URBAN DEVELOPMENT EXPLORATIONS USING NATURAL EXPERIMENTS

D5.3: Practical User Guidelines

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Abbreviations and Acronyms

Abbreviations/Acronyms	Description
EO	Earth Observation
SDG(s)	Sustainable Development Goal(s)
PCDE	Plan for Communication, Dissemination and Exploitation (Activities)
CDE	Communication, Dissemination and Exploitation
WP(s)	Work Package(s)
EAB	External Advisory Board
Dx.y	Deliverable x.y
DSDM	Dynamic Systems Development Method
NLP	Natural Language Processing
LST	Land Surface Temperature
UHI	Urban Heat Island
SUHI	Surface Urban Heat Island
PM2.5	Particle Matter pollutants with 2.5 microns or less in diameter
PM10	Particle Matter pollutants with 10 microns or less in diameter
MNDWI	Modified Normalized Difference Water Index
NDVI	Normalized Difference Vegetation Index
NDBI	Normalized Difference Built-Up Index
NDWI	Normalized Difference Water Index
SAVI	Soil-Adjusted Vegetation Index
IBI	Index-Based Built-Up Index
EVI	Enhanced Vegetation Index
NGOs	Nongovernmental Organisations
SMEs	Small and Medium-sized Enterprises

Executive Summary

Deliverable 5.3 provides practical guidelines and comprehensive documentation for the use of the UDENE platform's key outputs: the Exploration and Matchmaking Tool. This tool is designed to enhance data-driven urban development and environmental planning by offering intuitive access to Earth Observation (EO) data and tailored analytics.

Integrated into the UDENE website, tool feature interactive elements and a sidebar tooltip system that provides contextual definitions and instructions, making the user experience more accessible. A detailed webinar is also available via the UDENE YouTube channel to support onboarding and deeper tool engagement.

The document outlines the tools' architecture, access pathways, and functionality – from user registration to dataset management and experiment execution. It also maps stakeholder profiles (e.g., urban planners, researchers, SMEs) and presents user-specific scenarios to guide engagement. Supporting resources include online training materials, in-situ/off-situ usage guidance and access to the UDENE Data Cube. Real-world applications are illustrated through use cases in Serbia, Tunisia, and Türkiye, showcasing the tools' relevance to diverse urban challenges.

Finally, the report establishes best practices and outlines a structured update and feedback mechanism to ensure the continuous improvement and long-term utility of the tools beyond the project's lifecycle.

The structure of the document follows the user journey and functionality of the tools:

– **Introduction**

Presents the background and objectives of the deliverable, framing the tools within the broader goals of the UDENE project.

– **Accessing the Tools**

Explains how users can access the platform and tools through the UDENE project website, including login, registration, and interface overview.

– **UDENE Tools**

Describes the architecture, features, and interactions of the Exploration and Matchmaking tools, with detailed guidance on dashboard use, datasets, and experiment functionalities.

– **User Profiles and Stakeholders**

Identifies key target groups—urban planners, researchers, SMEs, and public/private stakeholders—and explains how the tools meet their specific needs.

– **Use Case Description Guidelines & UDENE Use Cases – Excerpt**

Provides a structured format and guidance for partners to describe use cases consistently and effectively. Showcases applied examples from Serbia, Tunisia, and Türkiye to demonstrate the practical relevance and adaptability of the tools.

– **Guidelines for Effective Usage & Updates and Revisions**

Shares best practices and tips for maximizing the functionality and value of the tools in various urban development scenarios. Details the procedures for updating user guidelines and outlines the feedback mechanism to ensure continuous improvement.

Together, these chapters form a complete resource to support the adoption, application, and long-term sustainability of UDENE tool.

Introduction

Urbanization is rapidly increasing worldwide, with cities experiencing significant growth in population density. Climate change, social inequalities, and conflicts are key drivers pushing populations toward cities in search of better living conditions and opportunities. However, urban development, particularly in emerging regions, often lacks evidence-based planning, leading to deteriorating living conditions and increased pressure on infrastructure, resources, and public services. The UDENE Project aims to address these challenges by leveraging extensive Earth Observation (EO) data from Copernicus satellites and local sources to support data-driven urban development. By focusing on international partner countries, the project will align with UN SDG 11, which seeks to make cities inclusive, safe, resilient, and sustainable. The project will create a virtual laboratory where urban planners and innovators can experiment with different development ideas. These experiments will be powered by multi-dimensional models of urban areas, allowing users to examine similar development initiatives in other regions over time, thus conducting "natural experiments."

The vast EO data, available in an easily accessible Data Cube format, will offer planners a comprehensive search space for exploring these natural experiments, enriched by causal analysis. The project's outcomes include an exploration tool to support this research and a matchmaking tool that connects users with relevant EO products, processes, and services.

The Exploration Tool developed under the UDENE project will serve as a critical resource for urban planners, offering a virtual environment to simulate and analyse various urban development scenarios. By integrating multi-dimensional models with real-time and historical Earth Observation (EO) data, this tool enables users to explore "natural experiments" by observing how similar projects or ideas have unfolded in comparable urban areas across different regions and timelines. This empowers planners to make informed decisions based on evidence and patterns derived from EO data, ensuring that proposed interventions are more likely to succeed.

The Matchmaking Tool complements this by connecting users with EO service providers and solutions tailored to their specific urban planning needs. It leverages the insights generated from the Exploration Tool to suggest relevant products, services, and technologies that can be applied to implement the identified strategies. By streamlining access to these resources, the Matchmaking Tool facilitates collaboration between urban planners and EO providers, enabling faster, more efficient integration of EO-based solutions into urban development projects. Together, these tools provide a comprehensive, data-driven framework for advancing sustainable urban development.

Additionally, project activities will foster collaborations for data acquisition and build partnerships through Open (FSTP) Calls. The evidence-based approach promoted by UDENE will complement existing EO services, enhancing European leadership in EO technology, particularly in urban development with high economic and societal benefits.

The Deliverable 5.3 Practical User Guideline for the UDENE project's Exploration and Matchmaking Tools is designed to equip stakeholders and users, mainly urban planners, developers, and decision-makers with comprehensive instructions to effectively utilize these innovative resources. By leveraging Earth Observation (EO) data, these tools facilitate evidence-based urban planning, promoting sustainable and resilient city development.

Sustainable Development Goal (SDG) 11, the "urban SDG," aims to make cities and human settlements inclusive, safe, resilient, and sustainable. It emphasizes the importance of local perspectives for achieving sustainable development and aligns with the New Urban Agenda (NUA), which enhances SDG effectiveness at the community level. Both frameworks highlight the need for high-quality, timely, and reliable disaggregated data across social, economic, and environmental dimensions to ensure no one is left behind.

Earth Observation (EO) data plays a crucial role in monitoring SDG 11 indicators by providing spatial, spectral, and temporal insights that support urban planning and policymaking. National statistical offices, ministries, city governments, and communities can use EO data, such as satellite imagery and mapping products, to address urban monitoring needs and drive informed decisions. These stakeholders also contribute valuable feedback to improve EO missions and products for future applications.

Exploration Tool - The Exploration Tool integrates global remote sensing and in-situ data within an innovative Data Cube framework. This setup allows users to visualize and assess the potential impacts of urban development initiatives under various environmental and hazard conditions. By providing scenario-based projections, the tool serves as a virtual laboratory for testing and refining urban planning concepts.

The Practical User Guidelines will be made accessible through the project website. The content for these guidelines will be developed during UDENE's ongoing activities.

To support users, basic online training on Earth Observation (EO) technologies and products will also be provided. This training will include practical examples and use cases, ensuring potential users have a solid foundation to understand and utilize EO-based products and services effectively.

The Practical User Guidelines will serve as a key reference for stakeholders and participants in the Open Calls, catering to various user levels. These guidelines will undergo multiple revisions throughout the project, incorporating feedback from the External Advisory Board (EAB) to ensure their relevance and effectiveness.

Objectives

The objective of this deliverable is to provide comprehensive and user-friendly guidelines for effectively utilizing the UDENE project's Exploration and Matchmaking tools.

These guidelines aim to:

- Facilitate informed urban planning decisions by leveraging Earth Observation (EO) data and advanced tools.
- Promote the adoption of EO technologies across diverse user groups.
- Enhance the usability and accessibility of the tools by offering practical instructions and real-world use cases.

Scope and Relation with other WPs

The Deliverable 5.3 Practical User Guide aligns closely with the overarching goals of the UDENE project, integrating inputs and outcomes from related work packages and associated deliverables:

- WP2 - Building and Operationalizing the Data Cube Building and Operationalizing the Data Cube- Staging available in-situ data to be ready for analysis and store in data cubes that link to existing EO data cube federations:
    - D2.1 – UDENE Data Cube
- WP3 - Causal Effects Analysis of Natural Experiments - Selection and descriptions of representative natural experiments and tools development through:
    - D3.1 – Use Case Descriptions
    - D3.3 – Inventory of the European providers of EO-based Applications and Services
    - D3.4 – Operational Exploration Tool and Matchmaking Tool
- WP4 - International Partnerships and Exploitation – Establishing the Work program for Open Calls for beta testing of the tools through:
    - D4.1 – Work Programme of the Open Calls
- WP5 - Communications, Dissemination, and Visibility – Establishing the environment and community for users, development of users training sessions and outreach activities to maximize tool adoption and open calls outreach, through:
    - D5.1 – Project Web Site
    - D5.2 – Plan for Dissemination and Exploitation Including Communication Activities

The scope of this deliverable covers the creation of a structured, hypertext-accessible guideline that incorporates basic EO training, tool functionalities, and stakeholder engagement strategies.

Overview and Purpose of UDENE Tools

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 (an intervention or treatment). 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.

Exploration Tool

The **Exploration Tool** is a virtual laboratory for urban planners. It will enable them to explore various urban development ideas by analysing a large dataset of Earth Observation (EO) data, enriched with other local data sources. This tool allows users to simulate natural experiments in urban settings, using multivariate models to explore different urban development strategies across time and space. These simulations offer insights into how similar interventions have played out in other cities, providing a knowledge base that can inform future urban planning decisions. Through causal analysis and sensitivity studies, users can visualize the potential impacts of changes such as infrastructure development, energy efficiency projects or transportation upgrades on environmental sustainability, energy consumption or public health. The tool offers decision-makers detailed, actionable insights and evidence to support their urban development strategies and decisions.

The development of the **Exploration Tool** involves several stages of prototyping, following the Dynamic Systems Development Method (DSDM) framework. DSDM is an agile software development methodology that emphasizes user involvement and iterative design. After identifying the core requirements for the tool, wireframes, mock-ups, and concept videos will be developed to demonstrate the tool's potential capabilities. Once the initial design is validated, a preliminary (alpha) version of the tool will be created. User interactions with this version will be carefully monitored, and their feedback will be used to refine and enhance the tool's functionality. Short development cycles or sprints will be employed to implement these improvements rapidly while keeping track of ongoing development priorities.

The tool will also feature advanced information visualization capabilities. It will not only provide data, but also offer causal explanations, helping users understand the relationships between different variables in the urban environment. For example, it will allow users to see how changes in urban density might impact traffic congestion or air quality, offering both high-level insights and granular details. The visualizations will be supported by the models developed in earlier tasks (T3.1 and T3.2), enabling users to explore the evidence in a way that directly informs decision-making. An important aspect of the UX design is to ensure that users can easily interpret the data and extract meaningful conclusions from it, as this is critical to effective urban planning and policymaking.

Purpose: Supports urban planners by offering a Data Cube framework for scenario-based analysis, integrating EO and in-situ data.

Key Features: Visualizations, hazard mapping, and predictive analysis for urban development projects.

Matchmaking Tool

Complementing the **Exploration Tool** is the **Matchmaking Tool**, which aims to bridge the gap between urban planners and EO service providers. As urban planners explore the data and simulations within the Exploration Tool, the Matchmaking Tool is integrated into the Exploration tool and offers access to a curated list of EO-based products and service providers who can help implement the ideas. This tool will leverage a vast inventory of European EO providers, linking users with organizations that offer relevant services such as geospatial analysis, satellite imagery, or environmental monitoring solutions.

By utilizing a matchmaking algorithm, the tool will analyse the user's specific requirements, gleaned from their interaction with the Exploration Tool, and match them with providers that offer suitable services or products.

The development of the Matchmaking Tool was guided by principles of user-centric design. The matchmaking algorithm uses Natural Language Processing (NLP) techniques to extract relevant information from the online profiles and portfolios of EO service providers. The information is matched against the context provided by the user, ensuring that the tool offers highly relevant and tailored recommendations. Users can review detailed profiles of each service provider, including their expertise, contact information, and examples of past projects, making it easier for urban planners to establish partnerships and implement EO-based solutions in their cities.

Furthermore, the Matchmaking Tool provides an **Automated Reporting** feature that tracks user activity and interactions within both tools. This functionality will compile a log of the user's engagement with the tools, including the data they explored, the simulations they ran, and the service providers they contacted – Experiment History (Figure 7). These reports will be stored for future reference, allowing users to revisit their past work and build on it in future projects. This feature also enables organizations to maintain a record of their urban planning activities, facilitating better knowledge management and continuity in long-term urban development projects.

These tools collectively provide a robust platform for data-driven urban planning and decision-making.

Purpose: Connects users with relevant EO products, services, and expertise to address specific urban challenges.

Key Features: Searchable database, recommendations, and integration with European space sector solutions.

Accessing the Tools

Access via the Project Website

To access the Exploration Tool and Matchmaking Tool via the UDENE website, users can navigate to the designated "Tools and Services" section available on the main menu. Within this section, the Exploration Tool (***Figure 1***) provides an interactive interface to analyse urban scenarios, integrating Earth Observation (EO) data and predictive analytics for sustainable urban planning. Users can log in with their credentials or register for access (***Figure 6***), allowing them to explore datasets, visualize urban trends, and simulate development impacts. Similarly, the Matchmaking Tool (***Figure 2***) is accessible through the same section and connects users with tailored EO-based solutions, services, and products. This tool includes a user-friendly search function and recommendations based on specific project needs, fostering collaboration and adoption of EO technologies. Both tools are designed to ensure seamless navigation and accessibility, making it easy for urban planners, researchers, and other stakeholders to utilize their features effectively.

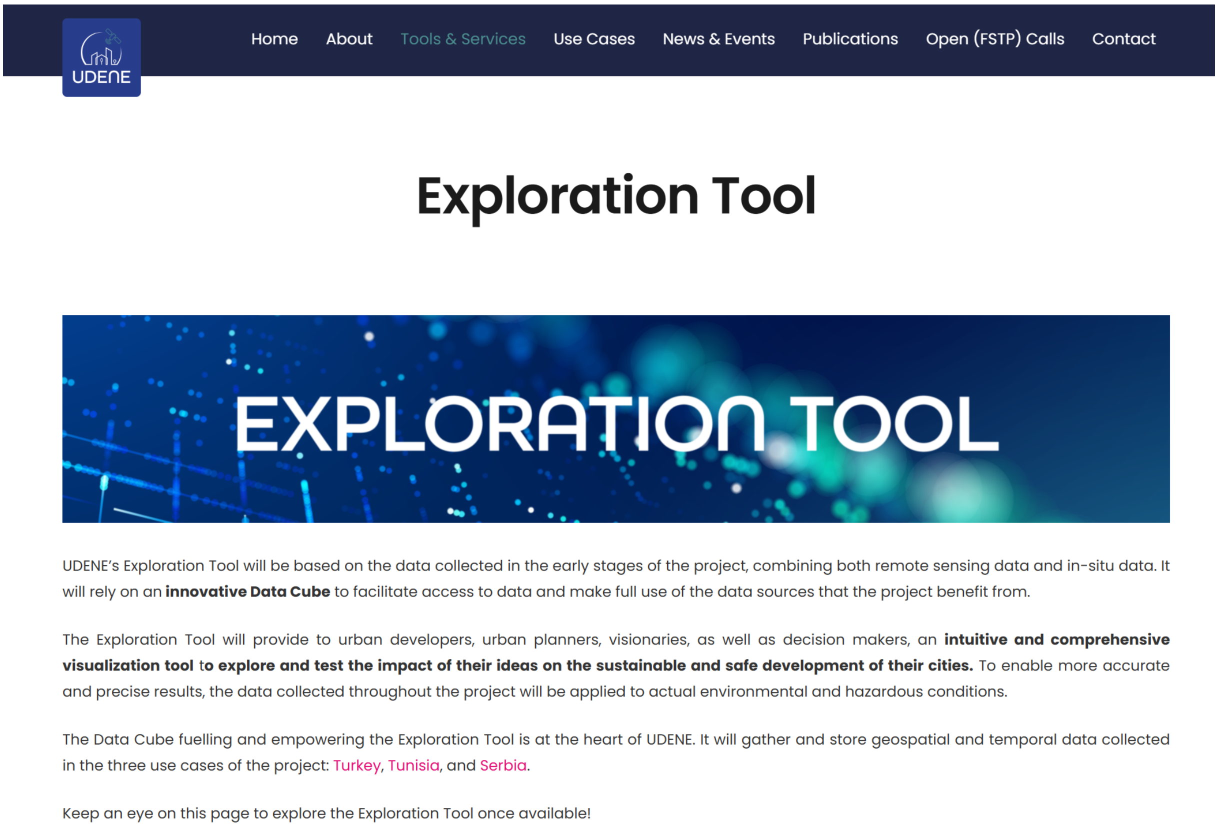


Figure 1.Access to Exploration tool via UDENE Website

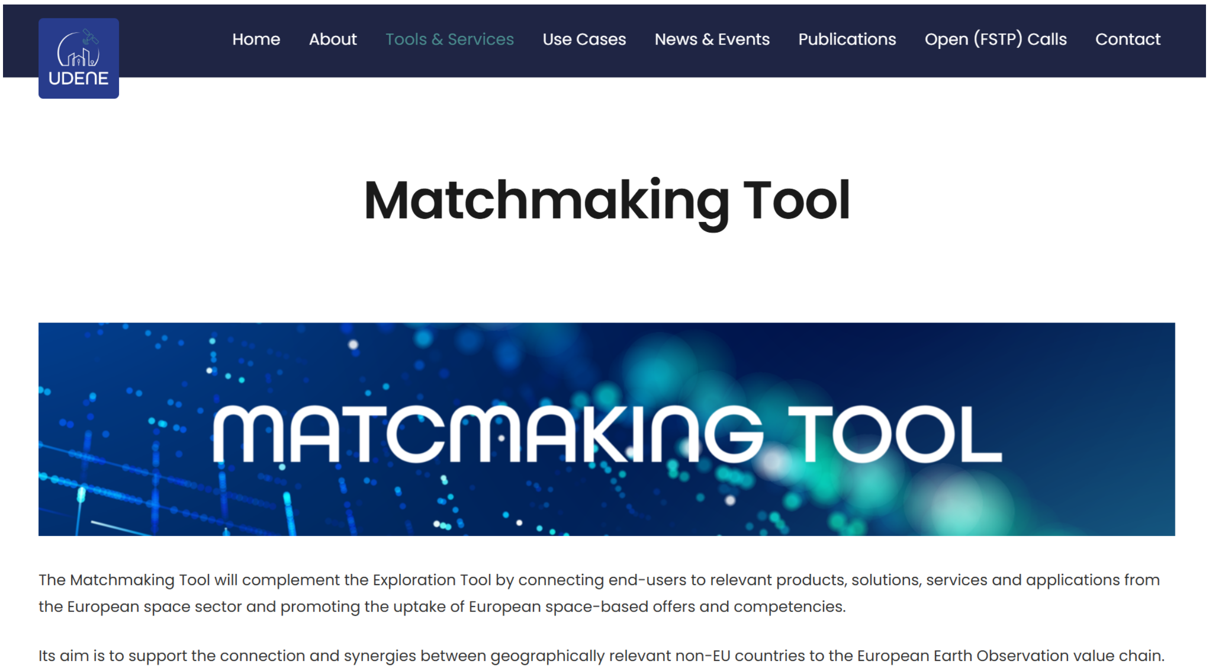


Figure 2. Access to Matchmaking tool via UDENE Website

UDENE Tools

To ensure the tools' usability across different regions, the interfaces for both the Exploration Tool and the Matchmaking Tool are available in English, making them accessible to a broad range of users. Additionally, the tools will support a diverse array of urban development scenarios, from small-scale interventions to large, city-wide planning initiatives, allowing for flexibility in how they are used by urban planners and other stakeholders involved in urban development.

The tools are intuitive, easy to use and capable of handling the complex datasets involved in urban planning. The goal was to create tools that provide valuable insights and make the process of exploring and applying the insights as straightforward as possible for users, thereby contributing to more informed and effective urban planning decisions across Europe and beyond

Architecture and Interactions

The **UDENE system architecture** consists of a multi-layered structure designed to facilitate efficient data management, processing, and analysis.

Figure 3 shows the **Analytics Workflow: Discovering Urban Development Natural Experiments in EO Data** as envisioned in the project preparation stage, details how the system processes and analyses Earth Observation (EO) data for urban development. It is structured into three key tools:

1. **Exploration Tool** – Allows users to select outcome variables and urban regions of interest, utilizing an **EO Data Cube** to filter similar regions and identify relevant input variables.
2. **Discovering Natural Experiments** – Helps users assess potential effects of development ideas by identifying locations with significant deviations in input variables and running **sensitivity analyses** to support decision-making.
3. **Matchmaking Tool** – Leverages a **tagged database** of Copernicus-based products, services, and events to match entities related to user-selected input variables, enriching analysis displays with relevant insights.

Together, these components create a **comprehensive framework** for analysing urban development impacts using AI-driven data cube integrations and advanced modelling techniques.

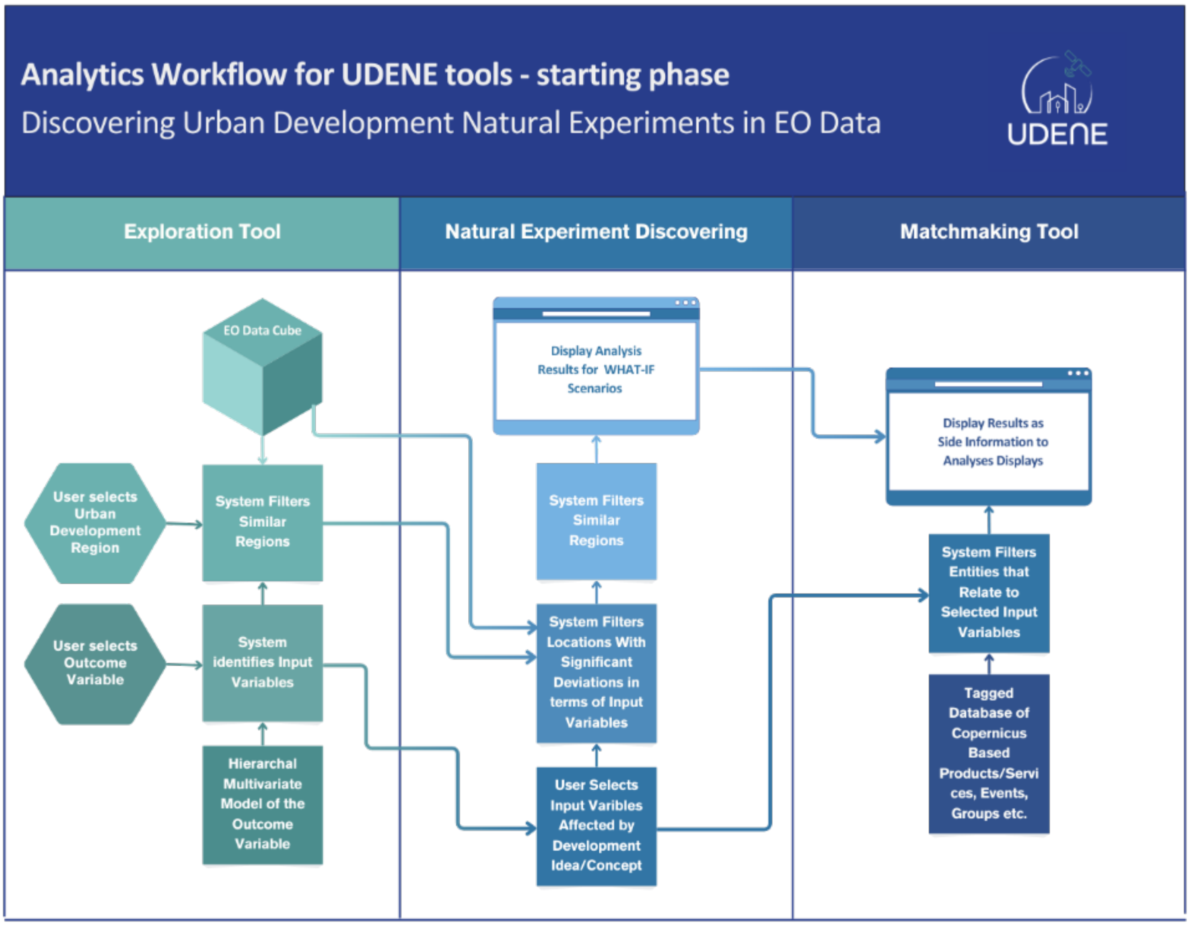


Figure 3. Analytics Workflow: Discovering Urban Development Natural Experiments in EO Data[1]

Figure 3 shows the **Analytics Workflow: Discovering Urban Development Natural Experiments in EO Data**

The **UDENE system architecture** consists of a multi-layered structure designed to facilitate efficient data management, processing, and analysis.

The diagram shown in ***Figure 4*** represents a **General System Architecture Overview**, outlining key components such as the **Frontend**, a **Middle Backend** responsible for user management and MongoDB integration, and an **AI Backend** that enables data cube integration. The AI Backend communicates with multiple **model services** (e.g., BioSense, TUNSA and NiK Systems) via model requests on designated ports.

Additionally, architecture supports future expansion to accommodate custom model services. A **data cube** structure enables integration with global federations, enhancing interoperability and scalability.

[1] UDENE Grant Agreement, 2023

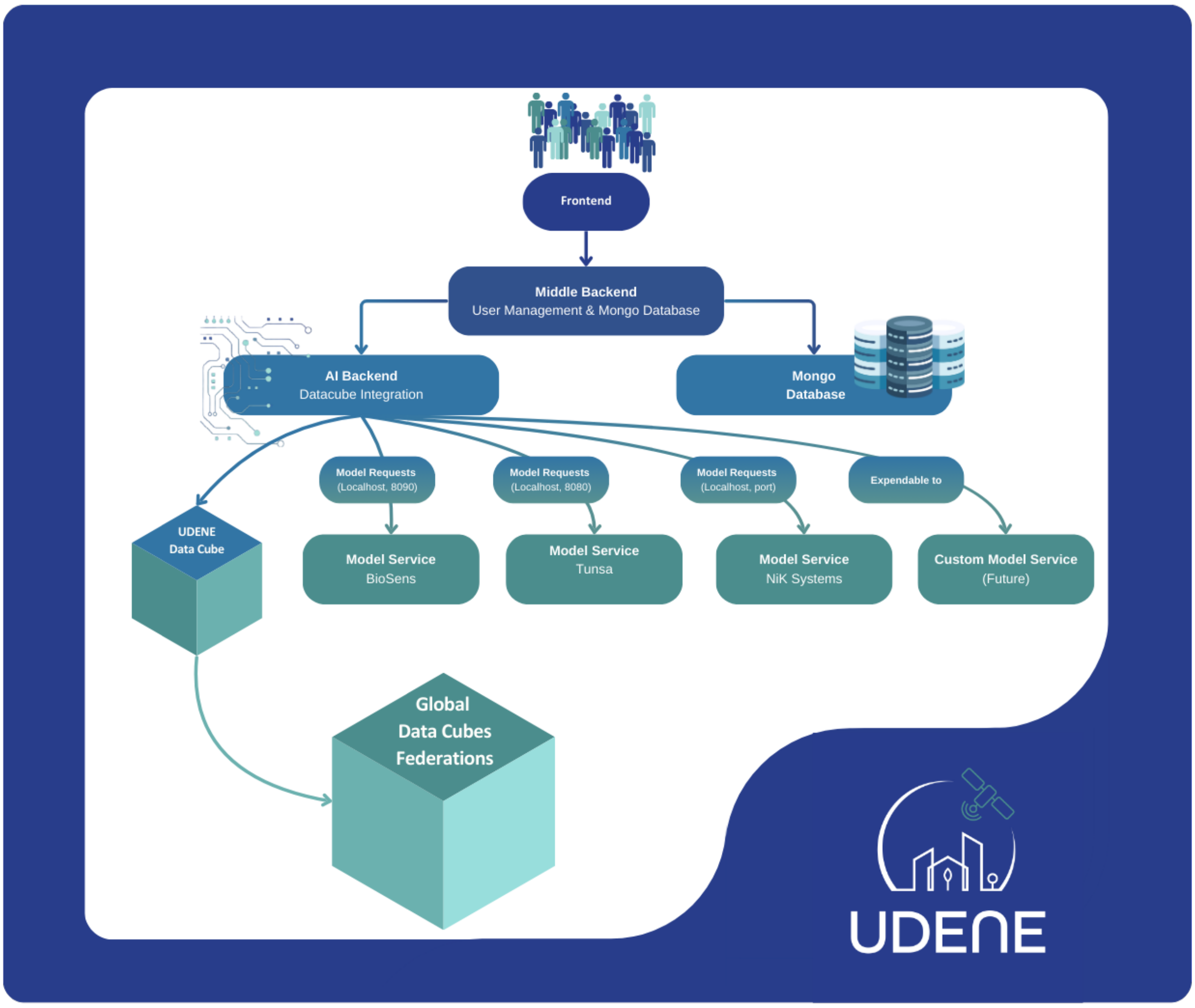


Figure 4. General System Architecture Overview

User Guidelines

After accessing the Exploration tool through the UDENE website **Exploration Tool webpage**, user comes in the contact of the Login page. The UDENE platform requires user authentication through Login and Registration screens, ensuring secure access to datasets and experiment functionalities. Below are the details of both interfaces.

Login and Registration

The **Login page** (***Figure 5***) allows registered users to access their accounts by entering their credentials.

Components:

- **Email Input Field** – Users must enter their registered email.
- **Password Input Field** – Users must enter their password.
- **Forgot Password Link** – Provides password recovery options if users cannot access their accounts.
- **Login Button** – Submits the entered credentials for authentication.
- **Register Link** – If the user does not have an account, they can click "Register" to create one.

Login Process:

1. Enter a valid **email** and **password** in the respective fields.
2. Click **Login** to access the UDENE platform.
3. If the credentials are incorrect, an error message will appear.
4. If the user has forgotten their password, they can click the **"Forgot your password?"** link to recover it.
5. If the user does not have an account, they can click **"Register"** to create a new account.

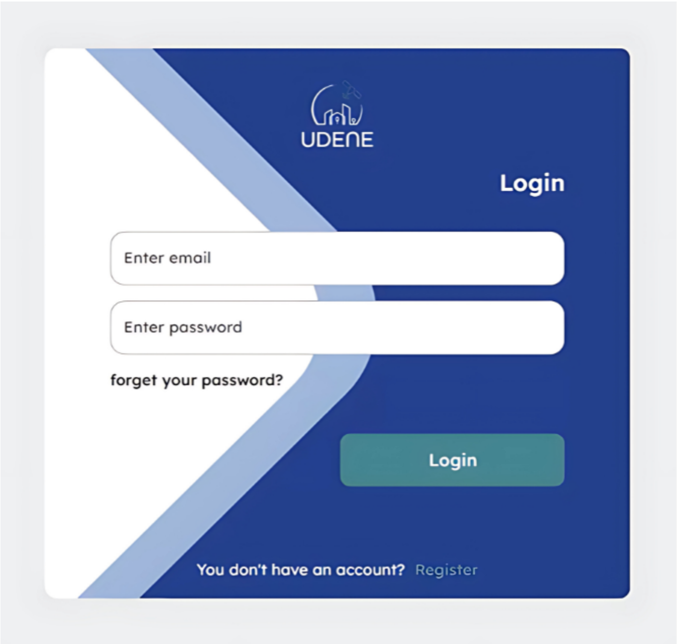


Figure 5. Login to UDENE Tools system

For the first time users, registration form enables account creation (***Figure 6***). The **Registration page** allows new users to create an account to access UDENE's features.

Components:

- **Name Input Field** – Users enter their first name.
- **Last Name Input Field** – Users enter their last name.
- **Email Input Field** – Users must provide a valid email address.
- **Password Input Field** – Users create a secure password.
- **Confirm Password Field** – Users re-enter their password to confirm.
- **Register Button** – Submits the form and creates a new account.
- **Login Link** – If the user already has an account, they can click "Login" to return to the sign-in page.

Registration Process:

1. Fill in all required fields: **Name, Last name, email and password.**
2. Re-enter the password in the **"Confirm Password"** field.

3. Click **Register** to create an account.
4. If registration is successful, the user is redirected to the **Login page.**
5. If there are errors (e.g., password mismatch or invalid email format), a message will prompt the user to correct them.

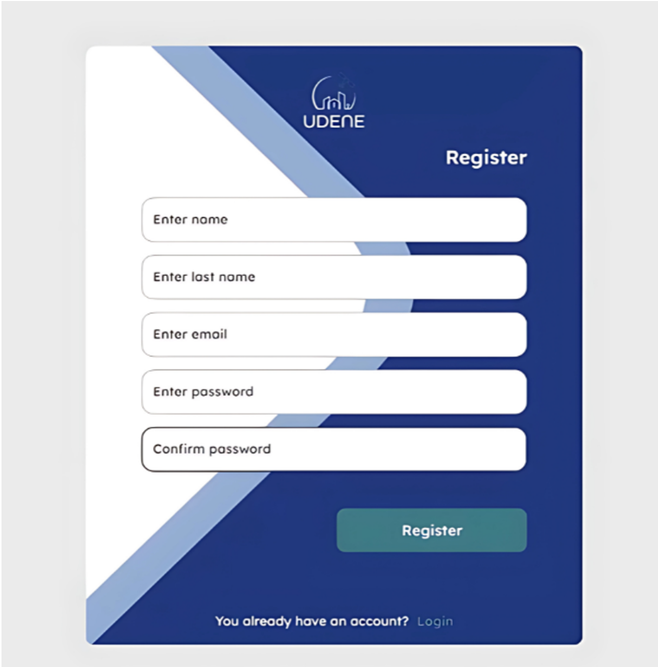


Figure 6. Registration to UDENE Tools system

These authentication steps ensure that **only authorized users** can access and interact with the platform. The **Login page** facilitates secure access for existing users, while the **Registration page** allows new users to sign up for an account. This system ensures data integrity and security within the UDENE platform.

Dashboard

The Dashboard Overview (***Figure 7***) provides users with a centralized space to access and manage datasets and previously conducted experiments. The interface consists of two primary sections: "Datasets" on the left and "Experiment History" on the right. The Datasets section allows users to browse and select datasets for their urban development simulations, enabling them to work with relevant geospatial and analytical data.

When user id signed in, at the top of the interface, three menu options are visible (Figure 7):

- **Datasets** – Allows access to different datasets relevant to urban planning and environmental factors.
- **Experiments** – Enables users to conduct exploration based on selected datasets.
- **Use Cases** – Provides information about UDENE Use Cases and examples results of urban development scenarios upon modelling.

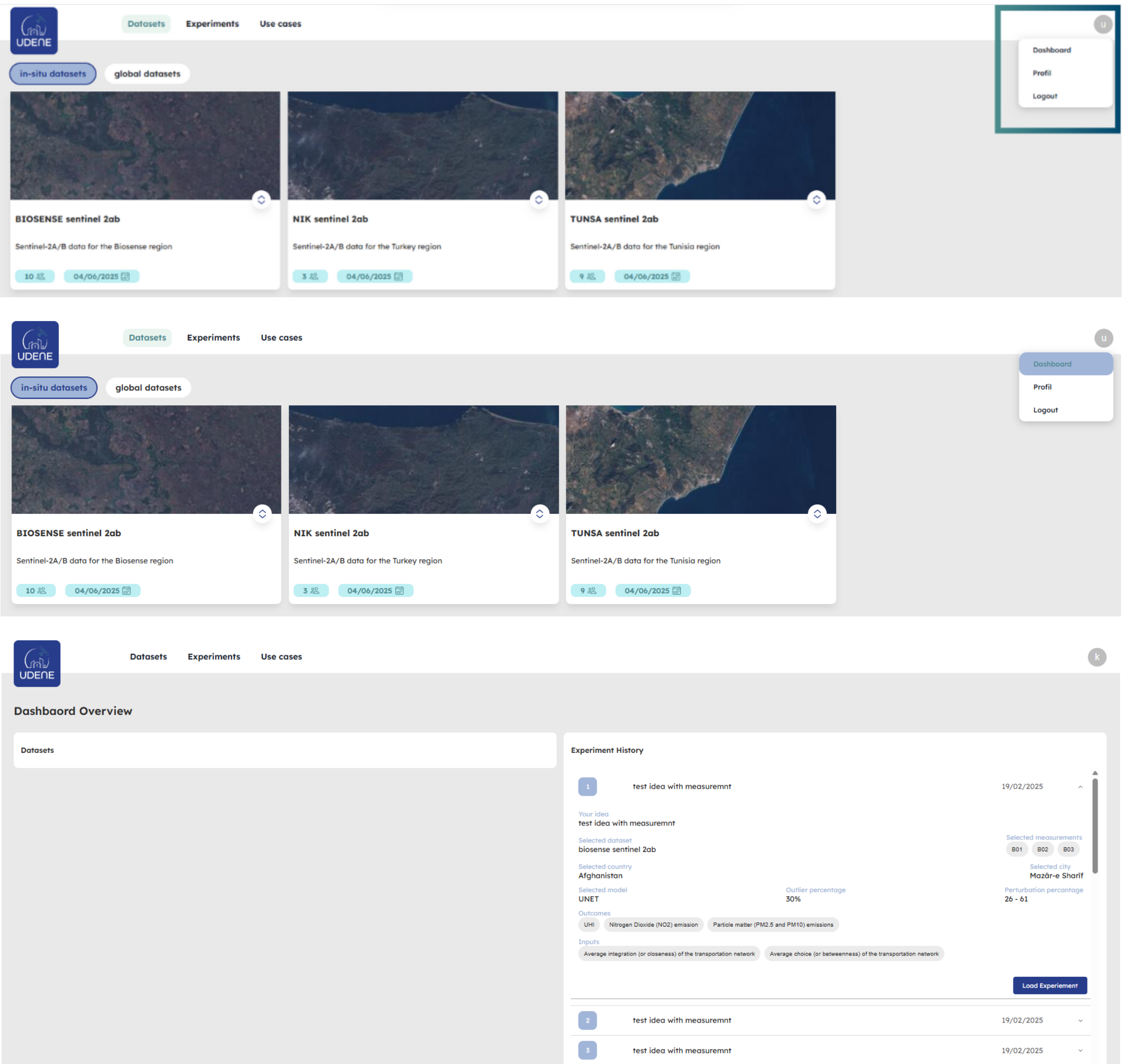


Figure 7. UDENE Tools Dashboard overview and access to Experiment History

The Experiment History section displays previously run experiments along with their corresponding dates. Each recorded experiment is listed with a numerical identifier and name (e.g., "Experiment 1"), followed by the execution date (19/02/2025). Users can reload an experiment by clicking the "Load" button, which restores the settings and data from that session, allowing for further analysis or modifications. This feature is particularly useful for iterative research and model refinement. The dashboard ensures quick access to past work, improving workflow efficiency within the UDENE platform.

Dataset tab

This section of the UDENE platform displays available datasets categorized into "In-Situ Data Sets" and "Global Data Sets." Users can switch between these categories using the respective buttons at the top. Each dataset is represented as a card containing a thumbnail of the dataset, a title, a short description, and metadata.

Each dataset card provides:

- **Title -** Name of the dataset (e.g., alos palsar mosaic, biosense sentinel 2ab, cci landcover).
- **Short Description -** Brief details about the dataset's content (e.g. Sentinel-2A/B data, ALOS/PALSAR annual mosaics).

- **User and Date Information -** An icon with a number indicating how many users have interacted with the dataset. A calendar icon with a date showing when the dataset was last updated (e.g. 15/02/2025).
- **Expanding Dataset Details** - On the bottom right corner of each dataset card, there is a up-down arrow icon enclosed in a button. Clicking this button expands the dataset card to reveal additional details or actions, such as previewing metadata.

This interface allows users to efficiently browse and get familiar with datasets that will be used in urban development and environmental research simulations (***Figure 8***).

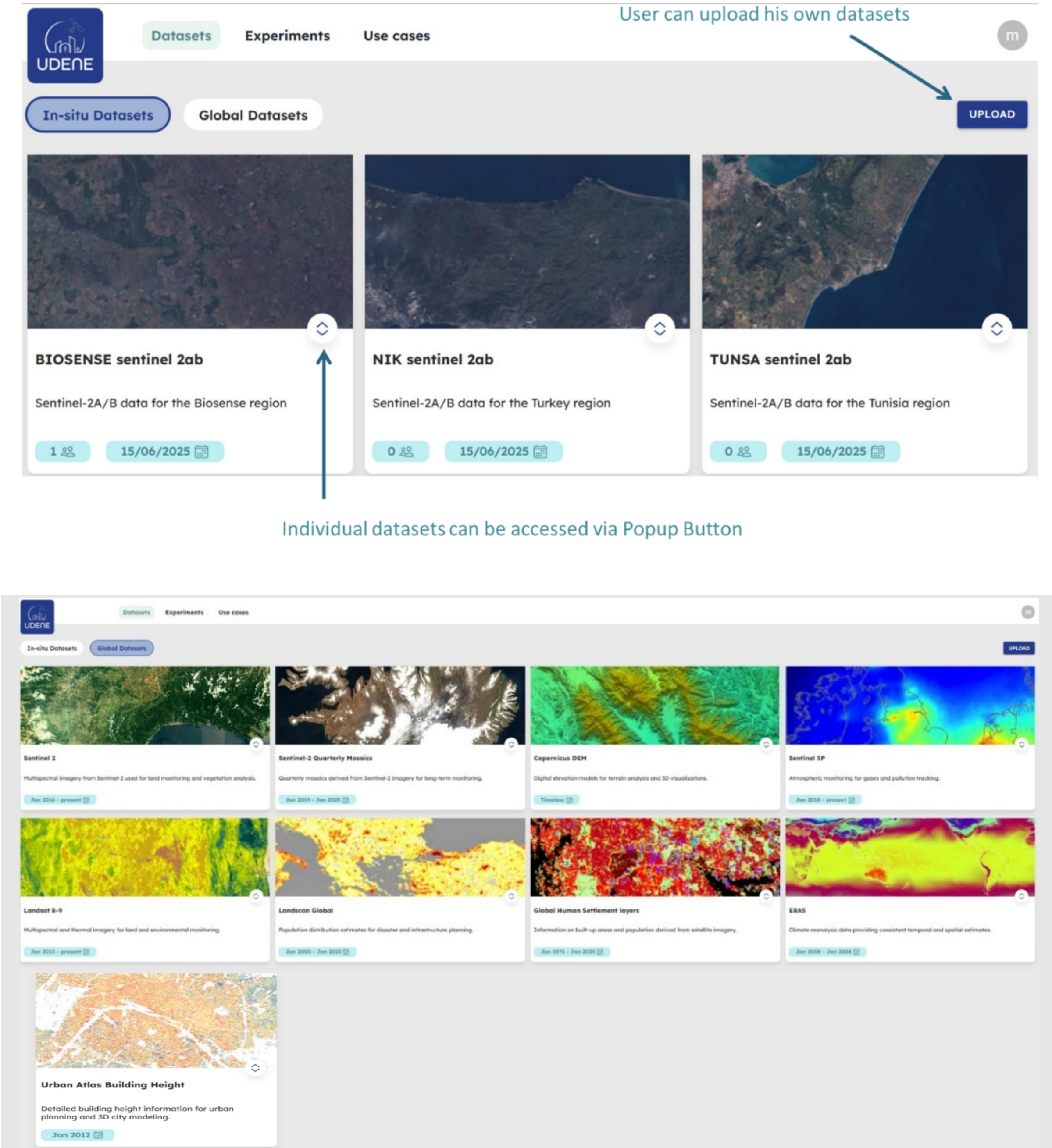


Figure 8. How to access UDENE global data sets

After selecting the dataset to access, users can explore the available data in the provided menu, shown in ***Figure 9***. In addition to the dataset information, this interface provides an interactive way to select and visualize some predefined remote sensing indices. All indices are generated on the fly.

The Data cube keeps only the raw reflectance bands (e.g., Sentinel-2 B01–B12). When a user requests an index, the backend performs the raster algebra in real time and streams the result. This minimizes storage, lets the user roll out new indices instantly, and always reflects the latest data input .

Figure 9 illustrate selecting and visualizing data.

Index Selection and Map Display - Users can choose from four indices in the dropdown menu:

- **Vegetation Index** - **NDVI (Normalized Difference Vegetation Index)** – Numerical measure used in remote sensing to assess the presence, density, and health of vegetation.

  How It Works: It is typically derived from the reflectance values of near-infrared (NIR) and red light, as healthy plants strongly reflect NIR and absorb red light. It is one of the most used vegetation indices.

  Use Cases: Monitoring crop health, deforestation tracking, and ecological studies.

- **Water Index** – Spectral index designed to detect and map water bodies such as lakes, rivers, and wetlands.

  How It Works: It enhances water features by using the difference between visible and shortwave infrared (SWIR) reflectance, as water absorbs most infrared light.

  Example: NDWI (Normalized Difference Water Index).

  Use Cases: Flood mapping, water resource management, and drought assessment.

- **Build-Up Index - NDBI (Normalized Difference Built-Up Index)** – Measure used in remote sensing to identify urban and built-up areas, distinguishing them from natural land cover.

  How It Works: It differentiates between artificial surfaces (such as concrete and asphalt) and vegetation or bare soil using spectral band combinations. **NDBI** highlights urban expansion.

  Use Cases: Urban growth monitoring, city planning, and land-use classification.

- **Soil Index** – Spectral index that evaluates soil properties such as moisture content, organic matter, and texture.

  How It Works: It analyses reflectance values in red, near infrared, and shortwave infrared bands to detect differences in soil composition.

  Example: SAVI (Soil-Adjusted Vegetation Index).

  Use Cases: Precision agriculture, land degradation studies, and soil fertility assessment.

Once an index is selected, the map updates dynamically to display relevant geospatial data. The zoom-in and zoom-out controls (top-left) allow users to navigate the map (Figure 9).

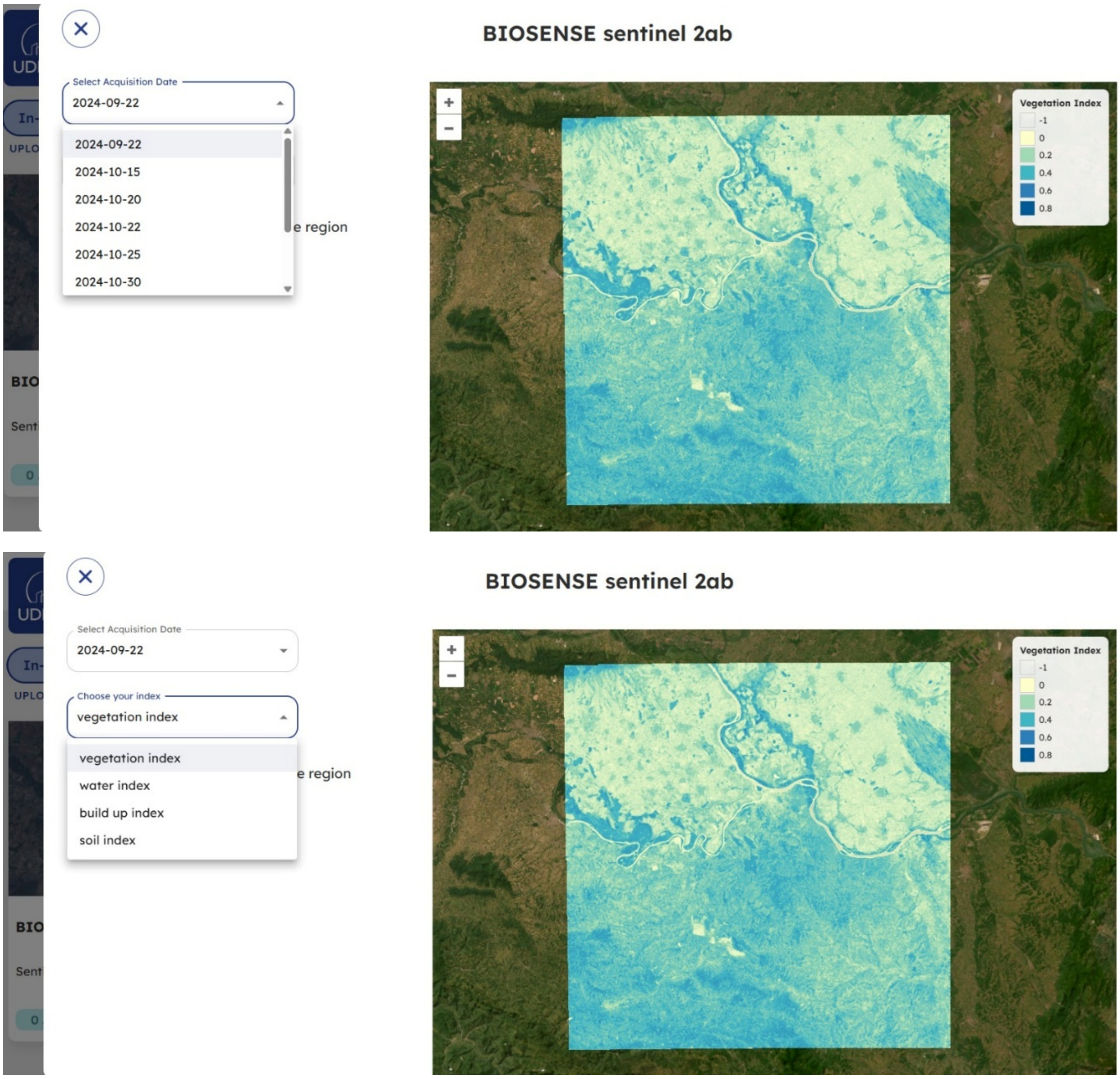


Figure 9. Selection of the acquisition date and data of interest from the selected data set

Users can upload their own datasets by clicking on the Upload button (***Figure 8***). Once clicked, a detailed guide on how to upload new data into UDENE Data cube will be automatically downloaded.

Experiments tab

This interface enables users to seamlessly switch between browsing datasets and conducting experiments using geospatial and remote sensing data. Selecting the Experiments tab will direct the user to a new interface of the UDENE Exploration tool where they can configure and run analyses using selected datasets (***Figure 10***).

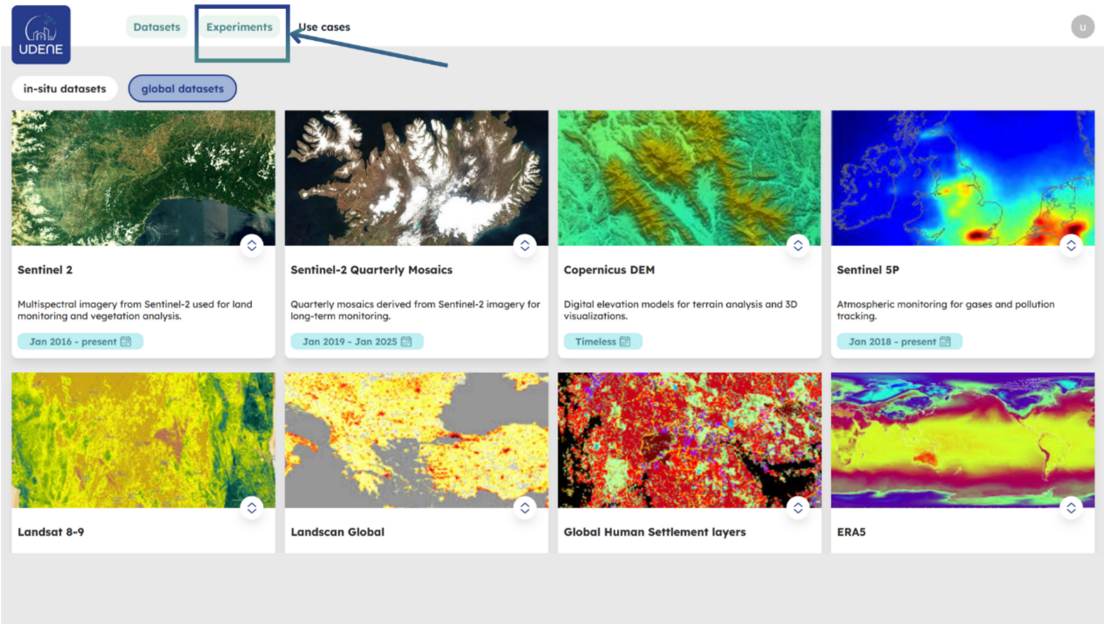


Figure 10. Accessing the Exploration tool – Experiments segment

When user accesses the Experiment segment of the Exploration tool the UDENE platform is structured with a **left-side control panel** for user inputs and a **right-side map display** for visualizing geographic data.

Users can conduct experiments through two options: an **automatic** mode for quick setup, and a **manual** mode that allows full customization by entering parameters, selecting datasets, and adjusting model settings (***Figure 11***).

Right-side Panel – Interactive Map

A responsive **satellite world map** powered by intuitive interaction tools occupies the majority of the interface:

- **Drawing Tools Toolbar (top right):** Includes shape tools (polygon, rectangle, circle) and edit/clear options. These allow users to define spatial zones for their experiments.
- **Map Style:** The map is highly readable, with labels for countries and continents, making it easy to identify regions for analysis.

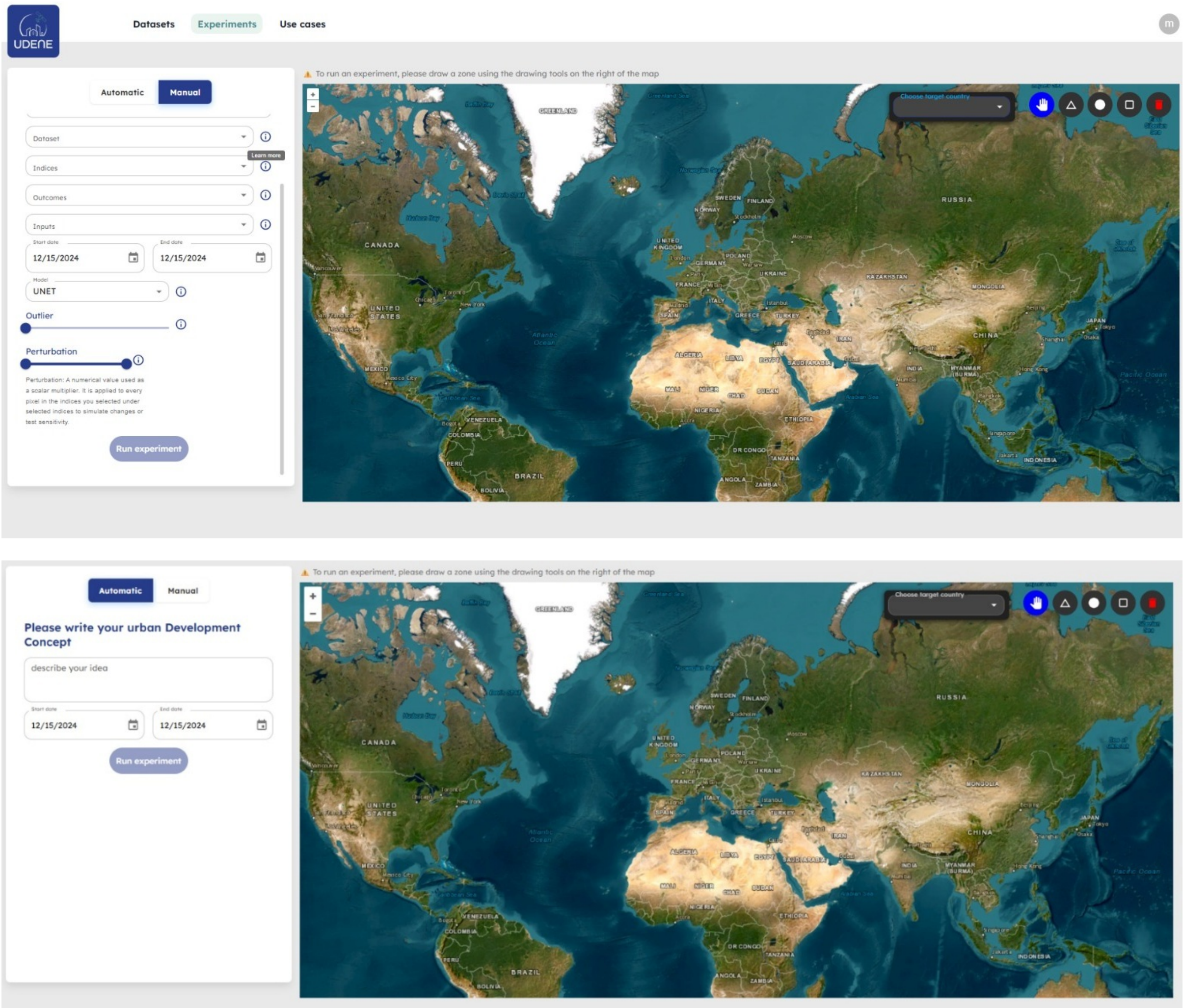


Figure 11. Exploration tool control panel and overview for automatic and manual options

Left Panel – Experiment Configuration

This vertical panel provides all necessary controls for setting up an experiment manually or automatically. It includes a Mode Switch (Automatic/Manual) and it allows the user to toggle between automated or manual configuration modes. The "Manual" mode is currently selected, emphasizing user control.

For the manual mode, the control panel consists of several input fields (Figure 12):

- **Prompt Box** – A text input field where users can describe their urban development concept.
- **Dataset** - the base spatiotemporal product (e.g., Sentinel-2 AB Level-2A, CCI Land-Cover, Copernicus GLS-Landsat 8 annual composite) that supplies the imagery or thematic raster stack on which the Exploration tool operates.
- **Indices -** the indices calculated based on spectral bands or thematic layers inside a dataset (for example, Sentinel-2 indices or the land-cover class layer) that users can choose to visualise or feed into models.
- **Outcome Dropdown** – Provides options for different expected outcomes of the urban development scenario. This is a single-choice selection. Users select the variables they want to measure as the result of the experiment from a pre-prepared list of outcome variables.

- **Inputs Dropdown** – Provides options for different parameters necessary to develop a prediction for the provided urban development scenario in the prompt. Users choose one or more input variables from another predefined list. These inputs represent the factors influencing the outcome variables. This is a multiple-choice selection.
- **Start Date & End Date** – Users can define a timeframe for their urban development simulation.
- **Outlier[2] Slider**– Allows users to control the level of inclusion or exclusion of outliers in the results. The helper keeps only the most “normal” results by discarding the bottom fraction you call an outlier. **Example**: with an outlier ratio = 0.15, the user will see a reduced set of results where the 15 % least-similar algorithm will disappear from the final payload.
- **Model** - From a list of available models, users select the one most suitable for their experiment. This allows for flexibility in testing different modelling approaches. Additionally, users specify the percentage of outliers to account for in the analysis.
- **Perturbation -** A perturbation is a value used to slightly increase or decrease the brightness of selected image bands by multiplying each pixel. By repeatedly stretching or shrinking the raw band intensities it creates synthetic “what-if” versions of the same spatial window, letting you see how the model reacts to brighter/darker inputs.
- **Run Experiment button** allows users to execute the simulation based on the configured parameters.

For the automatic mode, the control panel consists of (***Figure 12***):

- **Prompt Box** – A text input field where users can describe their urban development concept. The prompt box leverages a dedicated Large Language Model which aims to fill the required fields with the most suitable options according to the user's description. The prompt is powered by an OpenAI-based LLM that:
    - Reads the user’s free-text description.
    - Picks the most suitable analytic model from our inventory.
    - Autoconfigures the Exploration tool (area of interest, time span, indices, thresholds, etc.).
    - Pulls the matching data from the data cube, runs the chosen model, and fine-tunes parameters dynamically.

  In practice, a user can type something like, “I want to build a linked park system” and the system will handle every step - data selection, index calculation, and model execution - without further manual input.
- **Start Date & End Date** – Users can define a timeframe for their urban development simulation.

[2] An outlier is a data point that significantly deviates from the rest of the dataset. It is an observation that lies far from the central trend, either due to variability in the data or an error in measurement. Outliers can occur due to various reasons, such as measurement errors, natural deviations, or unusual events. **Example:** If the test scores of a class mostly range from 50-90, but one student scores 10 or 100, that score might be considered an outlier.

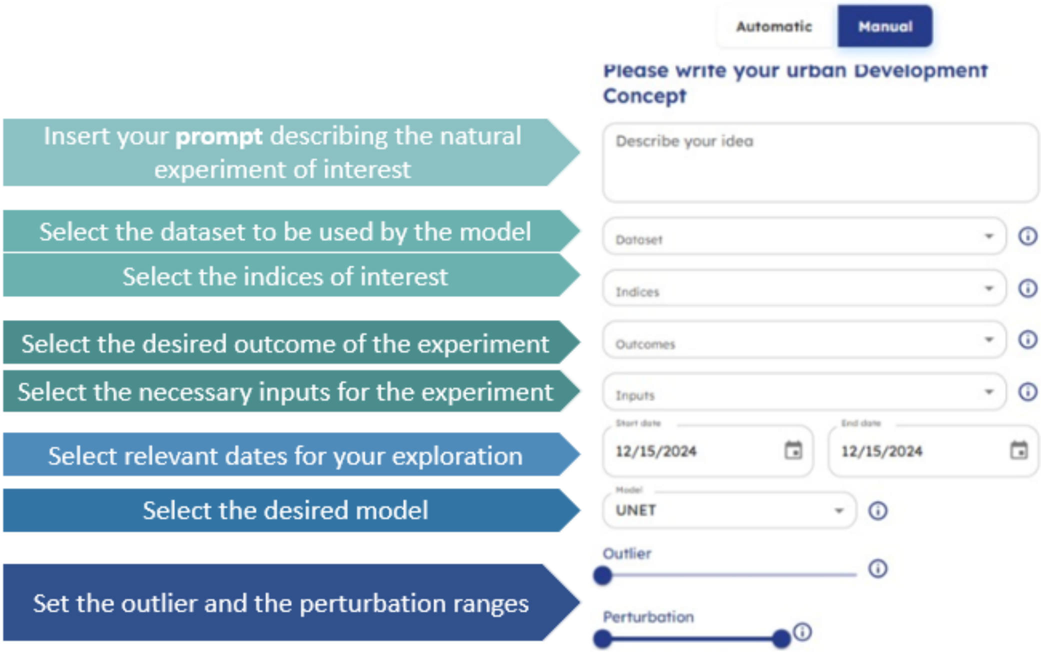


Figure 12. Exploration tool control panel

In ***Table 1*** are summarized the outcomes and inputs available in the Experiment tab.

Table 1. Definitions of Available groups of Outcomes and Inputs in Exploration tool control panel

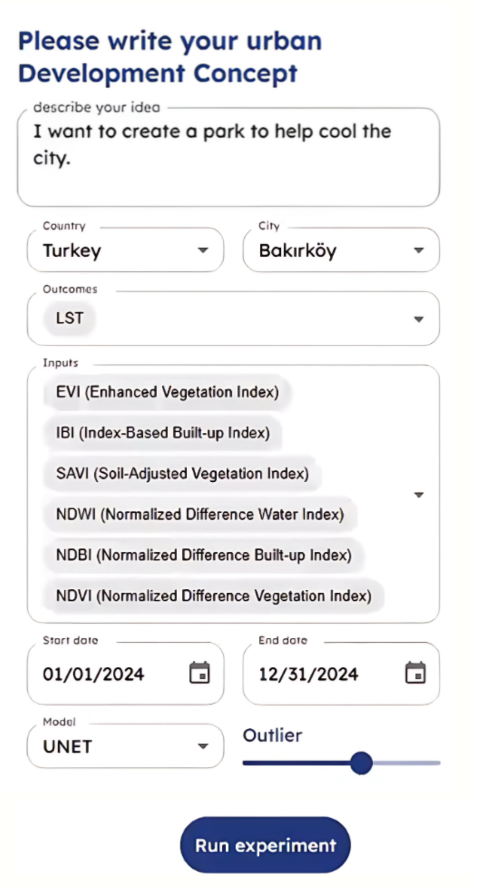
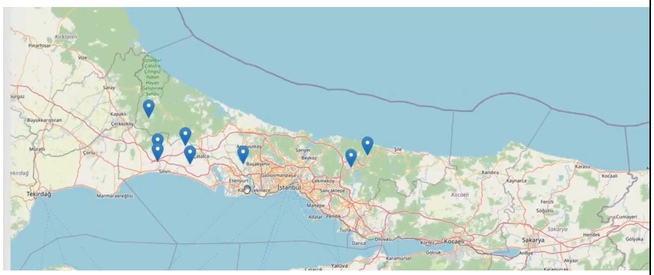
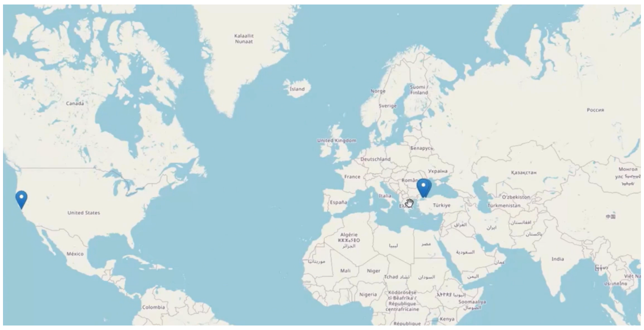
OUTPUTS	INPUTS
Environmental and Air Quality Indicators	Climate and Weather Indicators
UHI (Urban Heat Island) - A phenomenon where urban areas experience higher temperatures than surrounding rural areas due to human activities and built-up surfaces absorbing heat. **Use Cases:** Climate adaptation planning, urban cooling strategies. Nitrogen Dioxide (NO_2) concentrations - A measure of NO_2 levels in the atmosphere, primarily from vehicle exhaust and industrial activities. **Use Cases:** Air quality monitoring, environmental health studies. Particle Matter (PM2.5 and PM10) concentrations - Particulate pollutants that can affect respiratory health, often produced by combustion processes and industrial activities.	Surface Urban Heat Island (SUHI) – Measures temperature differences between urban areas and surrounding rural regions, often based on satellite data. **Use Cases:** Urban climate modelling, heat mitigation strategies. Heat Load - The total thermal energy accumulated in an area. **Use Cases:** Energy demand forecasting, heatwave response planning. Land Surface Temperature (LST) - The temperature of the Earth's surface as measured by satellites, distinct from air temperature. **Use Cases:** Climate monitoring, drought assessment. Wind Speed and Direction - The velocity and orientation of airflow in a given location. **Use**

Use Cases: Pollution control, respiratory disease studies. Carbon Monoxide (CO) concentrations - A measure of CO gas released from combustion engines and industrial processes. **Use Cases:** Traffic emissions analysis, air quality impact studies. Sulphur Dioxide (SO_2) concentrations - A gas emitted from burning fossil fuels and volcanic activity, contributing to acid rain. **Use Cases:** Industrial pollution monitoring, environmental impact assessments.	**Cases:** Wind energy potential analysis, meteorological forecasting. Dew Point **-** A measure of atmospheric moisture. It is the temperature to which air must be cooled in order to reach saturation (assuming air pressure and moisture content are constant). **Use Cases:** Weather prediction, agricultural planning. Humidity – A measure of the water vapor content of the air. Popularly, it is used synonymously with relative humidity. **Use Cases:** Weather prediction, agricultural planning. Rainfall - The total amount of precipitation measured in a specific area over a given time. **Use Cases:** Flood forecasting, water resource management.
Land Cover and Building Indicators	**Geospatial and Earthquake Indicators**
Building Type and Density - Categorization of structures based on use and their concentration in each area. **Use Cases:** Urban development planning, housing policy analysis. **Education Levels and Occupation Distribution per District -** Statistical data on the educational background and employment sectors of residents within different districts. **Use Cases:** Socioeconomic analysis, workforce planning.	**Epicentral Coordinates and Focal Depth** - The geographical location of an earthquake's epicentre and its depth below the Earth's surface. **Use Cases:** Seismic risk assessment, disaster preparedness. **Fault Line Rupture** - Measures the movement of the Earth's crust along a fault line after an earthquake. **Use Cases:** Earthquake impact studies, structural safety evaluations. **V30 Shear Wave Velocity** - A measure of seismic wave speed in the top 30 meters of soil, used to classify ground shaking potential. **Use Cases:** Earthquake engineering, geotechnical analysis.
Transportation and Mobility Indicators	**Remote Sensing Indices**
Average Integration of the Transportation Network - A measure of how interconnected roads and transit routes are within a network, affecting accessibility and traffic distribution.	Water Surface Spectral Indices (MNDWI - Modified Normalized Difference Water Index) - A spectral index used to identify and monitor

Use Cases: City planning, transit efficiency analysis. **Average Choice of the Transportation Network** Evaluates the number of alternative routes available within a transportation network, affecting congestion and travel efficiency. **Use Cases:** Traffic optimization, emergency route planning. **Normalized Choice of the Transportation Network** - A standardized metric for evaluating the likelihood of a particular road or path being chosen relative to all available paths. **Use Cases:** Road design improvements, transportation simulations. **Average Traffic Lane Occupancy** - The proportion of road lanes occupied by vehicles at a given time. **Use Cases:** Congestion management, road expansion studies. **Average Vehicle Speed** - The mean speed of vehicles on a road network over a defined time period. **Use Cases:** Traffic flow analysis, speed limit regulation. **Traffic Volume** - The number of vehicles passing a specific point on a road during a given period. **Use Cases:** Infrastructure planning, congestion mitigation strategies. **Average Number of Vehicles (bicycles, motorcycles, cars, buses, and cargo vehicles) -** Counts of different vehicle types traversing roadways over a set time period. **Use Cases:** Sustainable transport planning, road safety assessments. **Distribution of Vehicle Types per District** – Breakdown of different vehicle categories within geographic areas. **Use Cases:** Transportation policy development, emissions control.	surface water using satellite data. **Use Cases:** Flood detection, water resource management. NDVI (Normalized Difference Vegetation Index) - index used to assess vegetation health based on satellite imagery. **Use Cases:** Deforestation monitoring, agricultural yield prediction. NDBI (Normalized Difference Built-Up Index) - A spectral index used to detect built-up and urbanized areas. **Use Cases:** Urban growth monitoring, land-use classification. NDWI (Normalized Difference Water Index) – index used to identify and assess water bodies using remote sensing data. **Use Cases:** Drought analysis, water conservation efforts. SAVI (Soil-Adjusted Vegetation Index) - A vegetation index that accounts for soil brightness effects, useful in arid regions. **Use Cases:** Soil moisture assessment, ecosystem monitoring. IBI (Index-Based Built-Up Index) - A remote sensing index used to highlight urban development. **Use Cases:** Infrastructure expansion monitoring, zoning regulation. EVI (Enhanced Vegetation Index) **-** An advanced vegetation index designed to improve sensitivity to high biomass areas. **Use Cases:** Precision agriculture, land degradation analysis.

An example Experiment Query is presented in ***Table 2***, along the example set of parameters with the overview of the results.

Table 2. Example with the results of the set experiment

Example	Results
	Prompt can be simple – Show me the places in urban areas where park helped to cool down the temperature in the cities.  

Use cases

The Use Case tab (***Figure 13***) functions as a centralized hub where users can access the central for project practical examples and applications, organized to support inspiration and insight for project development. The layout is designed to facilitate intuitive navigation and focused exploration.

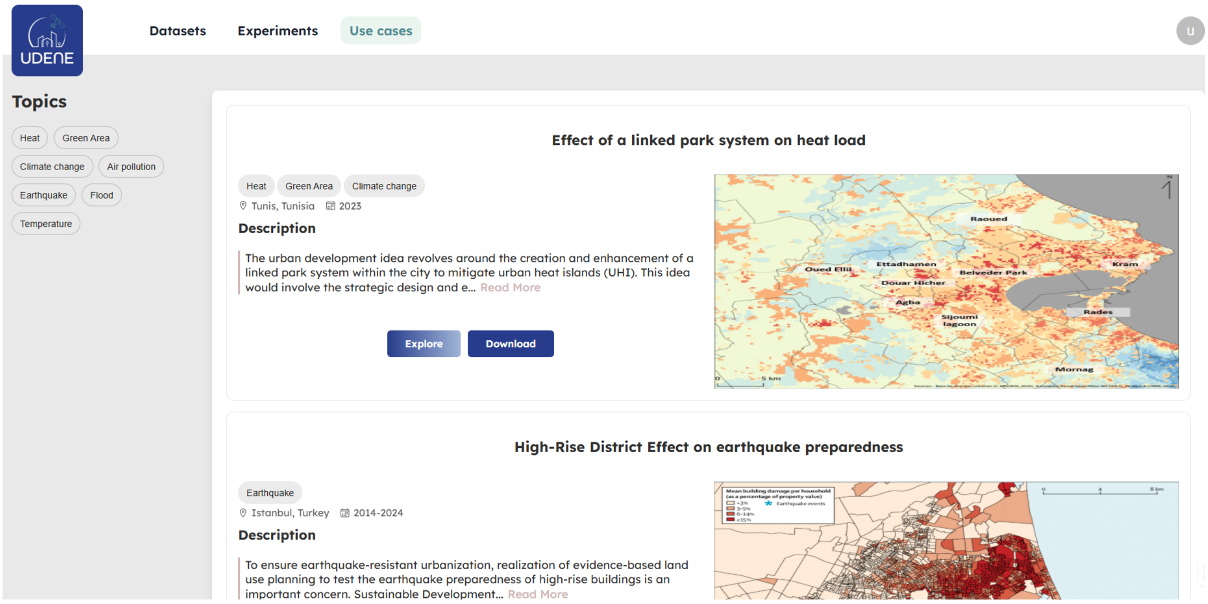


Figure 13. Use case panel

On the left side of the page, a categorized list of topics is presented. This serves as a filtering mechanism, allowing the user to browse use cases that align with specific interests or thematic areas. When a topic is selected, it becomes visually highlighted to indicate its active status, helping the user maintain orientation while navigating the available content.

The central section of the page displays the corresponding list of use cases related to the selected topic. Each use case is presented with a detailed description, including the date of acquisition or generation of data or results, the geographical location (such as city or region) associated with the case, and the topics relevant to it. Additional contextual information is also provided to enrich the user's understanding of the scenario and highlight potential applications or significance.

To support sharing, or offline reference, the page includes features that enable the user to download the listed use cases. This functionality ensures that valuable insights can be retained, revisited, or integrated into other projects as needed.
For further analysis, the Explore functionality automatically fills the experiment form with the Use Case information, allowing users to rerun the experiment with the option to modify the inputs as needed.

Effect of a linked park system on heat load - Tunis

The use case models an urban development concept aimed at reducing the Urban Heat Island (UHI) effect by designing a linked park system to help cool the city during increasingly hot summers.

User Input - Concept Description

The user starts by describing their urban development concept. In this case, the concept is:

"Designing a linked park system to help cool the city during increasingly hot summers and reduce the UHI affect."

This description sets the objective of the experiment, which focuses on mitigating urban heat through the strategic implementation of increased tree coverage and interconnected green spaces.

Selection of Dataset, Outputs, and Inputs

The user selects a specific dataset from a dropdown menu. **Ls9 sr** (***Figure 14***) refers to Landsat 9 surface reflectance which is a satellite launched by NASA and USGS, part of the Landsat program which provides multispectral images of the Earth's surface reflectance. The "Ls9 sr" product is from the analysis ready data (ARD) collection that has been pre-processed to provide accurate surface reflectance information.

On one hand, ARD is currently preferred because it saves significant preprocessing time and effort and reduces technical prerequisites. On the other hand, the Landsat collection is one of the most open-source remote sensing datasets, offering high temporal coverage (since 1972), with spatial resolution at tens of meters and broad geographic coverage. Landsat 9, the most recent mission, was launched in 2021. If there is a need to analyse an older data or conduct spatio-temporal observations, earlier missions, such as Landsat 5, 7, and 8 are available and ready to use from the UDENE Data Cube. Landsat 8 and 9 are currently operating synchronously, offering an improved temporal resolution of 8 days instead of the usual 16.

Figure 14. Runing the experiment of Tunisia Use Case

Country and City Selection

The user selects the country where the experiment is to be applied. Typing the first few letters filters the options. In this use case, Tunisia is selected. After the Country is selected the option to choose a city opens up. Within Tunisia, the user selects a specific city to focus on. The example city is Sfax (***Figure 14***).

Input Variables

The inputs include various remote sensing and environmental predictors related to vegetation, such as EVI, NDVI, and SAVI, along with urban form indicators like NDBI to represent built-up areas and NDWI for water presence. These spectral indices are relevant for analysing urban heat in relation to land cover, particularly green spaces. These variables are used as inputs to model or simulate the expected impact of tree planting and their spatial pattern on urban heat.

These inputs are carefully selected because they directly relate to the goal of understanding how planting trees impacts urban heat. Vegetation indices such as NDVI, SAVI, and EVI provide crucial information about the quantity and health of vegetation, which are key factors in cooling urban environments. Additionally, NDWI is included to account for water availability and soil moisture, both of which significantly influence the cooling effects of plants through processes like evapotranspiration. NDBI is also integrated to represent the extent of built-up areas, which is the main land cover class in urban areas and typically contribute to higher surface temperatures.

Since these indices are derived from remote sensing data, such as satellite imagery, they allow for detailed spatial analysis across the city. By integrating these inputs into the model, the experiment can effectively predict or assess how variations in vegetation cover and moisture levels contribute to changes in the UHI effect.

Outcomes Selection

The user selects the outcome or target variable to measure, in this case, UHI. This means the experiment aims to evaluate how the proposed concept influences urban heat patterns.

The UHI effect refers to the increased temperatures in urban areas compared to surrounding rural regions, primarily caused by human activities and infrastructure. It is commonly represented through land cover types and their associated surface reflectance.

Planting more trees is expected to reduce UHI by providing shade and cooling through evapotranspiration. In addition, a strategic park design (linked system) favours corridors and enhances the cooling effect of green cover. Therefore, measuring UHI as the output directly assesses the success of the intervention.

Experiment Parameters

The user sets a date range for the data considered (though dates shown are placeholders) and selects additional model parameters like "Outlier" and "Perturbation" using sliders. These parameters control aspects of the statistical or machine learning model sensitivity or data filtering.

Run Experiment

Once all inputs and parameters are set, the user clicks the "Run experiment" button to execute the simulation or analysis.

Results Visualization

These cities are likely examples or test sites within the dataset or model where similar urban greening techniques (like designing linked park system) are studied or implemented to assess their impact on the UHI effect.

The experiment uses spectral indices derived from satellite data to predict UHI which helps evaluate how green cover can mitigate heat stress in different urban environments.

The presence of these cities on the map implies that the model's predicted UHI apply to these urban areas, suggesting that these techniques either are in use or have been modelled for use there. It does not necessarily mean all these cities are currently using the exact same techniques, but rather that the model or study includes them as relevant cases for analysis or application of similar nature-based solutions (***Figure 15***).

Figure 15. Results visualisation

This map visualizes the **geographic scope** and applicability of the experiment results, highlighting cities where the impact of designing more parks on reducing UHI has been modelled, providing insight into how such interventions might work globally in diverse urban settings.

This use case illustrates a workflow where a user defines an urban environmental intervention concept, selects relevant geographic and environmental datasets, specifies outcomes and input variables, and runs an experiment to simulate or assess the impact. The visualization helps stakeholders understand how urban greening measures can mitigate heat in specific cities by leveraging satellite data and machine learning models.

High-Rise District Effect on earthquake preparedness – Turkey

The Goal of the use case: The use case aims to explore evidence-based land use planning by estimating the possible building damages and their respective economic loss of high-rise urbanization due to earthquakes having magnetic moments of around 7.0 or greater in tectonically active regions.

The ultimate expectation is to ensure earthquake-resistant urbanization by:

- **Reviewing and updating land-use plans** to ensure that new developments adhere to seismic-resistant construction standards and building codes (considering engineering practices, local seismic hazards and soil/site conditions along with high-rise performance levels)
- **Identifying areas prone to seismic risk** and implementing zoning regulations to mitigate future damage.
- **Avoiding the design of narrow streets** in high-rise districts to overcome potential debris blocking for the evacuation.
- **Drafting land use regulations** to incorporate lessons learned from the scenario-based earthquake studies. (E.g., Restricting high-rise developments in areas with poor soil conditions and promoting low- to mid-rise buildings to reduce seismic vulnerability).

User Input - Concept Description

The user starts by describing his/her urban development concept due to a possible earthquake to occur in the vicinity of a city of interest if it is in a tectonic area (close to active fault lines creating large earthquakes in the time span accumulating strain within their earthquake recurrence period).

In such a case, the following concept can be considered:

"Living in a high-populated city segment where vertically high-rise buildings are constructed in narrow streets and roads. In the event of an earthquake having a magnitude moment of 7.0, the rates of damaged buildings may be high enough to block the possible evacuation routes. In the first point, the damaged building types and their standards are investigated, then the rate of high-rise ones are determined. If the rates are found high, their possible adverse effects to their nearest environment are examined along with their economic losses and suggestions for horizontal construction with updated codes/standards are envisaged in accordance with soil conditions of the area"

This description frames the objective of the experiment focusing on mitigating possible high-rise effects in highly populated areas (residential and/or business) through estimating building damages.

Selection of Dataset, Outputs and Inputs

1. The user first investigates the Istanbul/Türkiye case products where a scenario-based earthquake has already been implemented, and their damaged estimates along with predicted ground motion parameter distribution graphics (e.g., intense, Peak Ground Acceleration-PGA, Spectral Acceleration-SA) were obtained.

The input variables

Primary Variable

Scenario-based earthquake occurrence (definition in areas with intense seismic activity, close to active faults)

- Magnetic Moment (Magnitude)
- Geographic coordinates of the epicentre of the earthquake centre
- Depth of Focus

Secondary Variable:

- **Active Fault Lines** (Fractures determined by plate tectonics, seismological, geological, geodetic, paleo-seismological and geophysical imaging methods). The account used is defined in the model. Coordinated information of faults in the whole world dimension is also given for the ET application (In this context, two different global fault sources were used (the first is the Global Earthquake Model Foundation-GEM, the other is the European Seismic Hazard Model-ESHM20).
- **General geological soil structure of the region**. Ground motion values depend on the shear wave velocity (Vs30) profile and other local ground conditions (site amplification). The average slip S Wave Velocity for the top 30 m of the earth's crust-Vs30 is a basic parameter required in earthquake engineering to determine seismic ground conditions, dynamic properties of soils. Typically, it is based on geophysical measurements made according to invasive and non-invasive techniques in the relevant area. In the calculations, the data set covering the entire Euro-Mediterranean region is available and is included in the calculation routines by default. This dataset was compiled from the USGS Global Vs30 database.
- **Building Inventory**. This is one of the most important data in the estimation process. A building inventory is a catalogue of the buildings and facilities in each class of the taxonomy. In estimation algorithm structure, the building inventory should be geo coded and/or associated with respective geo-cells. The sophistication and completeness level of the building inventory determines the level of analysis that will be used in loss estimation. At this stage, a comprehensive classification of building types for Europe titled "An Advanced Approach to

Earthquake Risk Scenarios with Application to Different European Cities" was adopted within the RISK-UE Project (RISK-UE 2001-2004) developed and funded by the European Commission. The crudest level of building inventory corresponds to an approximate (proxy) European database of the number of buildings and their geographic distribution. This approximated building database is obtained from CORINE Land Cover (EEA 1999), LandScan population database (http://www.ornl.gov/sci/landscan/ landscan2005/index.html) and Google Earth (http://earth.google.com) and is provided within the estimation routines (Earthquake Loss Estimation Routine-ELER developed throughout the Euro Mediterranean region under the Joint Research Activity- (JRA3) of the EC FP6 Project entitled "Network of Research Infrastructures for European Seismology-NERIES) as the default inventory database for the analysis.

The output variables

The outputs are simply the estimates for the building damage and economic loss. For building damages, the primary variables indicated above are considered and ground motion parameters (Intensity, PGA etc.) are estimated and their spatial distributions are obtained. Consequently, building damages are calculated based on the building inventory information. Damage conditions with different levels of severity (D1-Light Damage, D2-Medium Damage, D3-Significant to Heavy Damage, D4-Very Heavy Damage, D5-Demolition)are defined in the building inventory for wooden, masonry, reinforced concrete, strong reinforced concrete and steel structures for low-rise (Low Rise 1 -4); mid-rise (Mid Rise 5-8); and high-rise (High Rise ≥ 9). Damage levels are based on the European Macroseismic Scale (EMS-98), which assigns seismic intensities in European countries. The economic losses are then calculated according to the building damage at the specified levels.

These economic losses are determined by combining the damage level with the replacement cost of the buildings. Some of the examples are depicted below figures to be visualized in Exploration tool.

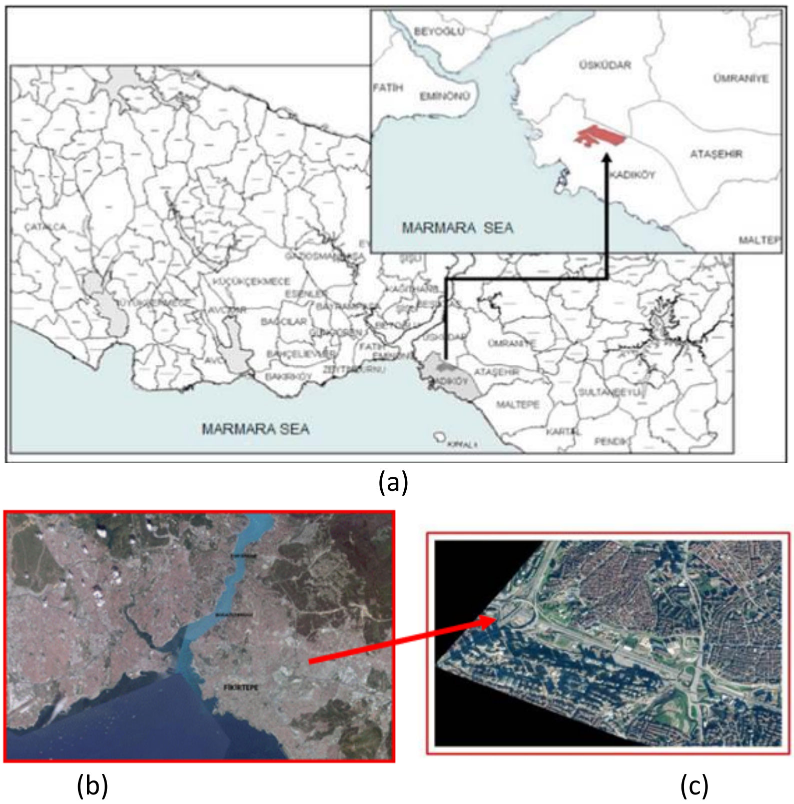


Figure 16. (a) The area of Interest in greater Istanbul (b) Smaller scale image representation (c) Fikirtepe Area, high resolution satellite image

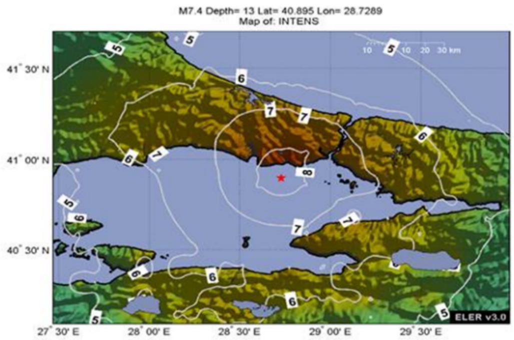


Figure 17. The spatial distribution of "intensity" due to scenario-based earthquake having magnitude 7.4 with depth 13 km and epicentre coordinates latitude 400.8950 N, and longitude 280.7289 E (WGS84)

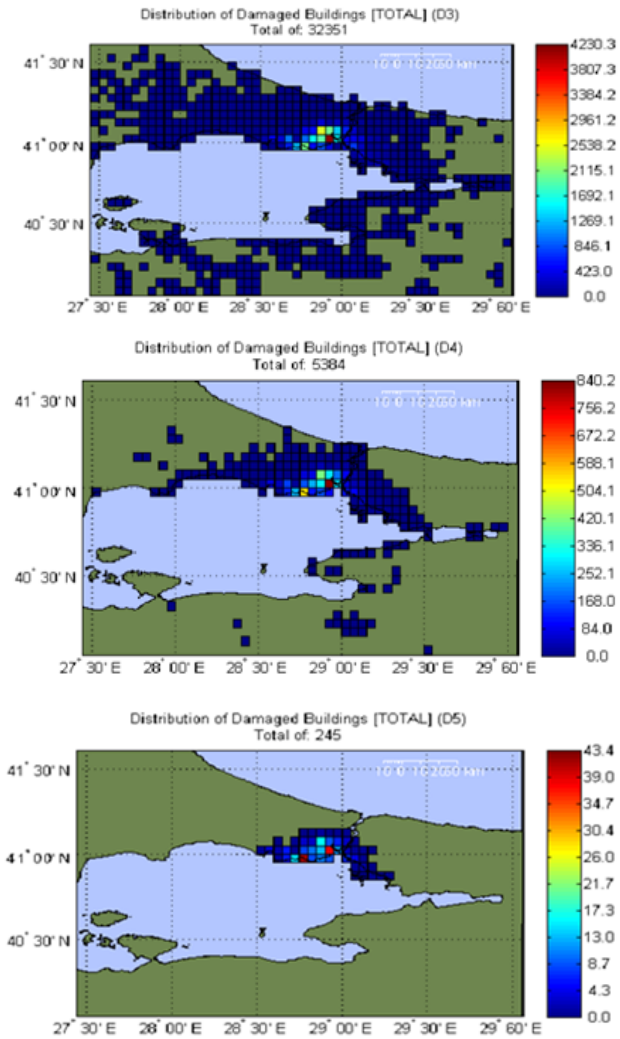


Figure 18. The geo-cell distribution of "damaged buildings" with D3 top-left), D4 (top-right) and D5 (bottom) level of severity states due to a scenario-based earthquake. The building types are Masonry and Reinforced Concrete (RC)

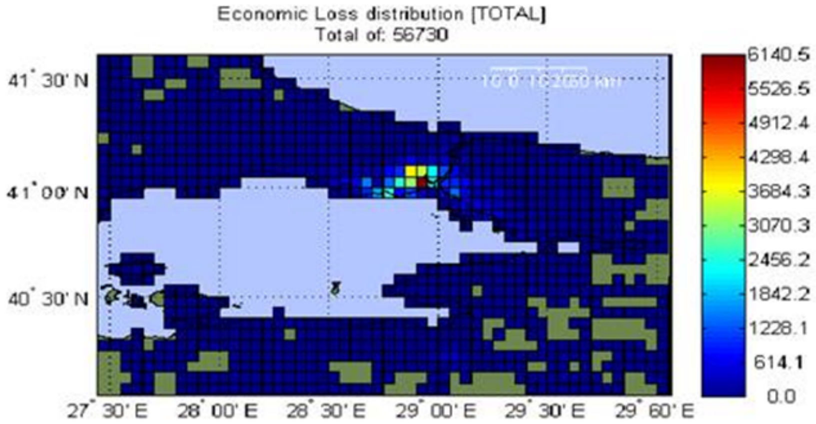


Figure 19. The geo-cell "economic loss distribution" for all (total) damaged buildings

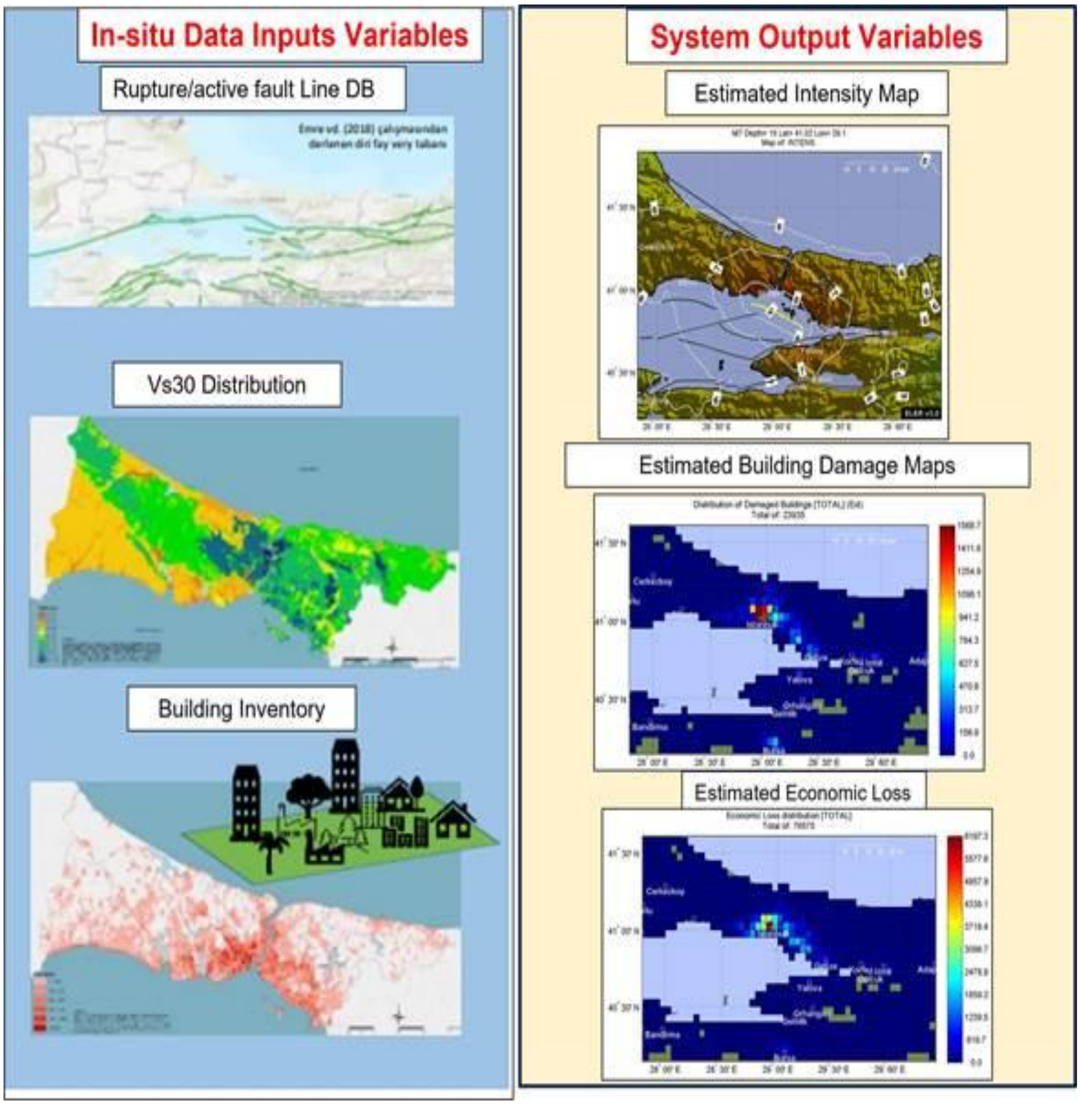


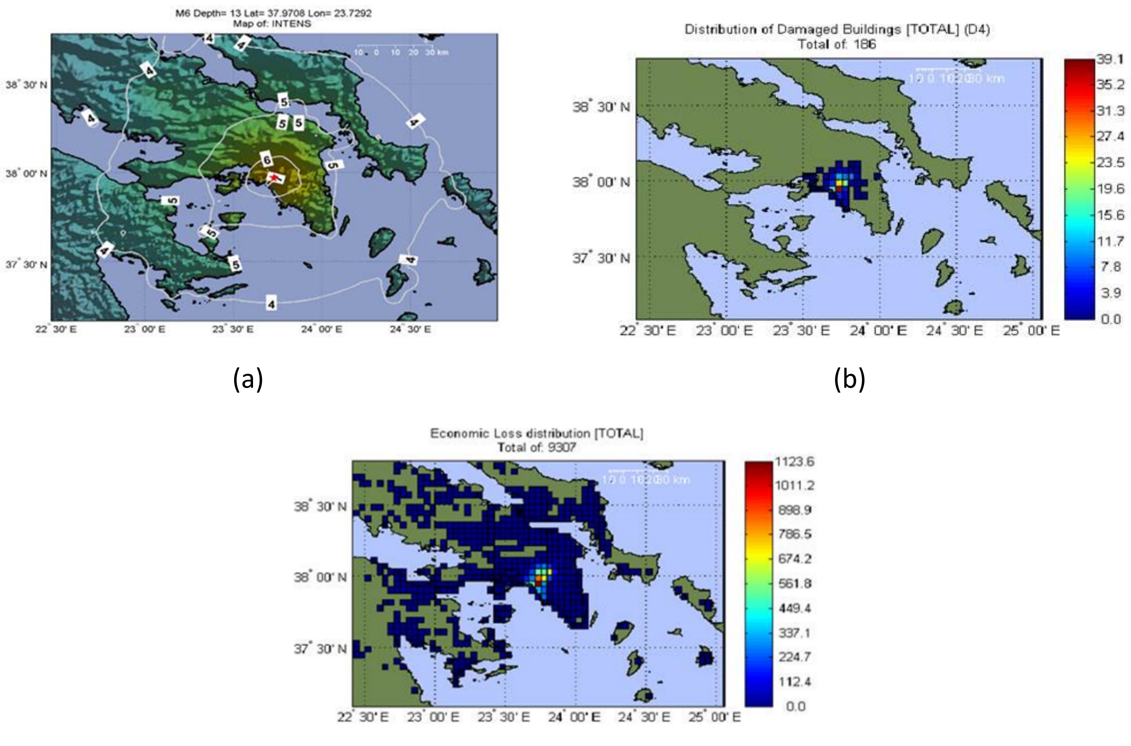
Figure 20. Summary of input and output variables

In provided ***Table 3*** then the user gets a map representation of similar and active seismic-prone areas in Europe, where damaging earthquakes had already occurred.

Table 3. Türkiye's use case similar places/cities list in Europe, as that of Istanbul

#	City	Latitude (°)	Longitude (°)	Nearest Fault Line Name	Magnitude
1	Istanbul	40.79055 N	29.08333 E	North Anatolian Fault	7.4
2	Lisbon	38.7223 N	9.1393 W	Azores-Gibraltar Transform	7.4
3	Nice	43.7102 N	7.262 E	Ligurian Fault	6.8
4	Athens	37.970833	23.729166 E	Hellenic Arc	6.0
5	Palermo	38.130555	13.379166 E	Sicilian-Maghrebian Thrust	6.0
6	Granada	37.170833	3.606944 E	Betic Cordillera Fault	7.4
7	Messina	38.2 N	15.55 E	Messina-Taormina Fault	7.4
8	Vienna	48.19555431 N	16.3870094E	Moderate Seismic Activity	6.1
9	Barcelona	41.39086881 N	2.18282042 E	Pyrenean Fault System	6.8
10	London	51.51505322 N	0.137694 W	Seismic Activity: Low	5.8
11	Paris	48.87051478 N	2.338027 E	Seismic Activity: Low to moderate	4.9
12	Vrancea	45.84100 N	26.668 E	Vrancea Seismic Zone	7.4
13	Rome	41.906944 N	12.504166 E	Apennine Fault System	6.7
14	Catania	37.14 N	15.1 E	Sicilian-Maltese Fault	7.4
15	Málaga	36.730555 N	4.419444 W	Alboran Ridge Fault	7.0
16	Naples	40.852777 N	14.258333 E	Campania-Lucania Arc	7.2

The user then observes the similar estimated outputs for tabulated European cities. Some examples are depicted below.



(a) (b) (c)

Figure 21.The spatial distribution of intensity (a), geo-cell distribution of damaged buildings in D4 level (b) and respective economic loss (c) due to scenario-based earthquake in Athens, Greece

Further assessments of the high-rise effect of damaged buildings and economic losses are achieved utilizing the numerical outputs (***Table 4***) data by the user). This is done by comparing the explanatory data with the high resolution available EO data and the rates (percentages) for each building type are then evaluated to make inferences.

Table 4. Calculated values of Building Damages in Excel CSV format on geo-cell basis. (Istanbul)

ID	RC_L	M5_L	RC_M	M5_M	RC_H	M5_H	TOTAL_BLD	POPULATIC	MOT_INTENS	DMG_RC_	DMG_M5_L
5490831	14.07314	39.20684	1.107158	3.08447	0.001039	0.002895	57.475541	440	3.851337	13.92779	38.55298 0.
5500831	15.52253	47.15592	1.112855	3.380743	0.000992	0.003013	67.176055	509	3.973074	15.34263	46.26987 0.
5510831	9.291861	58.82516	0.249544	1.579823	0	0	69.946392	493	3.947539	9.18675 0.	57.74726 0.
5520831	16.97097	10.35795	0.071427	0.043594	0	0	27.443935	184	4.006863	16.76786	10.15673 0.

DMG_RC_M	DMG_M5_M	DMG_RC_H	DMG_M5_H	DMG_TOTAL	DMG_TMP_NUMN	GEOMETRY
1.09699 0.009	2.99987 0.0748	0.00103 0.00	0.00276 0.0001	56.58142 0.7	0.0074	POLYGON((27,4500000 41,60000
1.10140 0.010	3.27573 0.0927	0.00098 0.00	0.00285 0.0001	65.99347 1.0	0.00996	POLYGON((27,5000000 41,60000
0.24704 0.002	1.53202 0.042	0.00000 0.00	0.00000 0.0000	68.71307 1.0	0.01035	POLYGON((27,5500000 41,60000
0.07067 0.000	0.04219 0.001	0.00000 0.00	0.00000 0.0000	27.03745 0.3	0.00334	POLYGON((27,6000000 41,60000

Legend:

- ID= Unique Geo-cell number within the entire region,
- POPULATION= Population in the cell;
- RC3L and RC_L=Reinforced Concrete Low floor;
- RC3M and RC_M=Reinforced Concrete Middle floor;
- RC_H= Reinforced concrete high floor;
- MS_L= Reinforced concrete masonry low floor;
- M5M and MS_M = Reinforced concrete masonry Middle layer;
- MS_H = Reinforced concrete masonry is the high floor values, the number of buildings according to the construction nature of the building and the number of floors,
- TOTAL_BLD = Number of buildings in the cell;
- MOT_INTENSE = The average intensity value calculated for each grid cell (e.g., Modified Mercalli Intensity (such as MMI);
- DMG_M5_L = Calculated damages on the reinforced concrete masonry low floor;
- DMG_M5M and DMG_M5_M= Reinforced concrete masonry Calculated damages in mid-rise buildings;
- DMG_M5_H= Reinforced concrete masonry Damages calculated in high-rise buildings;
- DMG_RC3L and DMG_RC_L = Damages calculated in reinforced concrete low-rise buildings;
- DMG_RC3M and DMG_RC_M = Damages calculated in reinforced concrete mid-rise buildings;
- DMG_RC_H= Damages calculated in reinforced concrete high-rise buildings;
- DMG_TOTAL= Returns the total number of damaged buildings, taking into account all building types and damage levels.

Country and City Selection

The user selects the country where the experiment is to be applied.

Outcomes Selection

The user selects the outcome or target variable to measure.

Input Variables

The Input parameters and variables are the same as given item A.1 above.

Effect of a new ring road on air quality - Serbia

The purpose and final aim of this use case is to estimate the change of pollutant emissions caused by significant transport infrastructure changes, such as building a city bypass and retouring the heavy traffic, or creation of new pedestrian and semi-pedestrian areas.

Accessing the Case Study

Once the user logs in, the Use Cases tab becomes available for navigation. The user should locate and select the use case titled "Effect of a New Ring Road on Air Quality, Serbian Case Study." Beneath the case study description, a button named "Run Experiment" is available to access the implementation of the case stuy.

Using the "Run Experiment" Feature

1. Finding Similar Cities

In the first tool, the user can filter and identify cities with similar characteristics by selecting a latitude and population range.

Once all four required parameters are entered, the tool will return (***Figure 22***):

- A list of cities meeting the criteria.
- A visual display of their locations on t**he map canvas** on the right panel.

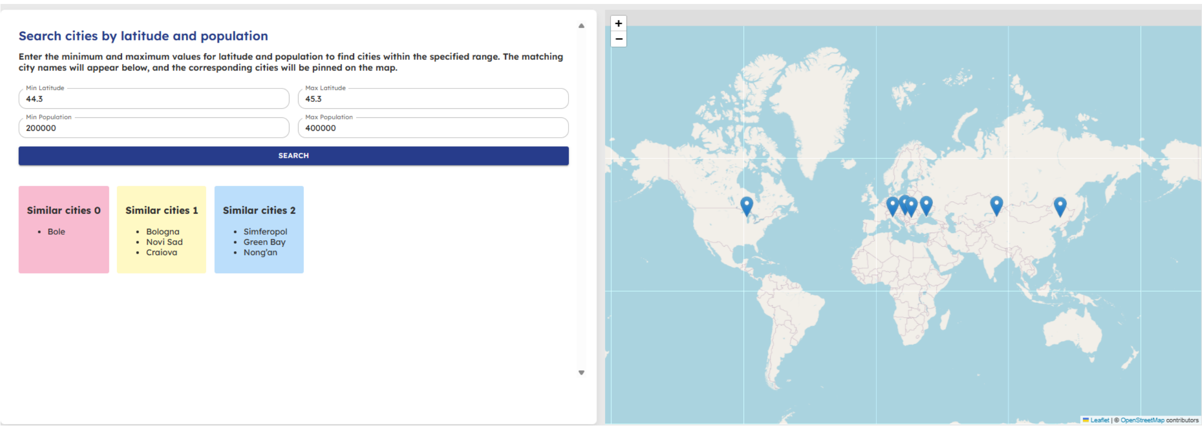


Figure 22. Search tools for finding similar cities

2. Air Pollution Prediction Tool

The second tool allows the user to estimate air pollution levels in Novi Sad using predefined models and user-input parameters.

Two predictive models are available for selection:

- **Model without metered, in-situ traffic inputs -** This is the random forest regression model that uses seasonally aggregated traffic and climate data, resulted as the best model from fine-tuning procedure using 3-fold cross-validation with grid search.
- **Model with the metered, in-situ traffic inputs -** Although built with the same methodology as the previous model, this model is decision tree regression model and also includes input variables representing online measurements of traffic data, such as vehicle counts and lane

occupation. However, many cities do not have such data, so the previous model allows avoiding their usage.

To run a prediction, the user must enter values for the following parameters, depending on the chosen model. Each parameter should be filled using the format shown in the example values within square brackets. Descriptions for each will be provided in future iterations.

For the model without metered, in-situ traffic data input (Figure 24):

1. **Choice (Norm)** - measures how likely an axial line or a street segment is to be passed through on all shortest routes from all spaces to all other spaces in the entire system or within a predetermined distance (radius) from each segment. [1.38908]
2. **Normalised distance to all spaces** - [1240]
3. **Total accessibility** - Total accessibility is calculated as the combination of Normalised choice and Integration, estimating the role of a segment in 'to' and 'through' movement. In this case global radius** (N) is used. [1723]
4. **Angular connectivity** - Angular connectivity focuses on the angular changes within a spatial network. It is defined as the cumulative turn angle to a root segment. Unlike simple connectivity, which counts the number of connections a street has, angular connectivity considers the angles between connected segments. [120]
5. **Axial Line Ref** - To be discarded. [152]
6. **Connectivity** - Connectivity measures the number of spaces immediately connecting a space of origin. [147]
7. **Segment length** - Given in meters. [201]
8. **Choice (Global)** - Choice measures how likely an axial line or a street segment is to be passed through on all shortest routes from all spaces to all other spaces in the entire system or within a predetermined distance (radius) from each segment. In this case global radius is used. [248]
9. **Choice R2000 (Norm)** - Normalised choice aims to solve the paradox that segregated designs add more total (and average) choice to the system than integrated ones. It divides total choice by total depth for each segment in the system. This adjusts choice values according to the depth of each segment in the system, since the more segregated it is, the more its choice value will be reduced by being divided by a higher total depth number. This would seem to have the effect of measuring choice in a cost-benefit way. The measure of Choice is said to predict through-movement. Through-movement refers to the movement passing through on shortest routes from all points to all other points in the layout. In this case the radius is 2000 m. [1.31]
10. **Choice R2000** - Choice measures how likely an axial line or a street segment is to be passed through on all shortest routes from all spaces to all other spaces in the entire system or within a predetermined distance (radius) from each segment. In this case radius* is 2000 m. [412]
11. **Integration R2000** - Integration is a normalised measure of distance from any space of origin to all others in a system. In general, it calculates how close the origin space is to all other spaces. The measure of Integration is said to predict to-movement. To-movement refers to the movement to a space as a destination from all others. In this case radius* is 2000 m. [100]
12. **Segments to all others** - Node count, measures the number of segments encountered on the route from the selected segment to all others. In this case global radius is used. [1526]
13. **Segments to all others, radius 2000m** - Node count, measures the number of segments encountered on the route from the selected segment to all others. In this case the radius is 2000 m. [4525]
14. **Topological depth sum** - Total depth is defined as the sum of the topological depth from any node to all the others. Depth exists wherever it is necessary to go through intervening spaces to get from one space to another. Topological means the shortest path is the one that uses the fewest number of turns. In this case global radius is used. [1024]

15. **Topological depth sum, radius 2000m** - Total depth is defined as the sum of the topological depth from any node to all the others. Depth exists wherever it is necessary to go through intervening spaces to get from one space to another. Topological means the shortest path is the one that uses the fewest number of turns. In this case radius* is 2000 m. [1794]
16. **Distance** - The distance between the closer end of the street segment to the air pollution metering station, in meters. [254]
17. u**-component of wind (10m)** - The 10m u-component of wind represents the eastward component of the wind at a height of 10 meters above the ground. It indicates the horizontal speed of wind moving eastward, with negative values indicating movement towards the west. This value is typically measured in meters per second (m/s). [124]
18. **v-component of wind (10m)** - The 10m v-component of wind refers to the northward component of the wind speed at a height of 10 meters above the ground. It's essentially the horizontal speed of air moving towards the north at that altitude. This component is measured in meters per second. [125]
19. **Total precipitation -** Total precipitation refers to the accumulated amount of liquid and frozen water (rain, snow, hail) that falls to the Earth's surface over a specific period, measured in litters per square meter (l/m^2). [78]
20. **Dew point temperature (2m)** - This parameter is the temperature to which the air, at 2 metres above the surface of the Earth, would have to be cooled for saturation to occur. This parameter has units of degrees Celsius (°C). [42]
21. **Temperature (2m)** - This parameter is the temperature of air at 2m above the surface of land. This parameter has units of degrees Celsius (°C). [10]

These attributes, except Distance, are aggregated on daily levels for the model without traffic inputs, while for the model with traffic inputs, the aggregation is done on a monthly level.

For the model with the metered, in-situ traffic inputs, this is the set of used input attributes:

1. **Number of vehicles (last hour)** - Hourly vehicles count.
2. **Average time headway** - The average time headway in a traffic stream is the average time between the passage of consecutive vehicles past a specific point, measured in seconds.
3. **Traffic lane occupancy** - Traffic Lane occupancy, determined in ‰, represents the ratio between the occupancy of measuring sensors and the observed time interval.
4. **Traffic flows with increased intensity** - True or False, depending on the decision system makes if the state of increased traffic is detected (the number of vehicles is increased compared to normal traffic flow).

These attributes are aggregated on a monthly level.

Once all parameters are filled (***Figure 23***), the user can click on the Predict button. The system will process the inputs and display estimated values for air pollutants - SO_2, NO_2, NOx, CO, NO, P.

Figure 23. Input and output of air pollution prediction model

3. MATSim Model Simulation Tool

The third tool enables the user to run a MATSim-based traffic simulation for Novi Sad. This tool supports the evaluation of different urban planning scenarios by simulating individual-level travel behaviour over a realistic transport network. It integrates synthetic population data with activity-based schedules and a detailed network representation to provide insights into traffic patterns, congestion, and mobility outcomes.

The tool supports three predefined simulation scenarios:

- **BASELINE** – Represents current city network conditions without any infrastructural interventions.
- **PZ (Pedestrian Zone)** – Introduces pedestrianization in a selected area in the historical Petrovaradin district to assess its impact on traffic flow and air pollution. This area is a critical

link between Petrovaradin and Novi Sad, and its closure may significantly increase congestion, making evaluation of this scenario essential for prospective stakeholders.

- **BRIDGES** – Simulates the building of two new bridges forming part of the city's outer ring in the east and west. The bypass is expected to redistribute a substantial volume of traffic between the western and eastern parts of the city.

To support effective urban planning, estimating the potential reduction in pollutant emissions due to changes in transport infrastructure can help in the decision-making process in urban planning.

Each scenario has its own configuration file, network file, and activity plans for each agent, though the simulation workflow remains the same. The user can choose between the three described scenarios: **BASELINE, PZ** and **BRIDGES.**

To execute the simulation, the user will use prepared configuration files and the following input parameters:

Network Settings - Network (Network with HBEFA) – The network file includes nodes and links representing Novi Sad's transportation infrastructure, with attributes such as capacity, maximum speed, number of lanes, and permitted transportation modes. The network is enhanced with road types and traffic situation attributes in accordance with the HBEFA classification, enabling the modelling of emissions alongside traffic dynamics. For each scenario, separate network files were prepared, taking into account proposed infrastructural changes.
Plans – This XML file defines daily activity sequences for synthetic agents, including activity types, coordinates of activity locations, start and end times, and travel modes. Separate plan files are provided for each scenario to reflect scenario-specific behavioural adaptations.

Once the input files are configured, the user can initiate the simulation by selecting **Start Simulation**. Upon completion, an archive containing the simulation results will be made available for download. The **output archive** includes all relevant results from the MATSim run. Detailed explanations of the output files can be found in the MATSim User Guide (https://matsim.org/files/book/partOne-latest.pdf). The main output files include:

- **events.xml.gz:** A detailed log of all agent activities, including departures, arrivals, link entries/exits, mode changes, etc.
- **output_plans.xml.gz:** The final optimized travel plans for all agents after the last iteration
- **scorestats.txt/png:** Summary statistics of plan scores across iterations
- **ITERS/…/plans.xml.gz, trips.csv.gz, events.xml.gz, legHistogram:** Iteration-specific travel plans, event logs, trip records, and histograms of activity start/end times.
- **emissionEvents.xml.gz:** Logs of emission events

These outputs can be used for post-simulation analysis, comparison across scenarios, and decision-making support for urban mobility planning.

User Profiles and Stakeholders

UDENE tools are specifically designed to support a wide array of stakeholders involved in urban planning and development. By leveraging EO data and advanced analytics, these tools provide critical insights and solutions tailored to the unique needs of each group. They empower users to make informed decisions, implement sustainable practices, and foster collaboration across sectors. Below is a detailed look at how UDENE tools cater to each stakeholder group:

Urban Planners - Urban planners are at the forefront of designing and managing cities, balancing the needs of growing populations with environmental sustainability and resilience. UDENE tools enable planners to Access high-resolution EO data for detailed urban mapping, land-use planning, and infrastructure development; analyse scenarios related to urban sprawl, environmental risks, and climate change impacts and evaluate the potential of sustainable solutions, such as green infrastructure or renewable energy integration, before implementation.

By providing data-driven insights, these tools allow urban planners to anticipate challenges and craft policies that align with long-term sustainability goals. For example, planners can use the Exploration Tool to simulate the effects of new developments on local ecosystems or infrastructure.

Academicians and Researchers - Academicians and researchers play a crucial role in advancing knowledge and innovation in urban planning and EO applications. UDENE tools offer them access to comprehensive EO datasets for studying urban dynamics, environmental impacts, and socio-economic trends; analytical frameworks to test hypotheses and develop models for sustainable urban development and real-world case studies and applications to validate research and provide evidence-based recommendations.

For example, researchers studying urban heat islands can use the tools to identify hotspots and propose cooling strategies, while others may analyse EO data to assess the effectiveness of sustainable city initiatives. By bridging research and practice, UDENE tools contribute to the development of actionable knowledge.

Public and Private Stakeholders

Public and private stakeholders, including governmental bodies, NGOs, and private enterprises, are pivotal in shaping urban environments. The benefit from UDENE tools for **public stakeholders** is via enabled use of EO data to monitor urban development, enforce regulations, and engage citizens in planning processes. For example, local governments can evaluate the effectiveness of zoning policies or monitor illegal construction using EO imagery. And for **private stakeholders**, the benefit lies in leveraging these tools to enable design innovative urban projects, such as smart city initiatives, and integrate EO insights into their business strategies.

By fostering collaboration between public and private sectors, UDENE tools enhance the ability to address complex urban challenges, such as managing rapid urbanization, improving infrastructure, or responding to environmental risks.

Small and Medium-sized Enterprises (SMEs) are vital drivers of innovation, offering specialized services and products that address niche urban challenges. UDENE tools empower SMEs to develop EO-based solutions for urban management, such as real-time monitoring systems or predictive analytics for resource allocation, collaborate with larger stakeholders by providing tailored services like EO-driven feasibility studies or urban sustainability assessments and expand their market reach by demonstrating the value of EO technology in solving pressing urban issues.

For example, an SME specializing in air quality monitoring could use UDENE tools to validate their sensors' data against EO datasets, providing more accurate and actionable insights to their clients. By lowering barriers to access and offering user-friendly interfaces, these tools make EO technology accessible to smaller enterprises, fostering innovation at all levels.

Urban Planners

National urban planning authorities play a central role in formulating policies and strategies to guide sustainable urban development. These entities ensure that urban growth aligns with national goals for economic, social, and environmental sustainability. By leveraging Earth Observation (EO) data, they can assess urban sprawl, identify risk-prone areas, and implement data-driven policies that promote resilience and inclusivity.

Examples: Ministry of Environment and Urbanization (Turkey) – Responsible for national urban and environmental planning policies; Ministry of Infrastructure and Sustainable Mobility (Italy) – Oversees urban transport and infrastructure strategies; Ministry of Housing, Territorial Planning, and Urban Development (Tunisia) – Focuses on urban expansion and housing projects; Ministry of Regional Development and Public Works (Bulgaria) – Develops regional planning frameworks and monitors urban growth; Ministry for Ecological Transition (France) – Promotes green urban initiatives and low-carbon city designs; Ministry of Environment, Urbanization, and Climate Change – Oversees national urban planning policies and environmental regulations; Directorate General of Spatial Planning – Develops spatial strategies and monitors land use on a national scale; Ministry of Housing and Urban Development – Governs urban expansion and housing projects; Agence de Réhabilitation et de Rénovation Urbaine (ARRU) – Focuses on urban renewal and slum upgrading projects; Ministry of Construction, Transport, and Infrastructure – Oversees urban development, transport, and spatial planning policies; Institute of Architecture and Urban & Spatial Planning of Serbia – Develops national spatial plans and urban policies.

Municipal planning offices are responsible for urban design, land use planning, and infrastructure development at the city or town level. They play a critical role in implementing national policies and adapting them to local needs. EO data allows these offices to monitor land use changes, plan transport networks, and manage resources efficiently.

Examples: Barcelona City Council Urban Planning Department (Spain) – Focuses on sustainable transport and urban resilience; Athens Urban Planning Division (Greece) – Manages green infrastructure and heritage conservation; Marseille Urban Development Agency (France) – Implements smart city initiatives and climate adaptation projects; Rome Urban Planning Authority (Italy) – Oversees urban regeneration and mixed-use developments; Municipality of Limassol Planning Office (Cyprus) – Coordinates coastal city resilience and urban expansion strategies; Istanbul Metropolitan Municipality – Focuses on urban transformation, transport infrastructure, and sustainability projects; Ankara Metropolitan Municipality – Implements projects for urban resilience and smart city development; Municipality of Tunisia – Implements urban policies for heritage conservation and modern city management; Municipality of Sfax – Works on urban development projects, including waste management and transport; City of Belgrade Urban Planning Department –

Focuses on modernizing urban infrastructure and transport systems; Novi Sad Urban Planning Institute – Manages urban projects, including green space development and housing.

Academicians and Researchers

Academicians and researchers contribute to advancing the understanding of urban challenges through studies and innovation. They explore EO applications in urban planning, develop analytical frameworks, and provide evidence-based recommendations. Their work bridges theoretical research with practical solutions for real-world problems.

Examples: University of Thessaloniki (Greece) – Researches urban planning strategies using EO data; Sapienza University of Rome (Italy) – Studies the impact of urbanization on ecosystems; Mediterranean Institute for Advanced Studies (Spain) – Focuses on urban environmental monitoring; Institute of Mediterranean Urbanism (Portugal) – Specializes in sustainable city design and urban policy; Cyprus Institute – Explores EO data for climate-resilient urban planning; Middle East Technical University (METU) – Conducts research on urban planning, environmental impact, and Earth Observation applications; Istanbul Technical University (ITU) – Focuses on urban sustainability and geospatial analysis; National Engineering School of Tunisia (ENIT) – Researches urban resilience and sustainable city strategies; University of Sousse – Studies environmental impacts and urban planning in coastal regions; University of Belgrade - Faculty of Geography – Conducts urban planning research and EO data analysis; University of Novi Sad – Faculty of Technical Science – Focuses on urban engineering and sustainable development.

Public and Private Stakeholders

Public stakeholders include government agencies, transport authorities, and non-governmental organizations (NGOs). These entities ensure public interests are served in urban development, often focusing on infrastructure, mobility, and sustainability. EO data empowers these stakeholders to monitor changes, design efficient public systems, and engage citizens.

Examples: Athens Urban Transport Organization (Greece) – Develops sustainable public transport solutions; Tunisian Urban Observatory (Tunisia) – Monitors urban expansion and identifies development trends; Sicily Regional Government (Italy) – Implements regional urban and transport policies; Turkish Statistical Institute (TurkStat): Provides urban data and analysis to support planning decisions; Istanbul Development Agency: Promotes regional development and sustainable urbanization; Tunisian National Observatory for Urbanism: Monitors urban development and provides analytical insights; Agence Nationale de la Maîtrise de l'Énergie (ANME) – Promotes energy efficiency and sustainability in urban areas; Statistical Office of the Republic of Serbia (SORS) – Provides urban and regional statistics to support planning; Institute for Nature Conservation of Serbia – Monitors urban impacts on natural resources and biodiversity.

Private stakeholders, including consultancy firms and corporations, contribute to urban planning by offering specialized services such as EO-based analysis, smart city solutions, and infrastructure design. These stakeholders often collaborate with public entities to deliver innovative solutions tailored to urban challenges.

Examples: Eni S.p.A. (Italy) – Integrates EO data into energy infrastructure planning; Terrasigna (Romania) – Provides EO services for urban and environmental monitoring; Arcadis Mediterranean

(Spain) – Offers consultancy on sustainable urban development projects; MeteoData Services (Cyprus) – Specializes in climate and urban resilience solutions; Arup Turkey – Provides consultancy for sustainable infrastructure and urban development projects; Zorlu Energy Group – Engages in urban energy efficiency and smart city solutions; Tunisiaie Engineering Group – Provides urban planning and infrastructure development services; Société d'Études et d'Aménagement Urbain (SEAU) – Engages in planning and sustainable urban design projects; Belgrade Urban Institute – Provides consultancy for urban planning and development; Nexe Group Serbia – Works on sustainable construction and urban infrastructure.

SMEs

Small and Medium-sized Enterprises (SMEs) are at the forefront of innovation in EO applications for urban planning. These businesses often develop niche solutions, such as data analytics platforms, mobile applications, and EO-driven monitoring tools, to address specific urban needs.

Examples: Smartland Analytics (Italy) – Develops EO tools for urban green space management; GeoTech Innovations (Greece) – Offers geospatial analysis for urban development; UrbanView Solutions (Spain) – Provides EO-based insights for city planners; GreenGrid Technologies (Turkey) – Designs EO-driven solutions for urban energy efficiency; GeoTech Innovations – Specializes in EO-based geospatial services for urban planning; SmartGrid Solutions Turkey – Develops smart city and energy management solutions using EO data; GeoUrban Tunisia – Develops geospatial tools for urban planning and resource management; GreenCity Solutions – Provides EO-based consultancy for sustainable urban development; UrbanEco Solutions – Offers urban sustainability and environmental impact assessment services; GeoData Serbia – Specializes in geospatial analysis for urban planning and decision-making.

Basic Training and Resources

Online Training Material

To support and prepare users for their sessions and to maximize the utilization of the Exploration and Matchmaking tools, recorded webinars and online training sessions will be made available on the UDENE website. These resources aim to facilitate a deeper understanding of the platform's capabilities and ensure effective engagement. The webinars will be conducted by project partners responsible for developing the tools, providing direct insights into their functionalities. Additionally, training sessions will be organized for winners of the Open Calls as well as UDENE partners, led by both the tool developers and partners involved in Task 5.3. All recorded sessions will undergo post-production editing before being published on the UDENE website and YouTube channel. These materials will serve as supplementary resources to Deliverable 5.3 Practical User Guidelines and Tools Tutorials. Furthermore, a Frequently Asked Questions (FAQ) document will be made available alongside these recordings to address common inquiries and enhance user experience.

In-Situ and Off-situ Guidelines

In-situ guidelines (hover-text) are integrated into the tools to assist users in navigating and ensuring an optimal user experience. These embedded guidelines provide step-by-step support, enhancing usability and accessibility. Additionally, scripts for off-situ the Tools Tutorials have been carefully prepared and validated by UDENE partners to ensure accuracy and clarity. Produced tutorial videos are focused on user-friendly experience, enabling users to fully leverage the tools functionalities. Off-situ guidelines will be completed with recorded webinars during the Open Calls and training sessions with UDENE partners.

Useful Earth Observation Products

EO plays a critical role in environmental monitoring, disaster management, climate change studies, and sustainable development. The UDENE project, focusing on urban sustainability and smart city solutions, can leverage EO technologies for monitoring urban environments, optimizing resource use, and improving resilience against climate-related risks. In this section of the deliverable overview of 5 EO products and their specific characteristics and uses are provided, with the roadmap to user guides and instruction materials:

- **Copernicus Browser** ➡ Ready-to-use urban environmental datasets
- **EO Browser** ➡ Raw imagery
- **NASA Worldview** ➡ Real-time data on urban climate, pollution, disasters
- **Google Earth Engine** ➡ Advanced geospatial analysis and AI-powered EO tools
- **Open Data Cube** ➡ Long-term EO data storage and deep analytics

Table 5 provides an overview of EO tools and their features. More information about different EO products, applications and services is available in Deliverable 3.3 Inventory of the European providers of EO-based Applications and Services.

Table 5. Overview and features of essential EO products

Tool	Copernicus Browser	EO Browser	NASA Worldview	Google Earth Engine	Open Data Cube

Operator	European Commission	Sinergise (Sentinel Hub)	NASA	Google	Open Source (CEOS, CSIRO)
Focus	Copernicus service data for policy/science	General satellite imagery for analysis	Near real-time visualization of environmental data	Advanced geospatial analysis and cloud computing	Time-series analysis of EO data for urban trends
Data Sources	Sentinel satellites + Copernicus service products	Sentinel, Landsat, MODIS, others	MODIS, VIIRS, Landsat, Sentinel	Landsat, Sentinel, MODIS, VIIRS	Sentinel, Landsat, MODIS, other EO datasets
Features	Designed for **policy support and scientific applications**. Provides **pre-processed Copernicus service products** rather than raw satellite imagery. Focused on **specific thematic areas** (land cover, air quality, emergency response).	**User-friendly interface** for browsing and visualizing satellite images. Allows **custom processing, band combinations and time-lapse analysis.** Includes **AI-powered analytics tools** for vegetation, water and land change detection.	Near real-time visualization of **environmental data.** Provides tools for **wildfire, air quality and weather monitoring.** Can overlay different datasets to analyze **urban heat islands, land-use changes and environmental impacts.**	**Advanced geospatial analysis** with cloud computing. Enables **machine learning and big data processing** for environmental monitoring. Users can create **custom algorithms** to analyze urban changes, land use and environmental sustainability.	**Long-term analysis** of EO data for cities and the environment. **Time-series analysis** for urban expansion, climate adaptation and water management. **Customized queries** for analyzing specific environmental factors over time.
Processing Tools	Limited, focused on Copernicus services	Advanced visualization, band combinations, AI analytics	Visualization overlays, real-time monitoring	Cloud computing, AI/ML analysis	Data cube storage, customized queries
Free Access	**Yes**	**Yes (basic)**	**Yes**	**Yes (non-commercial)**	**Yes**
Registration Required	**No**	Yes	**No**	Yes	**No**
Paid Features	No	Paid API access	No	Paid for commercial use	No
Guidelines & Instructions	In-App Tutorial User Guidelines Video tutorial	Sentinel EO Browser Webinar Sentinel EO Browser Tutorial Sentinel EO Browser User Guide	Getting Started with NASA Worldwide External Guide	Google Earth Engine Guide External User Manual	ODC Instructions
Best for UDENE tool users	**Urban climate monitoring, air quality, land use**	**Urban monitoring, land-use change detection**	**Urban air pollution, heat islands, extreme weather**	**Urban sustainability, land-use change analysis**	**Long-term climate and urban growth analysis**

Further Resources

1. Urban Development and Air Pollution via Traffic

– Evaluating the Impact of Urban Traffic Patterns on Air Pollution
– Urban and Air Pollution: A Multi-City Study of Long-Term Effects of Urban Form
– The Effects of Urban Form on Ambient Air Pollution and Public Health Risk: A Case Study in Chinese Cities
– Aggravated Air Pollution and Health Burden Due to Traffic Congestion in China
– High-Resolution Urban Air Pollution Mapping

2. Assessing Heat Load Reduction Using Local Climate Zones (LCZs)

– Warming and Cooling Effects of Local Climate Zones on Urban Thermal Environment
– Advancing the Local Climate Zones Framework: A Critical Review of Recent Developments and Future Directions
– Use of Local Climate Zones to Investigate Surface Urban Heat Islands in Canadian Cities
– Assessing the Impact of Urban Heat Island Effect on Building Cooling Load Based on the Local Climate Zone Scheme
– Contribution of Local Climate Zones to the Thermal Environment and Energy Demand: A Case Study

3. Evaluating the Efficiency of Linked Park Systems in Cooling Urban Spaces

– Evaluation and Optimization of Park Cooling Benefits Based on Cumulative Impact Perspective
– A Study of Size Threshold for Cooling Effect in Urban Parks and Their Surrounding Areas
– How to Measure the Urban Park Cooling Island? A Perspective of Landscape Metrics and Socioeconomic Factors
– Cooling Effect of Urban Parks and Their Relationship with Urban Heat Islands
– Quantifying and Comparing the Cooling Effects of Three Different Types of Urban Green Spaces

4. Determining Spatial and Temporal Variations in Heat Load Reduction

– Spatial and Temporal Changes of Outdoor Thermal Stress in Seoul's Urban Parks
– Spatial and Temporal Variabilities in Land Surface Temperatures and Their Relationship with Air Temperatures in Nanjing, China
– Spatial and Temporal Distribution Analysis of Industrial Heat Sources in the U.S. with Geocoded, Tree-Based, Large-Scale Clustering
– Spatial and Temporal Changes and Associated Determinants of Global Heating Degree Days
– The Relationship Between Thermal Spatial Variability and Mean Population Abundance in a Stream Salamander

5. Assessing Earthquake-Induced Damage in High-Rise Districts

– Earthquake-Induced Building-Damage Mapping Using Explainable Artificial Intelligence
– A Comprehensive Review of Earthquake-Induced Building Damage Detection with Remote Sensing Techniques
– Earthquake Building Damage Detection Based on Synthetic-Aperture Radar: A Review
– Detection of Earthquake-Induced Building Damages Using Satellite Remote Sensing
– Earthquake Damage Visualization (EDV) Technique for the Rapid Assessment of Damaged Areas

UDENE Data Cube

The **UDENE Data Cube** is a comprehensive platform designed for data management, analysis, and satellite data processing. It integrates various data types, including **raster, vector, textual data, external databases and APIs**, enabling users to perform advanced geospatial analysis. The system is composed of four main components:

1. **UDENE Data Cube Web Application** – A user-friendly interface for data queries, visualizations, and analysis.
2. **UDENE Data Cube Web Backend Application** – Manages data storage, user authentication, and security.
3. **UDENE Data Cube Services Web Service Application** – Provides API-based data access and processing capabilities.
4. **UDENE Data Cube Tools** – A set of tools for preparing and integrating satellite imagery into projects.

This ecosystem supports **customized data processing, AI model integration, and geospatial transformations**, offering a scalable infrastructure for various analytical needs.

Purpose

The UDENE Data Cube aims to provide a **robust, flexible, and scalable** environment for processing and analysing geospatial data. It supports **image classification, object detection, spatial analysis, change detection, and predictive modelling**, making it a powerful tool for **urban planning, environmental monitoring, disaster assessment, and land use analysis**.

Objectives

- **Enable Efficient Data Management** – Provide structured handling of raster, vector and textual data.
- **Enhance Data Processing & Analysis** – Support complex statistical computations, AI-driven models and real-time data integration.
- **Facilitate Cross-Domain Research** – Allow data integration from external databases, APIs and other data cubes.
- **Support Advanced Geospatial Analysis** – Provide powerful GIS tools for transformations, overlay analysis and thematic mapping.
- **Ensure Scalability & Flexibility** – Maintain an expandable system that adapts to evolving user needs and technological advancements.

With these capabilities, the **UDENE Data Cube** serves as a **centralized** and **intelligent** solution for managing diverse geospatial data and conducting high-level analyses across multiple disciplines.

In the ***Figure 24*** General Architecture and components of the UDENE Data Cube is shown.

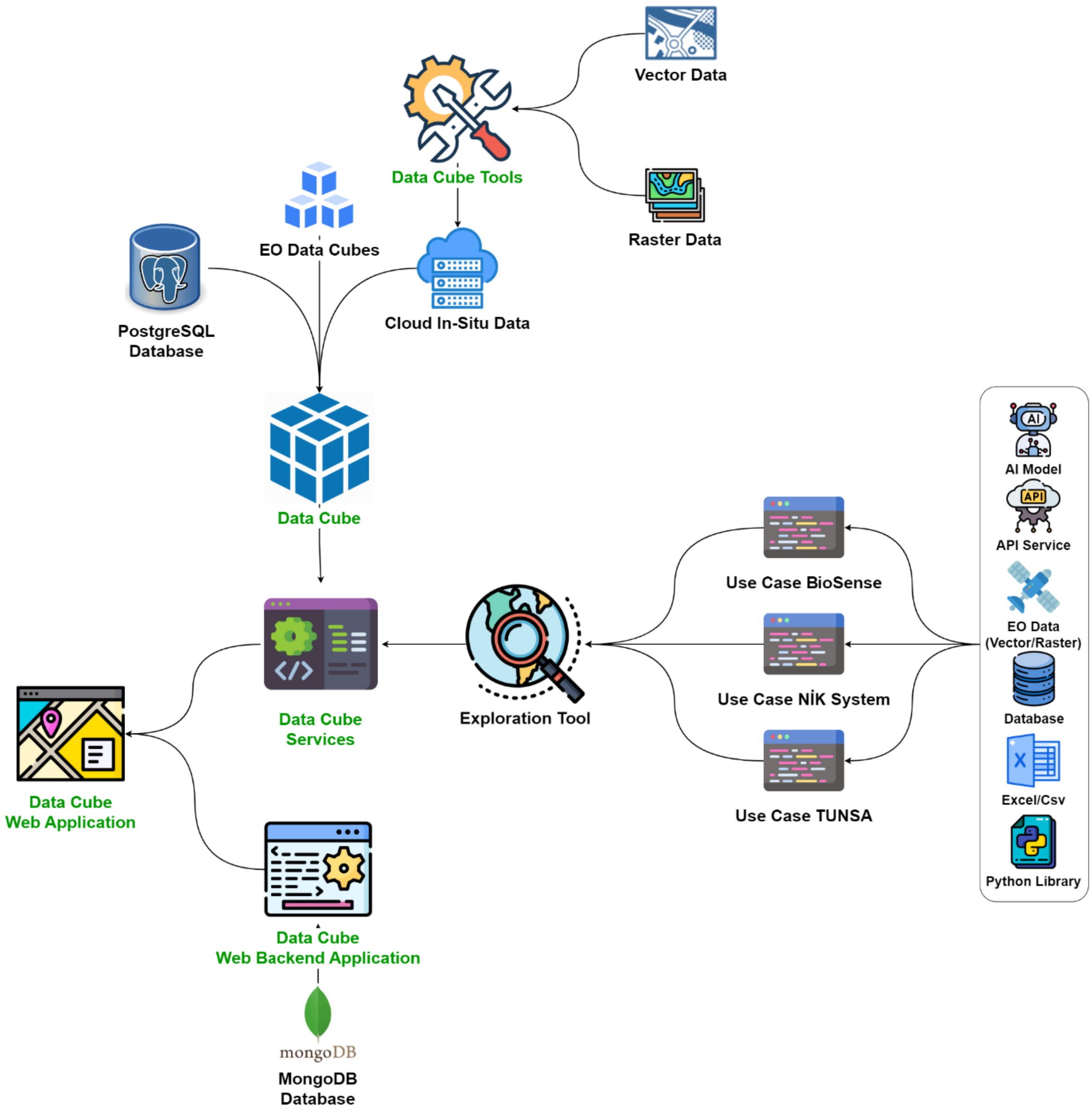


Figure 24. General Architecture and components of the UDENE Data Cube

Use Cases description guidelines

For the purpose of using the UDENE Exploration and Matchmaking tools it is necessary to define a specific Use Case. The required information UDENE's use cases is provided through the public Deliverable **D3.1: Use Case Descriptions.** In this section are provided the guidelines for filling the Use Case Descriptions form.

Detailed guidelines for filling the Use Case Descriptions form that will be used in UDENE Exploration and Matchmaking Tools is provided in the ***Table 6***.

Table 6. Guideline for Use Case Descriptions

Category	Guidelines
Use Case Title	The title should clearly **describe the focus of the use case** in a **concise and informative** manner, and reflect the **urban development challenge** or **research focus** of the case.
Example: *Assessment of Urban Development Plans from an Environmental Perspective* (Serbia).	
Use Case Idea	Provide a **high-level overview** of the urban development plan or concept. Explain **why** the development is needed and what **problem** it addresses. Describe **key urban interventions** (e.g., infrastructure improvements, climate adaptation strategies). Include **intended benefits** (e.g., reducing emissions, improving resilience, enhancing public spaces).
Example: *Introducing a linked park system to mitigate urban heat islands (Tunisia).*	
Objective	Clearly state **what the use case aims to achieve**. Break down the objectives into **specific measurable goals** if needed. Ensure objectives align with **UDENE's overall urban development and data-driven approach**.
Example: (i) Analyze how planned transportation changes impact air pollution; (ii) **Develop** adaptable methodologies for traffic and emission modeling.	
Inverse UseCase	Define **an alternative approach** that challenges or optimizes the original urban development idea. Often involves **opposite scenarios** or **optimized designs** based on data analysis. Should align with **policy recommendations** and potential **alternative strategies**.
Example: *Instead of pedestrianizing a street, optimize traffic flow to reduce congestion and emissions.*	
Use Case Study Area	**Define the geographical location** of the use case, including **specific districts, cities, or regions**. Provide **coordinates** if available. Mention any **relevant local conditions** (e.g., topography, urban density, infrastructure). Include **maps or visual references** if possible.
Example: *Novi Sad, Serbia, located in northern Serbia at 45°15′15″N 19°50′33″E, with a population of 368,967.*	

<table>
<tr><td>Study Area Characteristic Variables</td><td>Describe key physical, environmental, and socio-economic characteristics of the study area. Consider variables Climate & weather conditions; Population density & urbanization levels; Existing infrastructure & transport networks; Environmental risks (air pollution, seismic activity, heat islands, etc.)</td></tr>
<tr><td colspan="2">Example: Tunisia has a highly urbanized environment with a population of 2.6 million, characterized by heat island effects due to dense built-up areas.</td></tr>
<tr><td>Temporal Scope</td><td>Define the time frame for the analysis. Specify if the use case covers - Historical trends (e.g., past 10 years); Real-time monitoring; Future projections (e.g., climate impact over 50 years). Specify the time period covered by the use case. This could be a specific date range or a recurring time frame</td></tr>
<tr><td colspan="2">Example: Serbia's use case will analyze average daily traffic behaviors and pollutant emissions across different seasons.</td></tr>
<tr><td>Input Predictor Variables</td><td>List independent variables used for analysis – e.g. Environmental factors (temperature, wind, precipitation); Urban parameters (road networks, population density, land use); Traffic data (vehicle counts, speed, congestion levels); Socioeconomic indicators (employment rates, education levels). Define both for the case study and the inverse case study.</td></tr>
<tr><td colspan="2">Example: Serbia's use case includes variables such as wind speed, humidity, vehicle counts, and road network characteristics.</td></tr>
<tr><td>Outcome Variables</td><td>Define dependent variables that reflect the impact of urban interventions. These should align with objectives and expected results. Define both for the case study and the inverse case study.</td></tr>
<tr><td colspan="2">Example: Air pollution levels (NO_2, CO, PM2.5); Temperature changes in urban areas (heat island reduction); Structural damage risk in earthquake-prone regions.

For Türkiye, the primary variable is the level of earthquake-induced structural damage, while the inverse case considers undamaged buildings</td></tr>
<tr><td>Input Dataset/s</td><td>– Provide a list of datasets used in the analysis, categorized as:
▪ Remote sensing datasets (e.g., Sentinel-5P for air pollution, Landsat for land cover)
▪ In-situ measurements (e.g., weather stations, traffic counts)
▪ Government & census data (e.g., urban plans, building inventories)
▪ Other models & databases (e.g., Copernicus DEM, OSM data)
– Include details on spatial resolution, temporal frequency, and data sources.</td></tr>
<tr><td>Methodology</td><td>Describe the scientific and analytical approach used in the use case:

– Input data assessment - Only for data contributed by users, if the case.
– Data integration - Describe how EO and in-situ data will be integrated. Discuss any challenges or methods for merging these datasets effectively.</td></tr>
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– **Model implementation** - An overview of the analysis methods and techniques to be employed. Common methodologies include - Statistical regression models (e.g., pollution emission forecasts); Machine learning approaches (e.g., Random Forest for urban heat prediction); Simulation models (e.g., agent-based modelling for traffic impact); Remote sensing analysis (e.g., NDVI/EVI for green space monitoring).
– **Outcome validation** - Outline the approach for validating the results obtained from the use case.

</td></tr>
<tr><td colspan="2">

Example: *The Tunisia use case applies Random Forest regressors to model Surface Urban Heat Island effects based on satellite imagery and climate data.*

</td></tr>
<tr><td>

Use Case Integration with UDENE's Data Cube and Exploration Tools

</td><td>

Explain how the use case integrates with **UDENE's platform**, including:
– **Data ingestion** – how datasets are stored and processed.
– **Model execution** – how models are run within the exploration tool.
– **User interaction** – how decision-makers can use the insights.
Describe **any APIs, interfaces, or analytical workflows** involved.

</td></tr>
<tr><td>

Challenges/Risks and Mitigation

</td><td>

Identify potential **technical, data-related, or policy challenges**. Provide **practical solutions or risk mitigation strategies**.

</td></tr>
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Examples of common challenges:
– **Data availability** → Mitigation: Partner with local institutions for access.
– **Resolution mismatch in datasets** → Mitigation: Use interpolation techniques.
– **Uncertainty in model predictions** → Mitigation: Sensitivity analysis.

</td></tr>
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Planning

</td><td>

Provide a **timeline with key milestones** (Gantt chart format if needed). Define **responsibilities** (which partner handles what tasks).

</td></tr>
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Example of milestones:
– **M14 (Feb 2025):** Define methodology and data collection.
– **M15 (March 2025):** Conduct alpha testing with project partners.
– **M16 (April 2025):** Finalize user guidelines and prepare for beta testing.

</td></tr>
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Final Notes

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– **Consistency** is key – ensure uniform structure across all use cases.
– **Be specific** with data, variables, and methodologies.
– **Align objectives** with UDENE's overall goals in urban development and sustainability.
– **Include references** where applicable (datasets, methodologies, frameworks).

</td></tr>
</table>

UDENE Use Cases – excerpt

In this section of the Deliverable the excerpt of the UDENE Use Cases is provided. A more detailed descriptions of the UDENE Use Cases are provided in the Deliverable document **D3.1: Use Case Descriptions.** For more references and insights, the Deliverable 3.1 can be freely accessed via **UDENE Website section Publications**.

Serbia Use Case - Assessment of the urban development plans from environmental perspectives

In ***Table 7*** Characteristics of Use Case in Novi Sad, Serbia is provided as an excerpt from the Deliverable 3.1 Use Case Description.

Table 7. Serbian Use Case characteristics

Use Case	**How will air pollutant emissions change due to significant transport infrastructure modifications, with the focus on:** – **Construction** of new traffic infrastructure (bridges) in the Novi Sad outer ring. – **Restricting motor vehicle access in** sensitive parts of the urban area.
Objectives & Goals	**Analyse** effects of transportation network changes on pollutant emissions. **Develop methodologies** initially for Novi Sad but adaptable to other regions.
Inverse Use Case	**Concept:** Optimize transportation networks to minimize pollutant emissions. **Objective:** Define optimal traffic flow and road design to reduce emissions.
Study Area	**Location:** Novi Sad, Serbia (45°15′15″N 19°50′33″E) **Climate:** Temperate, exposed to strong winds **Population:** 368,967 **Key urban factors:** Planned Road expansions and pedestrian zones affecting traffic
Temporal Scope	Analysis of **daily traffic behaviours** and emissions during **different days (weekday, weekend) and seasons**.

Tunisia Use Case - Effect of a linked park system on heat load

In ***Table 8*** Characteristics of Use Case in Tunisia is provided as an excerpt from the **Deliverable 3.1 Use Case Description**.

Table 8. Tunisia Use Case characteristics

Use Case	**Creating a linked park system within Tunisia to mitigate Urban Heat Islands (UHI) through green spaces, urban forests, and shaded areas.**
Objectives & Goals	**Assess** heat load reduction using Local Climate Zones (LCZs). **Evaluate** efficiency of the linked park system in cooling urban spaces. **Determine** spatial and temporal variations in heat load reduction.
Inverse Use Case	**Concept:** Urban cooling strategies via improved infrastructure and natural solutions. **Objective:** Reduce surface temperatures using reflective surfaces and green infrastructure while improving urban ventilation through optimized city layouts.

Study Area	**Location:** Greater Tunisia, Tunisia (36°49'43.15"N - 36°54'58.5"N) **Population:** Approx. 2.6 million **Surface Area:** 126 km² **Urban Characteristics:** High-density, diverse urban-rural mix, sensitive to heat island effects
Temporal Scope	**10-year timeframe** with a focus on **2023** for historical analysis and validation.

Türkiye Use Case - Determination of Having a High-Rise District Effect in the context of Earthquake Preparedness

In ***Table 9*** Characteristics of Use Case in Asian part of Istanbul, Kadıköy, Ataşehir, Üsküdar, area (focusing Fikirtepe sub-zone for high-rise urbanization) Türkiye is provided as an excerpt from the **Deliverable 3.1 Use Case Description**.

Table 9. Türkiye Use Case Description

Use Case	Assessing earthquake preparedness of high-rise buildings and their urban impact in Istanbul, aligning with Sustainable Development Goal 11 (SDG11) on resilient urbanization.
Objectives & Goals	**Assess** earthquake-induced damage in high-rise districts, **determine** the proportion of damaged versus undamaged buildings, **evaluate** the economic impact of earthquakes, and **develop models** to predict seismic risks and infrastructure vulnerabilities.
Inverse Use Case	**Concept:** Develop resilient urban planning alternatives to reduce seismic risks. **Objective:** Minimize damage by **avoiding high-rise structures** in earthquake-prone areas.
Study Area	**Location:** Asian part of Istanbul (Kadıköy, Ataşehir, Üsküdar) **Population:** Approx. **383,596** **Density: 18,000 people/km²** **Surface Area: 12 km²** **Geological Concerns:** Close to **North Anatolian Fault Line**, with high seismic activity
Temporal Scope	Earthquake scenarios are modelled for **a specific daytime event**. **Global search** of similar urban areas for comparison over a **10-year window**.

Guidelines for Effective Usage

The Practical User Guidelines for UDENE tools are designed to help stakeholders navigate and optimize the tools' capabilities efficiently. Effective usage ensures that the tools deliver their full potential, enabling users to make informed decisions and achieve impactful outcomes. By following these guidelines, stakeholders, including urban planners, researchers, public authorities, and SMEs, can seamlessly integrate the tools into their workflows, leveraging Earth Observation (EO) data for sustainable urban development.

Best Practices

Effective use of the UDENE tools hinges on a solid understanding of their features and an application of best practices. These tools, powered by Earth Observation (EO) data and advanced analytics, offer users the ability to address complex urban planning challenges with precision and foresight. Best practices act as a roadmap for users, ensuring optimal navigation, high-quality data integration, and meaningful scenario-based analysis. By following these proven strategies, stakeholders such as urban planners, researchers, public authorities, and SMEs can fully leverage the tools' capabilities to achieve actionable insights and sustainable outcomes. A structured approach to using the tools fosters collaboration, accuracy, and innovation, empowering users to make data-driven decisions with confidence.

- **Understand the Tool’s Functionality** - Before using the tools, familiarize yourself with their features and capabilities. Review the user interface, data input requirements, and output formats to ensure seamless navigation. Utilize available training materials or tutorials provided within the UDENE platform to gain a comprehensive understanding of the tools.
- **Define Clear Objectives** - Clearly outline the purpose of your analysis before utilizing the tools. Whether it's assessing urban resilience, identifying risk-prone areas or evaluating infrastructure projects, a focused objective ensures effective use of the tools and relevant insights. Use the guidance in section ***Use Cases description guidelines*****.**
- **Leverage Quality Data Inputs** - The accuracy of tool outputs heavily depends on the quality of input data. Ensure that data entered is accurate, relevant, and up-to-date. For instance, while using the Exploration Tool, select datasets aligned with your geographic and thematic focus.
- **Utilize Scenario-Based Analyses** - For planning and decision-making, run multiple scenarios to compare outcomes. For example, the Exploration Tool allows you to assess the environmental impact of various urban development options. Comparing these scenarios provides a holistic understanding of possible outcomes.
- **Collaborative Team** - Collaborative use of the tools, combining inputs from planners, researchers, and policymakers, ensures a comprehensive approach and increases the reliability of decisions.
- **Document and Review Outputs** - Save and document results from the tools for future reference and review. This ensures continuity in planning efforts and allows comparisons across different analyses over time.

Maximizing Tool Potential

The full potential of the UDENE tools lies in their capacity to translate raw EO data into actionable insights for urban planning and development. Maximizing this potential involves not only understanding the tools' technical capabilities but also embedding their outputs into real-world decision-making processes. By integrating the Exploration and Matchmaking tools into strategic planning, users can identify risks, optimize resources and forge collaborations with EO service providers. Staying informed about new features and participating in training opportunities further ensures that users remain at the cutting edge of urban planning innovation. With thoughtful application, the tools become powerful allies in creating resilient, inclusive and sustainable urban spaces.

- **Integrate Outputs into Decision-Making -** Use the insights generated by the tools to inform policies, urban planning decisions and project designs. For example, insights from the Matchmaking Tool can guide partnerships with EO service providers for specific urban challenges.
- **Apply to Real-World Use Cases -** Identify practical applications where the tools can be used to solve pressing urban issues. For instance, the tools can help cities assess their vulnerability to climate risks or optimize energy-efficient infrastructure projects.
- **Combine Tools for Comprehensive Analyses** - Utilize both the Exploration and Matchmaking Tools together for a robust planning approach. For example, use the Exploration Tool to model urban scenarios and the Matchmaking Tool to connect with service providers who can implement the solutions.
- **Stay Updated on Features** - Regularly check for updates or new features added to the tools. The UDENE team continuously improves functionality based on user feedback, enhancing the tools’ performance and usability.
- **Participate Webinars and use all resources** - Take advantage of recorded training sessions and webinars by the UDENE project. These opportunities provide hands-on guidance and insights into advanced features, ensuring users can extract maximum value from the tools.

By adhering to these guidelines, users can effectively harness the power of UDENE tools, transforming data into actionable insights and driving impactful, sustainable urban development initiatives.

Updates and Revisions

To ensure the effectiveness, relevance, and usability of the Practical User Guidelines for UDENE tools, regular updates and revisions are integral to the process. The dynamic nature of urban planning and the continuous evolution of Earth Observation (EO) technologies necessitate periodic enhancements to the guidelines. Updates incorporate the latest data, methodologies, and user feedback, ensuring that the tools remain aligned with stakeholders' needs and technological advancements. Revisions also respond to changes in regional or global priorities, such as climate resilience, smart city initiatives, and regulatory frameworks.

The revision process involves assessing the functionality and applicability of the guidelines at defined intervals, integrating insights gained from tool users, and adapting to emerging challenges in urban development. A transparent and structured approach ensures consistency and inclusivity, allowing diverse user groups to benefit from the improvements.

Procedure for Updating Guidelines

The procedure for updating the guidelines follows a structured framework to ensure systematic revisions:

- **Testing and Review:** Before releasing an updated version, pilot testing is conducted with the UDENE partners developing the UDENE Use Cases. This step validates the revisions and ensures the guidelines meet the intended objectives without introducing unnecessary complexity. The next step is testing by Open Call winners in two cycles of open calls. In all three testing cycles feedback from users will be required. The reviews will provide the performance overview of the Exploration and Matchmaking Tools and their proficiency to address user needs.
- **Approval and Publication:** Updated guidelines undergo a review by the project's steering committee and reviewers to ensure quality and consistency. Once approved, the revised version is published on the UDENE website and made accessible to all stakeholders. The guidelines will be available in the video format in the form of two video guides on how to use the tools and the tools will incorporate hoover text and assistants throughout to help navigate the tools.

Feedback and Improvement Mechanism

Feedback is a cornerstone for continuous improvement of the guidelines. A robust mechanism for collecting, analysing, and integrating user feedback ensures that the guidelines evolve in response to user experiences and challenges. The mechanism includes:

- **Online Support Portal:** The UDENE website features an interactive portal where users can submit suggestions, report issues, or request clarifications. This platform provides real-time access to user insights.
- **Workshops and Training Sessions:** 2 Webinars and 2 Online Training Sessions serve as forums for direct interaction with users. These sessions will be recorded and provide and facilitate

discussions on the practical application of the tools and provide valuable feedback on their usability.

- **Surveys and Questionnaires:** Periodic surveys help assess user satisfaction and gather targeted input on specific aspects of the guidelines. Questions focus on the clarity, comprehensiveness, and practicality of the instructions.
- **Documentation of Feedback:** All feedback is systematically documented and categorized for analysis. Actionable insights are prioritized and incorporated into the next update cycle.

By maintaining a dynamic feedback loop, UDENE ensures that the guidelines incorporated into the tools remain an up-to-date and functional part of the tools, also providing the better user experience and evolving user needs while maintaining their role as a reliable resource for sustainable urban planning.

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