identify:** Environmental or socio-economic indicators (traffic, population density…).
Output Requirements	**Required:** Map of old building clusters. **Students identify:** Retrofit index (formula + spatial score).
Recommended Datasets	Urban Atlas, cadastral age data or proxy layers, Sentinel-5P NO_2/PM, CAMS reanalysis.
Expected workload	**8–11** hours total: • GIS preprocessing: 2–3 hours • Index calculations (NDVI, LST): 1–2 hours • Spatial analysis and overlays: 2 hours • Ranking of priority zones: 1 hour

	• Report writing and map layout: 2–3 hours
Scoring (100% total)	**Data and preprocessing - 25%** • Correct NDVI/LST extraction, clean inputs, reproducible workflow. **Analysis - 25%** • Accurate vegetation thresholding, overlays, and ranking logic. **Maps - 20%** • Clear priority map, readable symbology, consistent units/legends. **Interpretation - 15%** • Reasoned explanation of low-green/high-heat patterns and morphology links. **Report - 15%** • Well-structured summary with methods, maps, findings, and top 5 recommendations

UNIT 4 – Assignment 4 - Earthquake Damage Susceptibility Mapping for Kraljevo Region	
Description	Model susceptibility using terrain, soil type, building height/age, and land cover.
Learning objective	Understand which zones are more vulnerable to seismic impacts.
Task Breakdown	• Define hazard area around Kraljevo. • Choose vulnerability predictors (slope, soil moisture, building type…). • Produce susceptibility map (weighted overlay) • Identify high-risk settlement clusters. • Justify variable selection. • Produce a short report that compiles methods, results, maps, and conclusions.
Data Requirements	**Required:** DEM, land cover. **Students identify:** Soil type, building density, geotechnical proxies.
Output Requirements	**Required:** Susceptibility map. **Students identify:** Damage probability classes and final risk output.
Recommended Datasets	SRTM DEM, CCI Land Cover, Copernicus Soil Moisture, OSM Buildings.
Expected workload	**8–12** hours total: • Data collection and preprocessing: 2–3 hours • Predictor selection and derivation (slope, soil, buildings…): 2 hours • Weighted overlay and susceptibility mapping: 2 hours • Identifying high-risk clusters: 1 hour • Report writing and map layout: 2–3 hours
Scoring (100% total)	**Data and preprocessing - 25%** • Correct loading of DEM/land cover, clean preparation of additional predictors. **Analysis - 25%** • Proper derivation of predictors, justified weights, and correct susceptibility mapping. **Maps - 20%**

	• Clear susceptibility map with correct legends, classes, and readable symbology. **Interpretation - 15%** • Solid explanation of vulnerable zones, variable relevance, and model limitations. **Report - 15%** • Well-organized document with methods, maps, results, and conclusions.

UNIT 5 - Assignment 5 - Flood Susceptibility and Hazard Mapping for the Kolubara River Basin	
Description	Map zones vulnerable to flooding based on terrain, hydrology, land cover, and river proximity.
Learning objective	Understand drivers of flood susceptibility and produce actionable spatial risk layers.
Task Breakdown	• Delineate study area around Kolubara basin. • Derive hydrological layers: flow accumulation, flow direction, slope, TWI. • Identify low-elevation and flat areas near streams. • Combine predictors into flood susceptibility model (weighted overlay) • Students define flood hazard classes. • Identify settlements and infrastructure at risk. • Produce a short report that compiles methods, results, maps, and conclusions.
Data Requirements	**Required:** DEM, river network. **Students identify:** Soil type, land use, rainfall intensity, distance-to-river thresholds.
Output Requirements	**Required:** Flood susceptibility map. **Students identify:** Final hazard classes (low/medium/high) and exposure assessment.
Recommended Datasets	EU-DEM, SRTM DEM, Copernicus Land Cover, HydroSHEDS, OSM Rivers/Streams.
Expected workload	**9–13** hours total: • Data collection and preprocessing: 2–3 hours • Hydrological derivations (flow dir/accum, slope, TWI): 2 hours • Flood-prone terrain identification (low elevation, flat areas, buffers): 1–2 hours • Weighted overlay and susceptibility modeling: 1–2 hours • Exposure assessment (settlements & infrastructure): 1 hour • Report writing and map layout: 2–3 hours
Scoring (100% total)	**Data and preprocessing - 25%** • Correct DEM preparation, hydrological layers, and clean predictor inputs. **Analysis - 25%** • Accurate hydrological modeling, well-justified weights, logical hazard class definitions. **Maps - 20%** • Clear susceptibility/hazard maps with correct symbology, elevation units, and class labels.

	Interpretation - 15% • Sound explanation of flood drivers and identification of at-risk settlements/infrastructure. **Report - 15%** • Well-structured document summarizing workflow, maps, findings, and conclusions.

D. Glossary

- **Bounding box** – A rectangular geographic extent used to define the study area in a GIS project.
- **Land Surface Temperature (LST)** – Temperature of the Earth's surface derived from thermal satellite data, used to analyse heat patterns.
- **NDVI (Normalized Difference Vegetation Index)** – A satellite-based index measuring vegetation health and abundance.
- **NDBI (Normalized Difference Built-up Index**) – An index used to detect built-up or impervious surfaces in urban areas.
- **Imperviousness** – The proportion of sealed surfaces (asphalt, concrete) that prevents water infiltration and increases heat accumulation and runoff.
- **Built-up density** – The concentration of buildings or urban structures in a given area.
- **Flow accumulation** – Hydrological raster showing how water accumulates downslope; used to identify stream networks and flood-prone channels.
- **Flow direction** – Raster indicating the direction water flows across each pixel in a DEM.
- **TWI (Topographic Wetness Index) –** A terrain-derived indicator of soil moisture and potential water accumulation.
- **DEM (Digital Elevation Model)** – A raster representation of terrain elevation.
- **Susceptibility map** – A map that shows areas more likely to be affected by a specific hazard (heat, flood, earthquake).
- **Weighted overlay** – A GIS technique where multiple indicators are combined by assigning weights to produce a composite risk/suitability score.
- **Building age proxy** – Any dataset or method used to estimate the age of buildings when direct age data are unavailable.
- **Retrofit index** – A derived score indicating which buildings or areas most urgently need energy renovation.
- **Predictor variable** – A dataset or factor used as input for analysis or modelling (e.g., slope, vegetation, density).
- **Hazard classes** – Categories indicating levels of hazard intensity or probability (e.g., low, medium, high).
- **Exposure assessment** – Evaluation of which population, infrastructure, or assets are located within hazard-prone areas.
- **Settlement cluster** – A group of buildings or inhabited areas analysed together in risk mapping.

- **Morphological variables** – Physical characteristics of the urban form, such as height, density, and layout.
- **Mitigation measures** – Actions proposed to reduce environmental risk or improve resilience (e.g., adding green spaces, drainage improvements).
- **Spatial indicator** – A quantitative measure mapped across space to show patterns (e.g., vulnerability score, heat hotspot index).

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