

People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
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Faculty of Nature and Life Sciences and Earth Sciences
Department of Biology

PRACTICAL WORKS: GEOGRAPHIC INFORMATION SYSTEMS & REMOTE SENSING

For Master Students in Ecology



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Preamble

This practical guide provides an integrated methodological pathway for second-year Master's students in Environmental Science, facilitating their transition from theoretical understanding to the professional application of geospatial technologies. The structured process commences with guiding students through the proper installation of specialized software, such as QGIS, and familiarizing them thoroughly with its interface and analytical tool architecture. The program progressively advances to impart advanced data processing skills, culminating in the design and execution of miniature environmental projects that simulate real-world field challenges and land cover dynamics.

Practical sessions are designed to empower students to produce accurate thematic maps and visual outputs that precisely depict the spatial distribution of complex ecological phenomena. Furthermore, the curriculum places significant emphasis on training students to formulate final scientific reports in adherence to academic methodologies (IMRAD), enabling effective interpretation of results and their environmental implications. This training culminates in the presentation and defense of final projects, thereby enhancing scientific communication skills and the methodological justification of spatial models before academic committees. The ultimate aim of these outputs is to formulate actionable environmental recommendations, grounded in spatial analysis, to support informed decision-making and strategies for natural resource sustainability. This endeavor thus establishes a robust practical foundation, equipping students to produce distinguished Master's theses and meet the contemporary technical demands of scientific research in environmental conservation.

General Objectives

- **Technical Proficiency in Geospatial Software:** To equip students with the requisite operational skills for installing and utilizing Geographic Information Systems (GIS) software (e.g., QGIS), engaging professionally with its interfaces, employing its analytical tools, and managing spatial databases effectively.
- **Mastery of Digital Data Processing:** To enable students to acquire and process satellite imagery, extract spectral environmental indicators (such as vegetation indices), and

implement digital classification protocols for the interpretation and extraction of terrestrial features.

- **Spatial Modeling and Cartographic Production:** To develop researchers' competence in analyzing field-based environmental problems (e.g., ecological degradation, land cover changes) and translating these complex spatial analyses into precise thematic maps and unambiguous visual outputs.
- **Project Management and Scientific Reporting:** To qualify students in the design and execution of miniature environmental projects, alongside the ability to compose synthetic final reports following academic methodologies for result interpretation and the derivation of practical environmental recommendations that support decision-making.

Targeted Scientific and Methodological Skills

- **Operational Control of Spatial Software Environments:** Attaining high proficiency in utilizing Geographic Information Systems software (e.g., QGIS), managing geospatial databases, and performing digitization and spatial analysis operations on environmental data.
- **Professionalism in Digital Satellite Imagery Processing:** Achieving technical mastery in importing and processing satellite images, extracting precise spectral environmental indicators, and applying digital classification algorithms to interpret land cover dynamics.
- **Cartographic Production and Precise Visual Modeling:** Enhancing skills in designing and producing professional thematic maps that accurately depict the spatial distribution of ecological phenomena, in adherence to recognized cartographic standards.
- **Methodological Formulation and Scientific Argumentation:** Leveraging technical outputs to complete miniature environmental projects, compiling synthetic scientific reports for discussion following the IMRAD methodology, and developing the ability to academically defend findings and derive actionable recommendations for environmental decision support.

Prerequisites and Resources

- Cognitive Prerequisites: Prior theoretical understanding of ecological systems fundamentals, principles of Geographic Information Systems, and the physical characteristics of remote sensing.
- Technical Prerequisites: Basic proficiency in IT tools, fundamental map reading skills, and knowledge of coordinate systems to ensure seamless utilization of digital spatial data.
- Logistical Resources: Access to well-equipped laboratories featuring high-performance computers and stable network connectivity for downloading satellite imagery from global repositories.
- Software and Pedagogical Resources: Utilization of spatial processing software (e.g., QGIS), complemented by practical guidebooks and authentic environmental databases for project completion.

Practical work content

PW 01. Install QGIS – Load base map

1. Objective
2. Getting to Know the QGIS Interface
3. Software Installation and Settings
4. Opening a Simple Project and Displaying a Base Map
5. Applied Practical Exercise

PW 02. Enter spatial data and coordinate points

1. Objective
2. Spatial Data Input and Coordinate System Definition
3. Working with Different Vector Layers
4. Modifying Symbols and Adding a Legend
5. Scientific Summary

PW 03. Import vector and raster layers; edit attribute tables

1. Activity 1: Importing Spatial Layers into QGIS
2. Activity 2: Exploring the Attribute Table
3. Activity 3: Saving the Project and Managing Data

PW 04. Perform Buffer and Overlay analyses

1. Activity 1: Implementing the Buffer Operation in QGIS
2. Activity 2: Implementing the Overlay Operation
3. Activity 3: Creating an Initial Analytical Map
4. Environmental Implications of Spatial Analysis

PW 05. Prepare printable layout – Export as PDF

1. Activity 1: Preparing a Print-Ready Map Layout
2. Activity 2: Utilizing Measurement, Drawing, and Text Tools
3. Activity 3: Exporting the Map to Image or PDF Format
4. Environmental Dimension of Output Management

PW 06. Download and visualize satellite imagery (Sentinel/Landsat)

1. Downloading Free Satellite Imagery
2. Exploring Satellite Data within QGIS
3. Understanding Image Properties and Metadata

PW 07. Create composite images (e.g., 5-4-3) and analyze spectral variance

1. Performing Geometric Correction on Landsat Imagery
2. Creating a False Color Composite (e.g., Bands 3-4-5)
3. Comparing Spectral Signatures of Different Regions

PW 08. Calculate NDVI; detect land-use/land-cover changes

1. Vegetation Cover Analysis using NDVI
2. Tracking Land Use Changes Between Two Periods
3. Creating an Environmental Change Detection Map

PW 09. Apply supervised classification (Maximum Likelihood & Random Forest

1. Automated Supervised Classification Using the Maximum Likelihood Algorithm
2. Comparing Results Between Different Algorithms (Random Forest vs. Maximum Likelihood)
 - 2.1. Maximum Likelihood
 - 2.2. Random Forest
3. Interpretation and Analysis of Results

PW 10. Collect open-source data for mini-projects and integrate into GIS

1. Starting the Mini-Project
2. Data Processing and Analysis
3. Producing the Final Environmental Map

PW 11. Compile results; prepare final report and maps

1. Final Map Output Generation
2. Final Outputs Report Preparation
3. Data Documentation and Review

PW 12. Present final projects; discuss outcomes and environmental insig

1. Final Project Presentations
2. Group Discussion and Environmental Recommendations
3. Final Projects Evaluation
4. Closing Remarks

PW 01. Install QGIS – Load base map

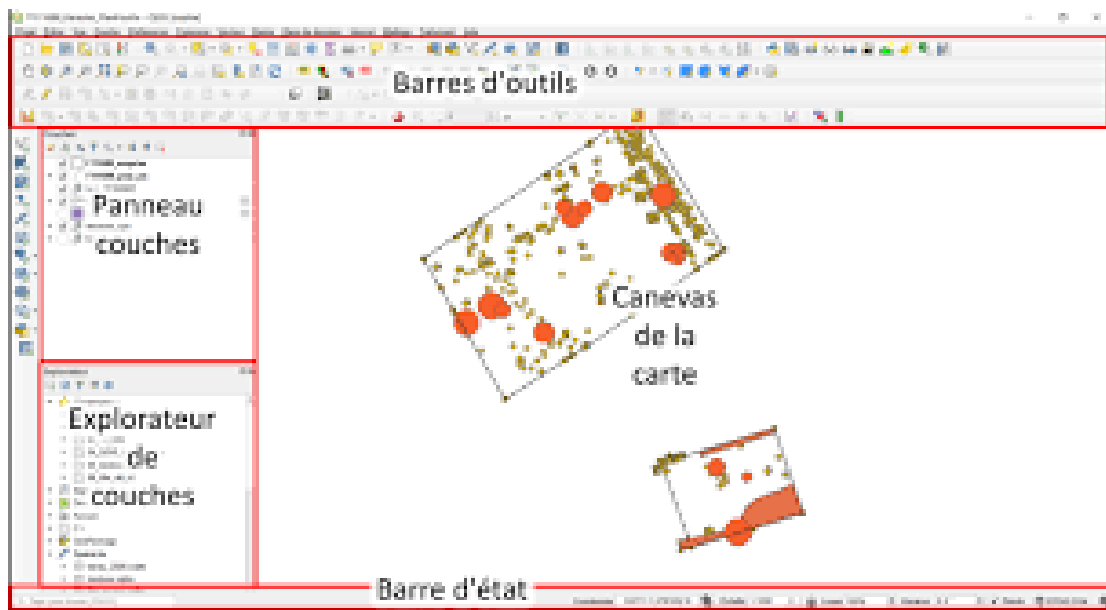
1. Objective

To familiarize students with the fundamental operating environment of QGIS, an open-source software for spatial data analysis and management.

2. Getting to Know the QGIS Interface

Students will become acquainted with the primary interface components:

- **Menu Bar:** Contains management and analysis tools.
- **Toolbars:** Provides quick access to essential functions.
- **Map Canvas:** Displays maps and data.
- **Layers Panel:** For managing project data.



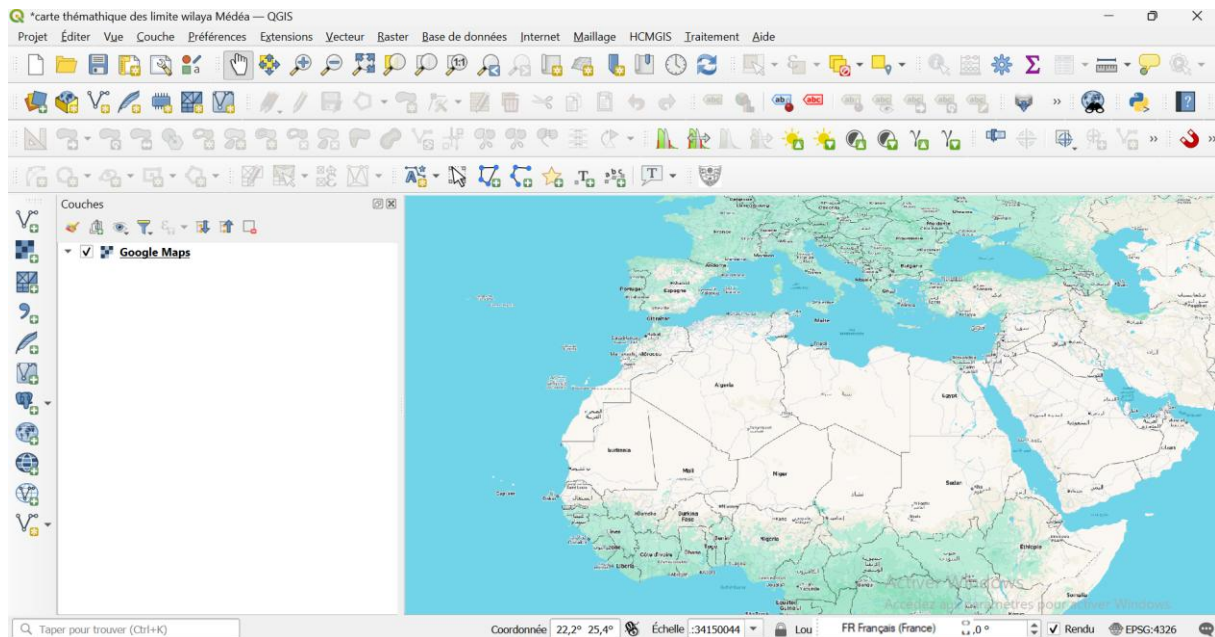
An illustrative screenshot of the QGIS software interface with labels for its main components.

3. Software Installation and Settings

- Download the software from the official website: <https://qgis.org/>
- Adjust Coordinate Reference System (CRS) settings to **WGS84 (EPSG:4326)**.
- Activate plugins, such as OpenLayers, to incorporate base maps.

4. Opening a Simple Project and Displaying a Base Map

- Create a new project via "*File → New Project*".
- Add a base map layer, such as **OpenStreetMap** or **Google Satellite**.
- Zoom to the target area.
- Save the project as "*GIS_Environmental_Intro.qgz*".



The QGIS project interface after adding an open-source base map.

5. Applied Practical Exercise

Students will add a point data layer representing **groundwater well locations** and link it to an attribute table containing data **on salinity levels** and **well depths**. Subsequently, they will utilize the **Symbology** tool to represent these values with color gradients. Each student is then required to prepare a **thematic map**, incorporating a **legend**, **title**, and **scale bar**.

PW 02. Enter spatial data and coordinate points

1. Objective

This practical session aims to equip students with the skills to input spatial data, set up coordinate systems, and manipulate map symbols and scales within the QGIS environment.

2. Spatial Data Input and Coordinate System Definition

- Initiate a new project in **QGIS**.
- Create a new vector layer by navigating to *Layer → Create Layer → New Shapefile Layer*.
- Select the appropriate layer type: **Point** (for features like monitoring stations or wells), **Line** (for rivers or roads), or **Polygon** (for environmental areas).
- Assign the coordinate reference system to **WGS84 (EPSG:4326)**.
- Manually digitize points using the *'Add Feature'* tool and populate the attribute table with descriptive data.

3. Working with Different Vector Layers

Students will learn to manage multiple layers within a project:

- **Point** layers representing environmental monitoring stations.
- **Line** layers depicting waterways or transportation networks.
- **Polygon** layers illustrating urban or agricultural zones.

Layers can be reordered by dragging to adjust their display sequence on the map.

4. Modifying Symbols and Adding a Legend

Customize symbol appearance (**colors, shapes, sizes**) through the *Layer Properties → Symbolology* window.

To design a final map layout:

- Open *Print Layout* → *New Layout*.
- Insert map elements: the main map, a **scale bar**, a **North arrow**, a **legend**, and a **title**.
- Export the completed map as a **PDF** or digital **image**.

5. Scientific Summary

A thorough understanding of maps, scales, and coordinate systems constitutes the foundational basis for any spatial analysis conducted within Geographic Information Systems. Accurate location, scale, and direction are key to precisely interpreting environmental relationships. Attempting environmental analysis without proper spatial definition is akin to navigating at sea without a compass. Therefore, this session serves as a crucial link, connecting theoretical concepts of cartography with their practical application in QGIS, thereby paving the way for advanced spatial analysis and environmental modeling in subsequent modules.



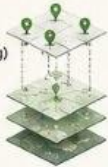
CREATING A POINT LAYER AND ENTERING COORDINATES IN QGIS

A step-by-step guide to create a point layer and add coordinates



WHAT IS A POINT LAYER?

A point layer represents locations as individual points defined by X (longitude/easting) and Y (latitude/northing) coordinates in a given coordinate reference system (CRS).



WHY USE POINT LAYERS?

- ✓ Store exact locations (e.g., wells, sampling sites, stations)
- ✓ Easy to analyze and visualize
- ✓ Essential for spatial analysis, interpolation, and modeling
- ✓ Support attribute information for each point

EXAMPLE APPLICATIONS

- Environmental monitoring sites
- Weather stations
- Cities and landmarks
- Field survey points



STEP-BY-STEP WORKFLOW IN QGIS

1 CREATE A NEW POINT LAYER

1. Go to Layer > Create Layer > New Shapefile Layer...
2. Choose 'Point' as Geometry Type.
3. Click '...' next to CRS and select the appropriate coordinate reference system.



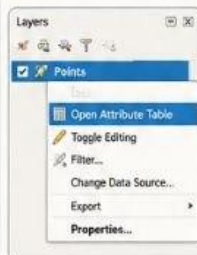
2 ADD FIELDS (ATTRIBUTES)

1. Click 'New Field'.
2. Define field name, type (e.g., Text, Integer, Decimal).
3. Click 'OK' and then 'OK' again to create the layer.



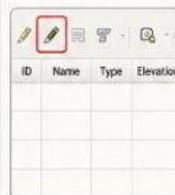
3 OPEN THE ATTRIBUTE TABLE

1. Right-click the new layer in the Layers panel.
2. Select 'Open Attribute Table'.



4 TOGGLE EDITING MODE

1. Click the 'Toggle Editing' button on the attribute table toolbar.
2. A pencil icon indicates editing mode is active.



5 ADD POINTS BY ENTERING COORDINATES

1. Click the 'Add Point Feature' button.
2. Click on the 'X' and 'Y' cells of a new row.
3. Enter coordinates:
 - For geographic CRS: use Longitude (X), Latitude (Y)
 - For projected CRS: use Easting (X), Northing (Y)
4. Fill in the attribute values.

ID	Name	Type	X	Y	Elevation
1	Site 1	Well	35.12345	36.98765	120.5
2	Site 2	Spring	35.23456	37.01234	98.2
3	Site 3	Station	35.34567	36.87654	134.7

6 SAVE EDITS

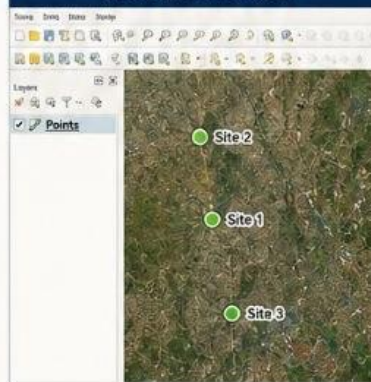
1. Click the 'Save Edits' button.
2. Click 'Toggle Editing' again to stop editing.
3. Your point layer is now ready!

GEOGRAPHIC vs PROJECTED COORDINATES

	Geographic CRS (GCS)	Projected CRS (PCS)
Surface	Ellipsoid (curved)	Flat plane
Units	Degrees (°)	Meters / Feet
Coordinates	Longitude (X), Latitude (Y)	Easting (X), Northing (Y)
Example CRS	WGS 84 (EPSG:4326)	UTM Zone 32N (EPSG:32632)



VISUAL RESULT IN QGIS



TIP
Always define the correct CRS before entering coordinates to avoid position errors.

BEST PRACTICES

- ✓ Always define the correct CRS.
- ✓ Use meaningful field names and data types.
- ✓ Enter coordinates carefully (check decimal separator).
- ✓ Save your work frequently.
- ✓ Validate your points on the map after entry.

COMMON USE CASES

- Sampling sites in environmental studies
- GPS survey points
- Infrastructure locations
- Boreholes and water wells
- Monitoring stations

QUICK SUMMARY



Create New Point Layer



Add Fields (Attributes)



Open Attribute Table



Toggle Editing Mode



Add Points by Entering Coordinates



Save Edits & Visualize



DESIGN & PREPARED BY OULAD HEDDAR Meriem





ESSENTIAL ELEMENTS OF A FINAL MAP DESIGN IN QGIS PRINT LAYOUT



Legend – Scale Bar – North Arrow



A well-designed map communicates spatial information clearly and accurately. Three fundamental elements must always be included in the final map layout: **Legend**, **Scale Bar**, and **North Arrow**.



Legend



Scale Bar



North Arrow

1 LEGEND

The legend explains the symbols, colors, and patterns used on the map.

✓ Purpose

Helps the map reader understand the meaning of each feature.

✓ Best Practices

- Use clear and concise labels.
- Group similar items.
- Follow a logical order.
- Keep it simple and consistent.



3 NORTH ARROW

The north arrow shows the orientation of the map to geographic north.

✓ Purpose

Indicates direction and helps users understand spatial orientation.

✓ Best Practices

- Place in a clear area of the map.
- Use a simple and recognizable design.
- Ensure the "N" is clearly visible.
- Do not rotate the north arrow.

2 SCALE BAR

The scale bar shows the relationship between a distance on the map and the corresponding real-world distance.

✓ Purpose

Enables accurate measurement of distances directly on the map.

✓ Best Practices

- Use appropriate units (m, km).
- Match the scale to the map extent.
- Use a simple, high-contrast design.
- Place it on a clean, uncluttered area.

WHERE TO ADD IN QGIS PRINT LAYOUT



Add Legend

Click "Add Item" → "Add Legend" and choose the layers to include.



Add Scale Bar

Click "Add Item" → "Add Scale Bar" and select style, units, and segments.



Add North Arrow

Click "Add Item" → "Add North Arrow" and choose a style.

QGIS Layout Panel

Add Item -

- Add Map
- Add Legend
- Add Scale Bar
- Add North Arrow
- Add Text
- Add Image
- Add Shape
- Add Arrow
- Add Table
- Add HTML

EXAMPLE IN QGIS PRINT LAYOUT

1 LEGEND

2 SCALE BAR

3 NORTH ARROW

WHY THESE ELEMENTS ARE CRUCIAL



CLARITY

They make the map easy to read and interpret.



ACCURACY

They enable precise measurement and orientation.



PROFESSIONALISM

They give your map a complete and credible appearance.



COMMUNICATION

They ensure your spatial message is effectively communicated.



PW 03. Import vector and raster layers; edit attribute tables

1. Activity 1: Importing Spatial Layers into QGIS

Students will open QGIS and import the following:

- A vector layer representing a road network (Shapefile).
- A raster layer depicting land use (Raster).

The two layers will then be displayed within the project, and their order adjusted in the Layers panel.

2. Activity 2: Exploring the Attribute Table

Students will open the attribute table for a selected layer and analyze its existing fields, such as:

- Location Name.
- Soil Type.
- Population Density.

Subsequently, students will add a new attribute (e.g., moisture content or pollution level) to the table to demonstrate in-system data editing capabilities.

3. Activity 3: Saving the Project and Managing Data

Students will be guided on saving the project and designating the path for its associated databases, with an emphasis on organizing files into clearly defined folders (e.g., Data, Outputs, Maps).

EXPLORING THE GIS ATTRIBUTE TABLE

View • Edit • Add Field • Analyze • Support Decisions

Attribute data describes WHAT features are like.

It is the descriptive power of GIS!

ATTRIBUTE TABLE

- ✓ Stores descriptive information of spatial features
- ✓ Each row represents one feature
- ✓ Each column represents an attribute (field)
- ✓ Linked to spatial features by a unique ID



QGIS - Attribute Table - Rivers

ID	Location Name	Soil Type	Population Density (persons/km²)	Humidity Level (%)	Pollution Index (0-100)
1	Green Valley	Clay Loam	245	62	28
2	Blue River Site	Sandy Loam	315	58	45
3	North Forest	Silt Loam	180	70	35
4	Lake View	Clay	210	68	32
5	South Plains	Sandy	160	55	22
6	Mountain Zone	Rocky Soil	95	72	18

Show All Features

Feature (River)
Selected on
Map

Why Attribute Data is Important?

- ✓ Enriches spatial data with meaning
- ✓ Enables analysis, querying and modeling
- ✓ Supports environmental assessment
- ✓ Helps decision-makers understand reality

ADDING A NEW FIELD

- 1 Open Attribute Table
- 2 Toggle Editing
- 3 Add Field...
- 4 Enter Name, Type and Save

Example of new field:
✓ Pollution Index

ATTRIBUTE TABLE OPERATIONS

- VIEW**
Explore and understand your data
- EDIT**
Correct and update information
- ADD FIELD**
Create new attributes to enrich data
- ANALYZE**
Use statistics, filters and queries
- DECISION MAKING**
Use results to solve environmental problems

Link Between Map and Attribute Table



Spatial Feature (River)



Attribute Table (Description)

Examples of Attributes



ATTRIBUTE TABLE WORKFLOW



Visit our website

<https://gisarabi.com>

- ✓ Better Data
- ✓ Better Analysis
- ✓ Better Decisions
- ✓ Better World



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PW 04. Perform Buffer and Overlay analyses

1. Activity 1: Implementing the Buffer Operation in QGIS

2. Students will open a layer representing water sources.
3. The Buffer tool will be utilized to define a 500-meter radius buffer zone around each water source.
4. The resulting buffer zones will be displayed on the map, distinctively colored (e.g., light blue).
5. Areas located within these buffer zones, such as industrial facilities or villages, will be analyzed.
6. Students will be required to interpret the results from the perspective of water resource protection.

2. Activity 2: Implementing the Overlay Operation

- Students will import two distinct layers:
 - A vegetation cover layer.
 - A pollution sources layer (e.g., factories).
- The "**Intersect**" command will be used to create a new layer representing the areas of overlap between industrial zones and vegetation cover.
- The results will be interpreted to identify environmental hazard zones resulting from human activities.



QGIS



OVERLAY ANALYSIS: REVEALING HIDDEN ENVIRONMENTAL RISKS

Combining Multiple Spatial Layers to Support Smarter Decisions



INTEGRATE
LAYERS



ANALYZE
RELATIONSHIPS



IDENTIFY
RISKS



SUPPORT
DECISIONS

1. SPATIAL LAYERS (INPUT DATA)



LAND USE LAYER

Represents different categories of land use such as urban, agricultural, forest, water, barren land.



SOIL LAYER

Shows soil types and characteristics such as clay, loam, sand, silt, and rocky areas.



INDUSTRIAL ACTIVITY LAYER

Locations of industries, factories, and other industrial activities that may cause pollution.



WATER RESOURCES LAYER

Rivers, lakes, reservoirs and water bodies that are vital to ecosystems and human life.



VEGETATION LAYER

Vegetation cover density including forests, shrubs, grasslands and bare areas.



2. OVERLAY ANALYSIS PROCESS



3. OUTPUT: ENVIRONMENTAL RISK MAP

ENVIRONMENTAL RISK MAP



RISK LEVEL

- High Risk
- Moderate Risk
- Low Risk
- Very Low Risk



High risk areas are where multiple environmental stressors overlap.



Helps identify critical zones that need immediate attention.



Supports sustainable planning and responsible resource management.

4. WHAT CAN OVERLAY ANALYSIS HELP US DISCOVER?



LAND SUITABILITY ASSESSMENT



Find the best areas for agriculture, urban development or conservation.



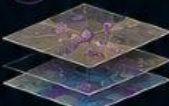
DESERTIFICATION RISK MAPPING



Identify areas vulnerable to land degradation and soil decline.



POLLUTION VULNERABILITY



Detect areas where industries and sensitive resources intersect.



ENVIRONMENTAL PLANNING



Support land-use planning, protected zones, and ecological restoration.

WHY OVERLAY ANALYSIS MATTERS



Integrates multiple data sources for a complete understanding.



Reveals complex spatial relationships hidden in individual layers.



Improves decision-making accuracy for environmental management.



Promotes sustainable development and risk reduction.

OVERLAY ANALYSIS WORKFLOW IN GIS

1

DATA COLLECTION

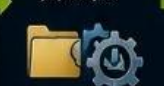
Collect spatial data from various sources (satellites, surveys, databases, sensors).



2

DATA PREPARATION

Standardize projection, clean data, and prepare layers.



3

OVERLAY PROCESS

Use GIS tools (Intersect, Union, Weighted Overlay) to combine layers.



4

ANALYSIS & EVALUATION

Analyze results, validate patterns and assess environmental impacts.



5

DECISION SUPPORT

Create maps and reports to support policies and action plans.



COMMON OVERLAY TOOLS IN QGIS

- Intersect
- Union
- Clip
- Erase
- Spatial Join
- Weighted Overlay



QGIS

POWERFUL TOOLS FOR
SPATIAL ANALYSIS

REAL-WORLD APPLICATIONS



Environmental
Impact
Assessment



Watershed
Management



Disaster Risk
Reduction



Biodiversity
Conservation



Sustainable
Land Use
Planning



KEY TAKEAWAY

Overlay analysis transforms separate layers of information into meaningful insights, allowing us to detect hidden risks, protect natural resources, and build a sustainable future.



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3. Activity 3: Creating an Initial Analytical Map

- The previously generated layers (buffer zones + overlay areas) will be combined.
- A clear title (e.g., "Analysis of Industrial Pollution Around Water Sources") and a legend will be added.
- A scale bar and north arrow will be incorporated, and the map will then be saved in PDF or digital image format.
- This map constitutes **the student's initial integrated analytical product** for the course's practical project.

4. Environnemental Implications of Spatial Analysis

Through these practical activities, students will recognize that spatial analysis extends beyond a mere digital technique; it is a **scientific methodology for comprehending spatial environmental relationships**. Spatial analysis empowers the development of more intelligent environmental policies by:

- Identifying priority areas for environmental protection.
- Ensuring equitable distribution of water resources.
- Creating environmental hazard maps to assist in natural disaster response.

Transforming decision-making from intuition to evidence-based science by rendering the **environment digitally visible** through spatial analysis.



PW 05. Prepare printable layout – Export as PDF

1. Activity 1: Preparing a Print-Ready Map Layout

 This practical segment focuses on hands-on application of GIS principles

Students will engage in creating a 'Print Layout' in QGIS. This involves incorporating essential map elements:

- The main map
- Legend
- Scale bar
- North arrow
- Prominent title and a concise content description.

Students will also learn to configure print settings, including paper size (e.g., **A3 or A4**) and resolution (e.g., **300 dpi**) to ensure high-quality output.

2. Activity 2: Utilizing Measurement, Drawing, and Text Tools

Learners will acquire skills in

- Measuring distances between features (e.g., the proximity of a pollution source to a river)
- Calculating areas (e.g., for urban or agricultural zones).
- They will also practice drawing supplementary map elements (such as symbols or boundary lines)
- Inputting text for labels and explanatory annotations.

These tools are crucial for enhancing **the professionalism and analytical expressiveness** of maps.

3. Activity 3: Exporting the Map to Image or PDF Format

Upon completion of the map design, students will export the map into common formats such as **PDF**, **PNG**, or **TIFF**. Critical considerations during this stage include:

- Ensuring appropriate image resolution.
- Confirming the inclusion of all symbols and associated data.
- Saving a project copy in .qgz format for future retrieval.

Finally, students will be instructed to append their generated map to a concise report that articulates its specific environmental objective, for instance, Analysis of Industrial Pollution around Rivers.

4. Environnemental Dimension of Output Management

The maps and outputs generated by GIS are powerful instruments for informing and influencing environmental policies and decision-making processes. For example:

- Maps delineating environmental risk zones can assist ministries of environment in prioritizing monitoring efforts.
- Agricultural land-use maps contribute to improving sustainable agricultural planning.
- Water resource maps support effective groundwater management and aid in preventing resource depletion.

Ultimately, these environmental maps are not merely visual representations; they function as **scientific analytical documents** that encapsulate the complex interplay between humans, the environment, and geographic space.



FROM GIS DATA TO PROFESSIONAL MAPS

The Complete Workflow of Map Production in QGIS

Creating High-Quality GIS Maps for Research and Decision-Making



1 DATA COLLECTION



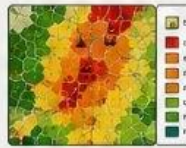
- Satellite Imagery
- GPS / Field Data
- Surveys & Sensors
- Existing Maps

2 SPATIAL PROCESSING



- Data Cleaning
- Georeferencing
- Digitizing
- Spatial Analysis

3 VISUALIZATION & SYMBOLOGY



- Symbology
- Classification
- Color Ramps
- Thematic Styling

4 LAYOUT DESIGN



- Add Map Elements
- Arrange Layout
- Labels & Annotations
- Professional Design

5 EXPORT & SHARING



- High Resolution (300 dpi)
- PDF / PNG / TIFF
- Print Ready
- Share & Publish

MAP LAYOUT ELEMENTS



MAP FRAME
Main map display area



TITLE
Descriptive map title



LEGEND
Explains map symbols



NORTH ARROW
Shows orientation



SCALE BAR
Represents real world distances



COORDINATE GRID
Shows map coordinates

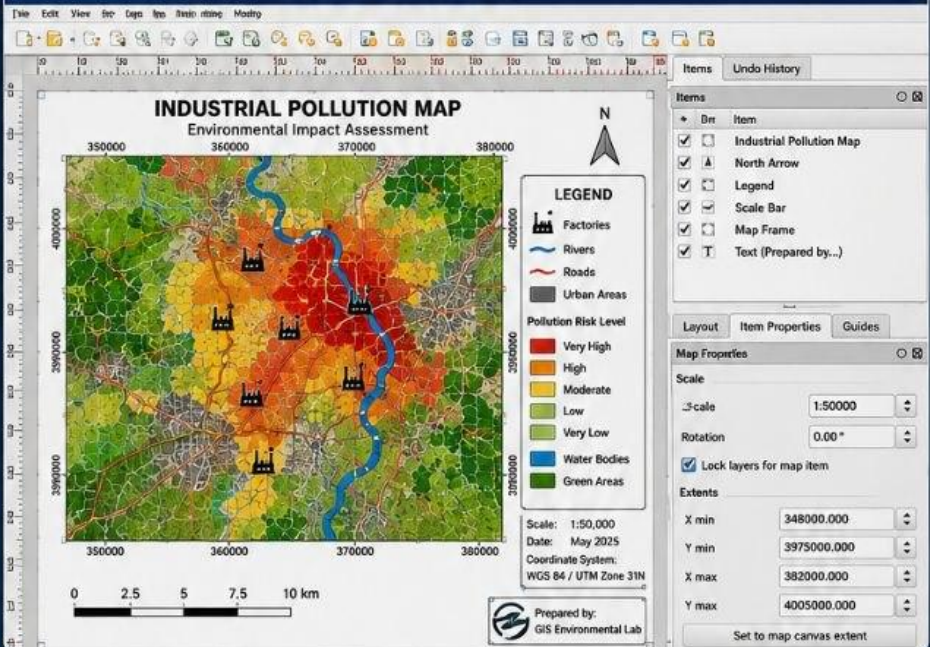


TEXT / ANNOTATIONS
Add descriptions and notes



LOGO / CREDITS
Institution or project information

QGIS PRINT LAYOUT (LAYOUT VIEW)



SYMBOLOGY EXAMPLE (POLLUTION RISK LEVEL)

- Very High Risk (Critical Pollution Zones)
- High Risk (Significant Impact)
- Moderate Risk (Potential Impact)
- Low Risk (Minimal Impact)
- Very Low Risk (Safe Zones)



PROFESSIONAL MAP FEATURES



Clear Title & Subtitle
Communicates the map purpose clearly.



Consistent Symbology
Uses standard symbols and color schemes.



Accurate Scale & North
Ensures spatial accuracy and orientation.



Complete Legend
Explains all map symbols and classes.



Metadata Information
Includes source, date, and coordinate system.



High Visual Quality
Clean layout, balanced colors, and readability.

OUTPUT FORMATS



PDF
Best for printing and sharing



PNG
Best for digital presentations



TIFF
Best for high-quality archiving

PRINT SETTINGS (RECOMMENDED)



Paper Size:
A4 / A3



Resolution:
300 dpi



Color Mode:
CMYK

APPLICATIONS OF PROFESSIONAL MAPS



Environmental
Impact Assessment



Resource
Management



Urban Planning
& Development



Disaster Risk
Reduction



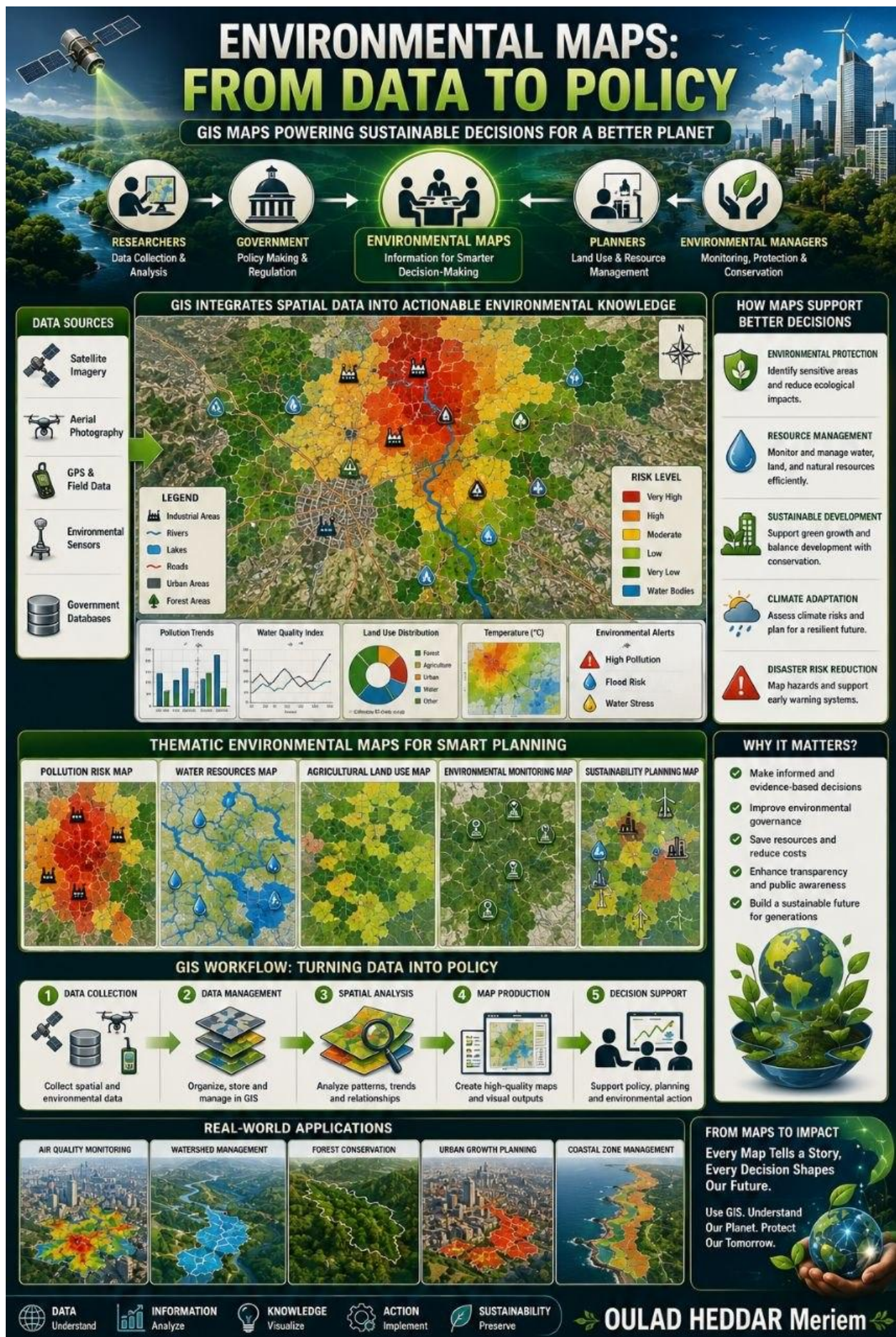
Policy Making
& Reporting

BEST PRACTICES FOR MAP PRODUCTION

- ✓ Use accurate and updated data.
- ✓ Apply appropriate symbology and classification.
- ✓ Keep the layout clean and uncluttered.
- ✓ Include all essential map elements.
- ✓ Export with high resolution for best quality.



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PW 06. Download and visualize satellite imagery (Sentinel/Landsat)

1. Downloading Free Satellite Imagery

The practical application phase commences with students learning to access real-world satellite data from open-source platforms, such as:

- **USGS Earth Explorer:** A platform facilitating free downloads of Landsat satellite imagery.
- **Copernicus Sentinel Hub:** An interactive portal for obtaining high-resolution, multi-spectral Sentinel imagery.

Students are guided to define their study area (e.g., a local environmental or agricultural region), select an appropriate image acquisition date, and consider atmospheric conditions (specifically avoiding cloud-covered imagery) as well as relevant spectral bands.

2. Exploring Satellite Data within QGIS

Upon downloading, satellite images are imported into the **QGIS** interface. Students then analyze their inherent properties via the **Information Panel**, which includes details such as the number of **bands** and the size of each band.

Students are introduced to the distinction between **single-band** and **multi-band** imagery and learn how these can be combined to form **composite images**. These composites can render the Earth's surface in either true or false colors, depending on the specific analytical objective.

3. Understanding Image Properties and Metadata

Every satellite image is accompanied by a **Metadata** file containing crucial information, such as:

- The specific satellite and sensor utilized.
- The precise date and time of image acquisition.

- The coordinate system employed.
- The image's spatial resolution and number of spectral bands.

A thorough understanding of this metadata is imperative before commencing any analytical procedures, as it ensures the accuracy and reliability of subsequent spatial and spectral processing.

LANDSAT VS SENTINEL VS SPOT

COMPARING EARTH OBSERVATION SATELLITES FOR ENVIRONMENTAL ANALYSIS

LANDSAT

The World's Longest Running Earth Observation Program



SINCE 1972
A joint program of NASA and USGS

SENTINEL

European Space Agency Copernicus Programme



SINCE 2014
A constellation of satellites for global monitoring

SPOT

High Resolution Imaging for Detailed Applications



SINCE 1986
Developed by CNES (France) and partners

TECHNICAL COMPARISON				SATELLITES IN ORBIT
FEATURE	LANDSAT	SENTINEL	SPOT	
Satellite Program	Landsat 1-9 (Operational) Landsat Next (Upcoming)	Sentinel-2A, 2B (More in development)	SPOT 1-7 (Historical) SPOT 6, 7 (Operational)	 LANDSAT 8/9
Organization	NASA / USGS	European Space Agency (ESA)	CNES (France) and Partners	
Launch Period	1972 - Present	2014 - Present	1986 - Present	 SENTINEL-2A/2B
Spatial Resolution	15 m (Panchromatic) 30 m (Multispectral)	10 m (Multispectral) 20 m (Red Edge) 60 m (Atmospheric)	1.5 m (Panchromatic) 6 m (Multispectral)	
Temporal Resolution	16 Days	5 Days (with 2 satellites)	1 - 3 Days (depending on latitude)	 SPOT 6/7
Spectral Resolution	11 Spectral Bands (VNIR, SWIR, Thermal)	13 Spectral Bands (Visible, NIR, SWIR)	4 Spectral Bands (Visible & NIR)	
Swath Width	185 km	290 km	60 km	
Data Availability	Free & Open (USGS Earth Explorer)	Free & Open (Copernicus Hub)	Commercial Data (High Resolution)	
Main Strength	Long-term archive for environmental studies	High revisit frequency, modern sensors	Very high spatial resolution for detailed mapping	
Best For	Long-term environmental monitoring & change detection	Rapid monitoring of land, vegetation & water	Urban planning, agriculture, infrastructure mapping	

TYPICAL ENVIRONMENTAL APPLICATIONS					
	FOREST MONITORING	AGRICULTURE & CROP MONITORING	URBAN GROWTH ANALYSIS	WATER RESOURCES MONITORING	DISASTER & HAZARD MAPPING
LANDSAT					
SENTINEL	✓ Very Good	✓ Good	✓ Good	✓ Very Good	✓ Very Good
SPOT	✓ Excellent	✓ Excellent	✓ Good	✓ Excellent	✓ Very Good
	✓ Good	✓ Excellent	✓ Excellent	✓ Good	✓ Excellent

SPECTRAL COVERAGE COMPARISON

	Visible	Near Infrared (NIR)	Shortwave Infrared (SWIR)	Thermal Infrared	Microwave
	0.4 0.5 0.6 0.7 0.8 0.9	1 1.5 2	3 5 10 12		
LANDSAT 8/9	■ ■ ■ ■ ■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■		
SENTINEL-2	■ ■ ■ ■ ■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■	
SPOT 6/7	■ ■ ■ ■ ■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■		■ ■ ■ ■ ■ ■ ■ ■ ■ ■

■ Coastal
 ■ Blue
 ■ Green
 ■ Red
 ■ NIR
 ■ SWIR
 ■ Thermal
 ■ Microwave

WHY CHOOSE THE RIGHT SATELLITE?

- Match the resolution to your study scale (local, regional, global).
- Consider how often you need updated data.
- Check spectral bands for your analysis needs.
- Balance between cost, availability, and data quality.





Observe. Monitor. Analyze. Protect.



The Right Satellite, the Right Insight.



Better Data for a Better Planet.

OULAD HEDDAR Meriem

FROM SATELLITE IMAGERY TO GIS ANALYSIS

TRANSFORMING RAW SATELLITE DATA INTO ENVIRONMENTAL KNOWLEDGE

1 DOWNLOAD DATA

OPEN ACCESS PLATFORMS

USGS EARTH EXPLORER

Download Landsat satellite imagery for free.

COPERNICUS SENTINEL HUB

Access Sentinel data with multiple bands and products.

AVAILABLE DATA

- Landsat 8/9 (30m, 15m)
- Sentinel-2 (10m)
- Sentinel-1 (SAR)
- Multiple spectral bands
- Global coverage

DATA TYPES

- Optical Imagery
- SAR Data
- DEM
- Land Cover
- Atmospheric Data

2 SELECT STUDY AREA

- ✓ Choose your area of interest (AOI)
- ✓ Select appropriate date
- ✓ Check for cloud cover
- ✓ Consider seasonal conditions

Area of Interest (AOI)

Date Selection (Cloud Free)

Seasonal Consideration

3 LOAD DATA INTO QGIS

IMPORT SATELLITE IMAGERY

Drag and drop raster files into QGIS
Supports GeoTIFF, JP2, SAFE, and more.

4 EXPLORE IMAGE PROPERTIES

UNDERSTAND YOUR DATA

Layer Properties - Sentinel-2A (2024-05-15)

Information

Name: Sentinel-2A (2024-05-15)

Path: S2A_MSI_2A_20240515T094031_N0010_P102_136TVM_20240515T132309_SAFE

Provider: GDAL

Width: 10000 pixels

Height: 10000 pixels

Bands: 13

Pixel Size: 10.00 m x 10.00 m

Extent: 500000.000, 4100000.000 - 6100000.000, 4210000.000

CRS: EPSG:32636 - WGS 84 / UTM zone 36N

Data Type: UInt16

Metadata: No Data

WHAT YOU LEARN

- Number of Bands
- Resolution (Spatial Detail)
- Coordinate System
- Acquisition Date & Time
- Data Type & Bit Depth

Band	Description	Wavelength (µm)	Resolution
1	Coastal Aerosol	0.43 - 0.45	60 m
2	Blue	0.45 - 0.51	10 m
3	Green	0.53 - 0.59	10 m
4	Red	0.64 - 0.67	10 m
5	Vegetation Red Edge 1	0.69 - 0.71	20 m

5 CREATE COMPOSITE IMAGE

COMBINE BANDS FOR BETTER VISUALIZATION

NATURAL COLOR COMPOSITE (TRUE COLOR)

RGB = 4 (Red), 3 (Green), 2 (Blue)

FALSE COLOR COMPOSITE

RGB = 8 (NIR), 4 (Red), 3 (Green)

OTHER VISUALIZATIONS

- NDVI (Vegetation Index)
- NDWI (Water Index)
- Built-up Index
- Soil Index

6 ENVIRONMENTAL INTERPRETATION

TURN IMAGES INTO INFORMATION

VEGETATION ANALYSIS

Assess plant health, forest cover, and agriculture.

WATER MONITORING

Monitor water bodies, quality, and changes over time.

LAND USE / LAND COVER

Classify land cover types and detect land-use changes.

CHANGE DETECTION

Detect environmental changes across different dates.

METADATA: THE KEY TO DATA QUALITY

Every satellite image comes with metadata information.

METADATA EXAMPLE (SENTINEL-2)	
Satellite / Sensor	Sentinel-2A / MSI
Acquisition Date / Time	2024-05-15 / 09:40:31 UTC
Path / Row	36 / TVK
Coordinate System	EPSG:32636 (UTM Zone 36N)
Spatial Resolution	10 m
Number of Bands	13
Cloud Coverage	2.5 %
Data Level	Level-2A (Surface Reflectance)

WHY METADATA MATTERS

- ✓ Ensures accurate analysis
- ✓ Helps compare images
- ✓ Supports reproducible research
- ✓ Provides context for decisions
- ✓ Improves data quality & reliability

OUTPUTS & EXPORT

Export your results for reporting and sharing.

- Maps and figures
- Reports
- GIS projects (.qgz)
- Web maps

SATELLITE DATA
From Space

GIS TECHNOLOGY
On Your Desktop

ENVIRONMENTAL INSIGHT
For a Better Planet

DATA-DRIVEN DECISIONS
For Sustainable Future

OULAD HEDDARD Meriem

PW 07. Create composite images (e.g., 5-4-3) and analyze spectral variance

The practical component of this week's study involves the following steps:

1. Performing Geometric Correction on Landsat Imagery

Students will download a raw Landsat image and import it into a suitable image processing or GIS software (e.g., **QGIS**, **SNAP**, or **ENVI**). They will then identify Ground Control Points (**GCPs**) on the image (e.g., road intersections, corners of agricultural fields) and correlate them with their known geographic coordinates. The image is subsequently geometrically adjusted to align with these reference points. Post-correction, the accuracy is verified by comparing the spatial alignment of features in the corrected image with reference maps.

2. Creating a False Color Composite (e.g., Bands 3-4-5)

Within the chosen software (**QGIS** or **SNAP**), students will combine specific bands such as band 5 (**Near-Infrared**), band 4 (**Red**), and band 3 (**Green**) into an RGB composite. The resulting false-color image is then utilized to identify healthy vegetation and distinguish between agricultural and urban areas. Students are encouraged to optimize image clarity by adjusting **contrast and brightness** settings.

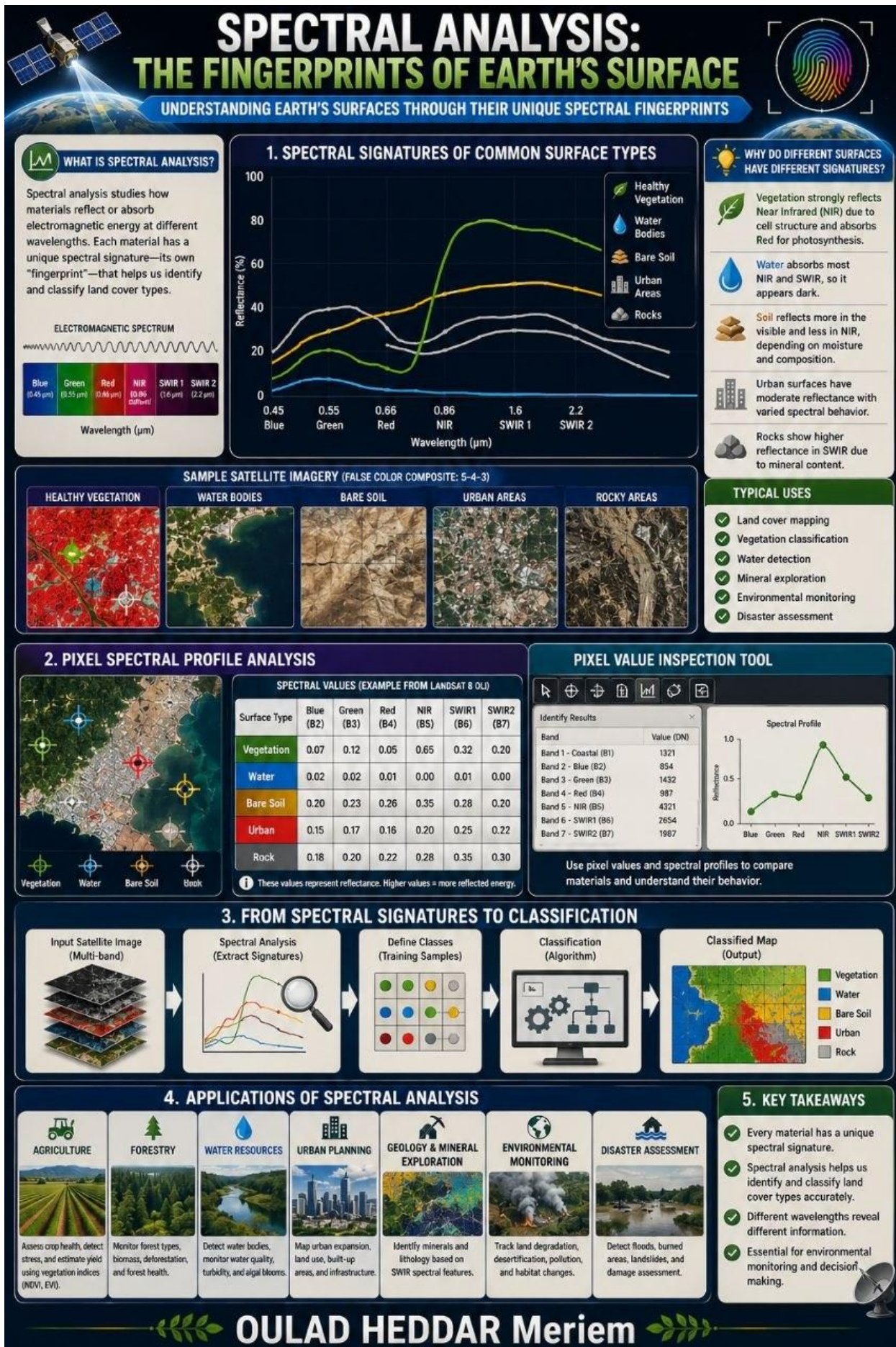
4. Comparing Spectral Signatures of Different Regions

This step involves selecting two distinct regions (e.g., a forest area and an urban area) and measuring the spectral values for each band within both regions. Using tools like **Identify Pixel Values** these digital numbers can be recorded and graphically compared, providing insight into how different surface types exhibit varying spectral reflectance characteristics.

This analysis serves as a fundamental preparatory step for subsequent land cover **classification**.

By the end of PW, students will have acquired proficiency in both preliminary and advanced satellite image processing techniques. This includes geometric and radiometric corrections, the creation of composite imagery, and spectral analysis to comprehend material signatures. This crucial stage empowers researchers to extract meaningful information from imagery, transforming it into a precise analytical tool for revealing environmental patterns and insights.





PW 08. Calculate NDVI; detect land-use/land-cover changes

1. Vegetation Cover Analysis using NDVI

The practical segment commences with analyzing vegetation cover using the **NDVI** in **QGIS**. Users are instructed to acquire satellite imagery (e.g., **Landsat 8** or **Sentinel-2**) and employ the Raster Calculator tool to compute the **NDVI** based on the formula:

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED}).$$

- **NIR** refers to the Near-Infrared band (**Landsat 8 Band 5, Sentinel-2 Band 8**)
- **RED** refers to the Red band (**Landsat 8 Band 4, Sentinel-2 Band 4**).

The computed **NDVI** values are then color-coded, typically with dark green representing dense vegetation, yellow indicating sparse vegetation, and brown signifying barren land.

2. Tracking Land Use Changes Between Two Periods

Tracking land use/cover changes over two distinct periods involves selecting a pair of satellite images for the study area (e.g., years 2000 and 2020).

A **supervised classification** is then applied to each image to categorize land cover types such as urban, agricultural, forest, or water. Subsequent comparison of the classified maps quantifies changes in area, revealing trends like urban expansion, agricultural land conversion, or forest depletion.

3. Creating an Environmental Change Detection Map

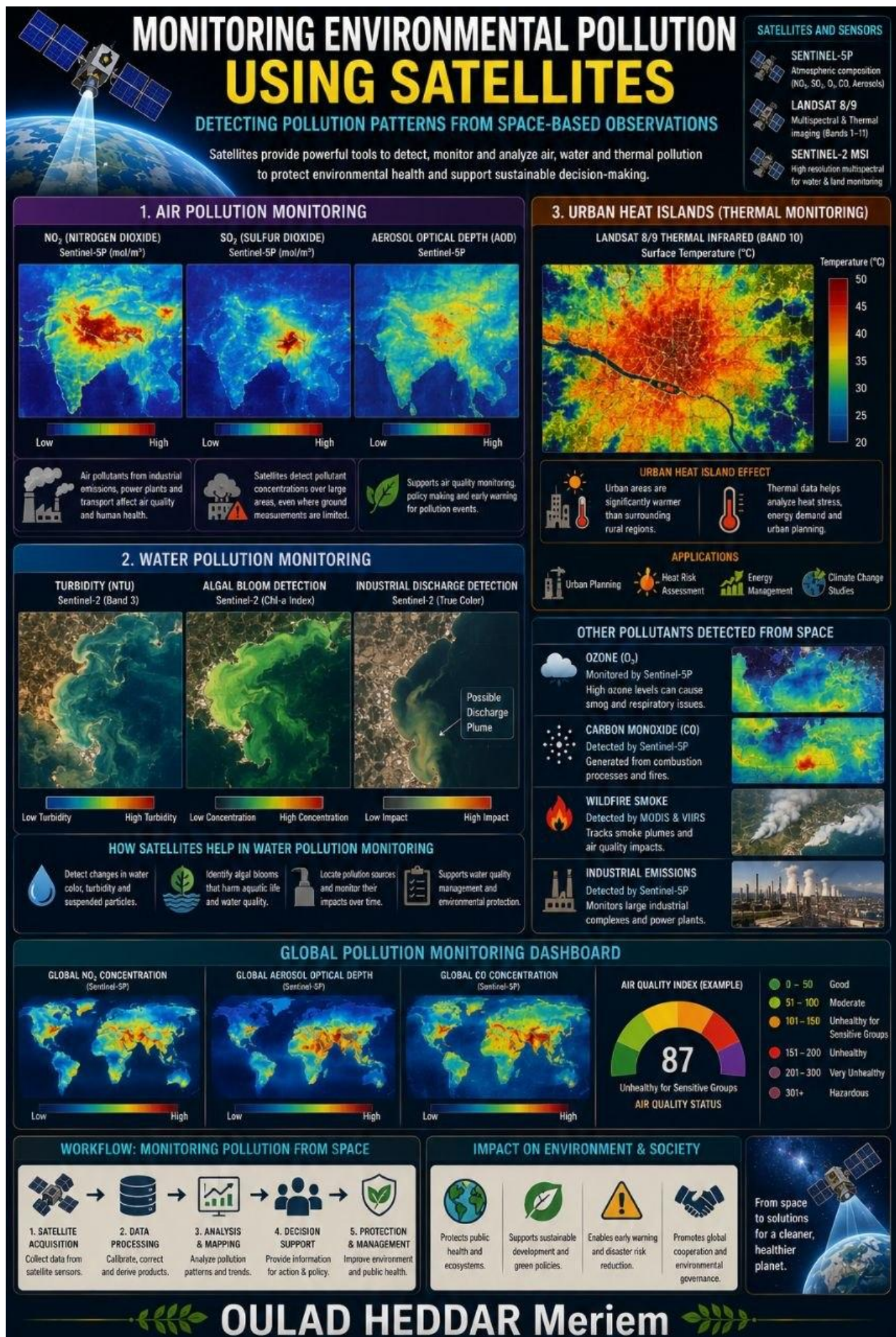
The final stage involves creating an environmental change detection map, representing the ultimate visualization of remote sensing-based environmental analysis.

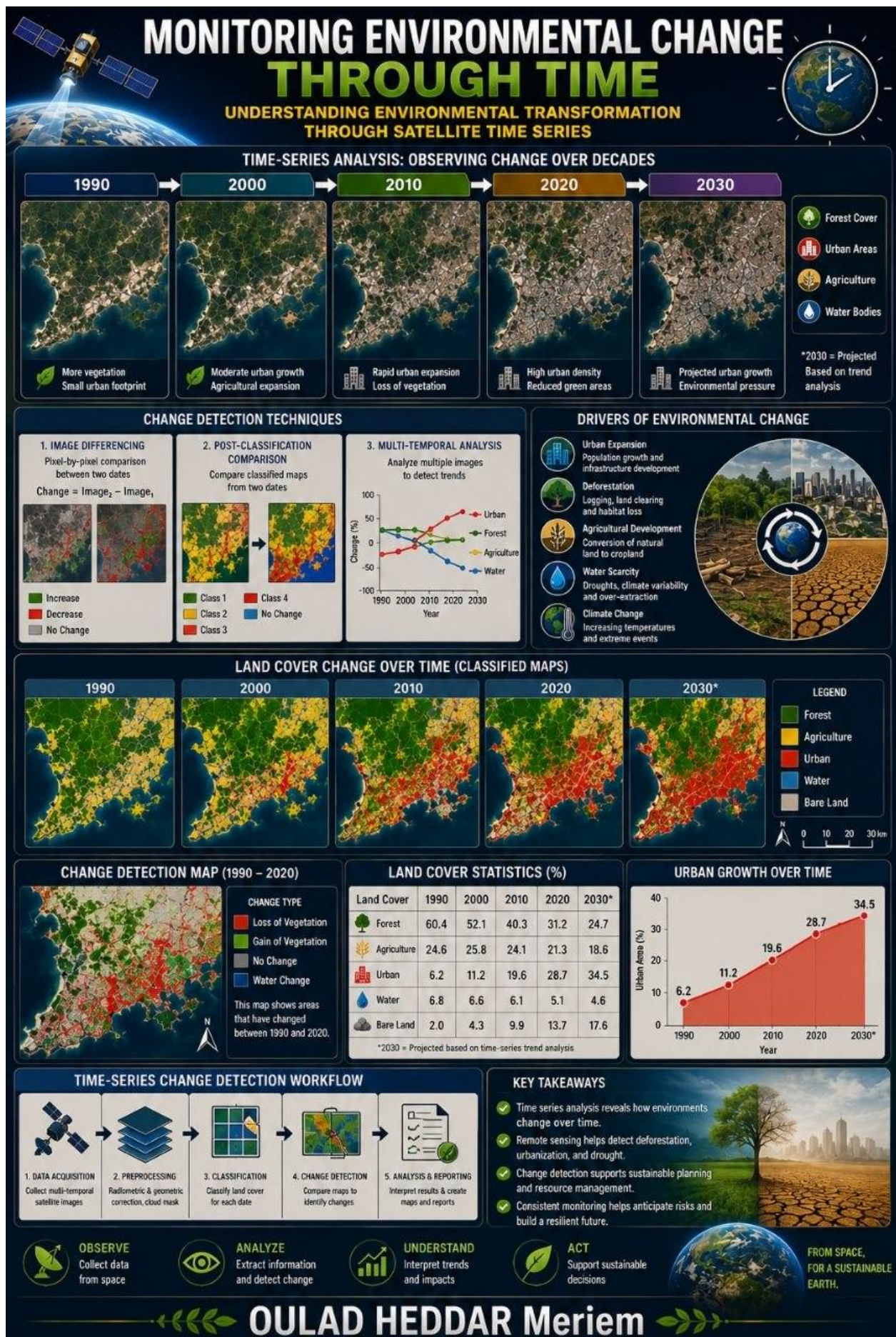
This is achieved by merging the results from the two temporal classifications to highlight areas of actual change using distinct symbols and colors:

for instance

- ❖ Red for vegetation loss
- ❖ Green for environmental improvement
- ❖ Grey for stable areas.

The completed map is then prepared for professional presentation, including a **legend**, **scale bar**, **north arrow**, and appropriate **title**, before being exported as a **PDF** or **GeoTIFF**.





PW 09. Apply supervised classification (Maximum Likelihood & Random Forest .

1. Automated Supervised Classification Using the Maximum Likelihood Algorithm

Automated classification is one of the most common applications of AI in satellite image analysis. Initially, "Training Samples" representing different land cover classes (e.g., water, forests, urban areas, agriculture) are selected.

Subsequently, the **Maximum Likelihood** algorithm is utilized, which relies on statistical probabilities to classify each pixel based on its similarity to the training areas.

Implementation steps in **QGIS** or **ENVI** software:

1. Input the multispectral satellite image (e.g., Landsat 8).
2. Manually define samples of the land classes.
3. Execute the automated classification using the algorithm.
2. Display the results and assess their accuracy via a Confusion Matrix.

3. Comparing Results Between Different Algorithms (Random Forest vs. Maximum Likelihood)

After executing the statistical classification, the student can apply a more advanced algorithm, Random Forest (**RF**). This is a non-linear machine learning algorithm that relies on building multiple Decision Trees and then using majority voting for a more stable and accurate final result.

Comparison between the two methods:

- a. **Maximum Likelihood:** Relies on a probability distribution and performs well when classes are distinct and clear. However, it assumes the data follows a normal (Gaussian) distribution, which does not always apply to complex environmental data.

- b. **Random Forest:** Handles complex and non-linear data, and is robust against noise and outliers. It yields higher accuracy in classifying multispectral images and is currently considered one of the most powerful GeoAI algorithms.

The results are then evaluated using metrics such as:

- **Overall Accuracy**
- **Kappa Coefficient**

4. Interpretation and Analysis of Results

After obtaining the classification maps, the spatial distribution of the various classes such as vegetation, urban areas, and water bodies is analyzed, and the results of the different algorithms are compared.

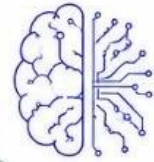
Additionally, temporal analysis can be utilized to identify trends of change in classes across multiple years, which is a preparatory step for building a **Smart Environmental Decision Support System**.

GeoAI technologies demonstrate how AI can transform geography into a proactive science that not merely describes reality, but predicts it. Thanks to machine learning and deep learning algorithms, it has become possible to analyze massive satellite images rapidly, discover subtle patterns in the environment, and predict the future of natural resources.

It is the dawn of the "**Spatial Mind**" era, which combines the power of AI with the depth of geographic insight. Through this week, students learn how GIS transitions from a mere data management system into a smart ecosystem capable of "understanding" and "inferring," positioning **GeoAI** as the ultimate tool of the future for understanding planet Earth and anticipating its destiny.

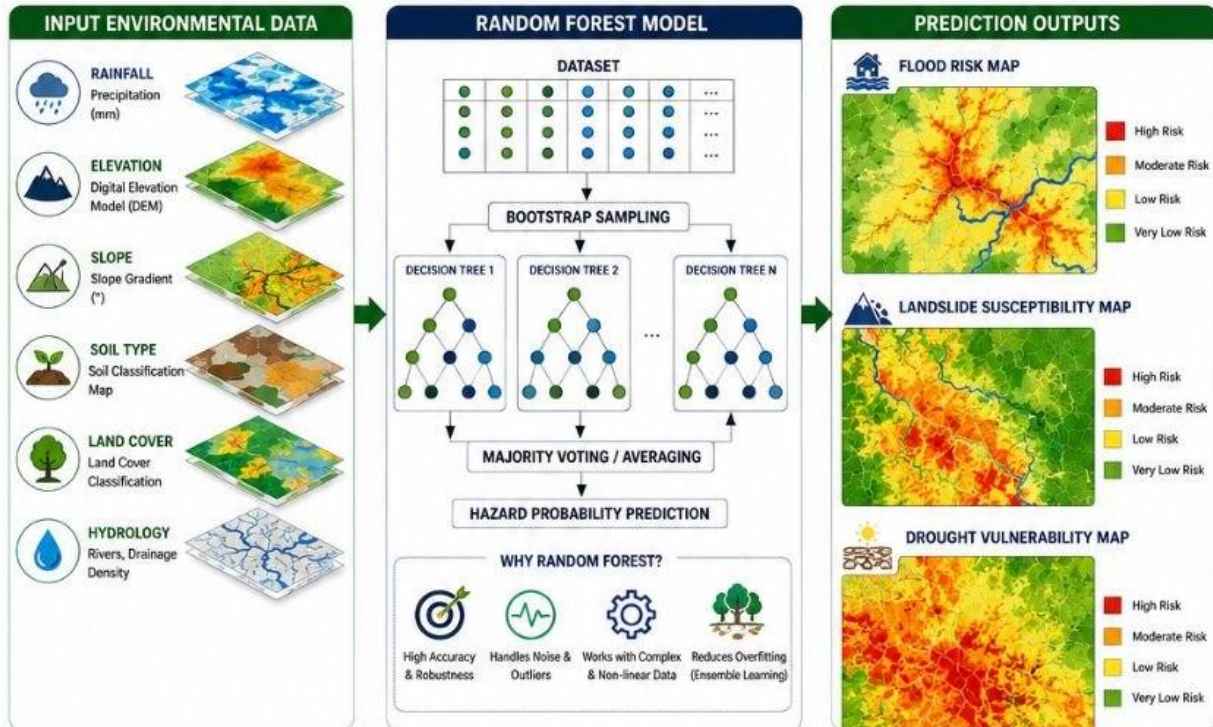


PREDICTING ENVIRONMENTAL HAZARDS WITH GeoAI

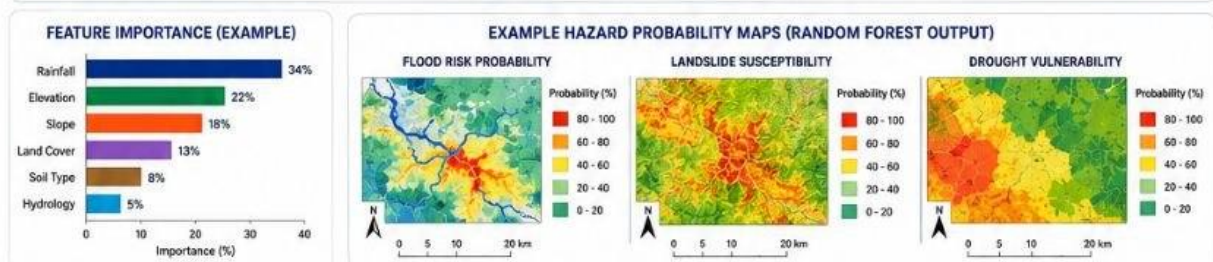
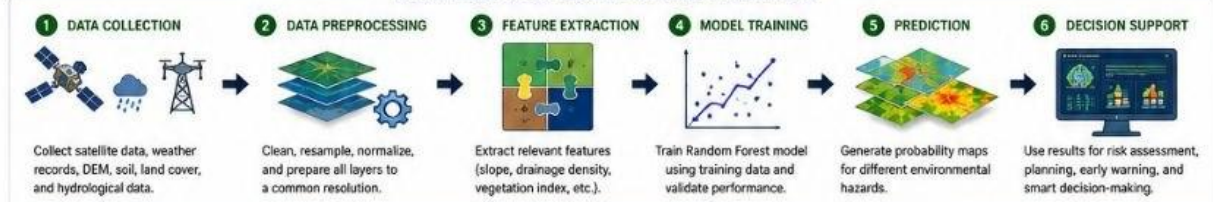


MACHINE LEARNING FOR SMARTER ENVIRONMENTAL RISK ASSESSMENT

GeoAI uses machine learning algorithms like Random Forest to analyze multiple environmental factors and predict the probability of environmental hazards such as floods, landslides, and droughts with high accuracy.



WORKFLOW: FROM DATA TO HAZARD PREDICTION



APPLICATIONS

- DISASTER RISK REDUCTION**
Identify high-risk areas and support preparedness and mitigation.
- LAND USE PLANNING**
Support sustainable development and infrastructure planning.
- CLIMATE CHANGE ADAPTATION**
Assess vulnerability and strengthen resilience to climate impacts.
- EARLY WARNING SYSTEMS**
Provide timely alerts for floods, landslides, and droughts to save lives and property.

ADVANTAGES OF RANDOM FOREST IN GeoAI

- ✓ High predictive accuracy and stability.
- ✓ Works well with large and high-dimensional datasets.
- ✓ Captures complex relationships between variables.
- ✓ Robust to noise, missing data, and overfitting.
- ✓ Provides feature importance for better understanding.
- ✓ Ideal for environmental and geospatial applications.

KEY TAKEAWAYS

- ✓ GeoAI with Random Forest combines multiple environmental datasets to predict hazards accurately.
- ✓ Helps identify risk zones and supports evidence-based decision-making.
- ✓ Essential for building resilient communities and a sustainable future.
- ✓ Integrating AI and GIS is the future of environmental intelligence.

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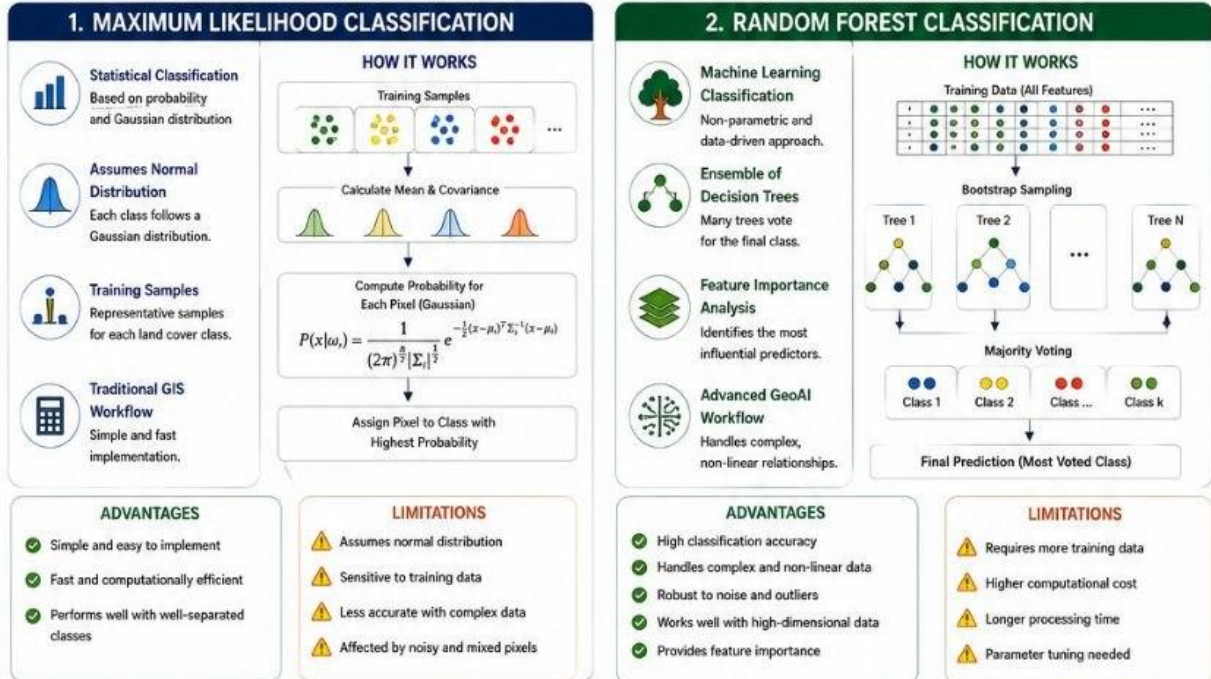


MAXIMUM LIKELIHOOD VS RANDOM FOREST



Comparing Traditional GIS Classification and Modern GeoAI Approaches

GeoAI combines machine learning and geospatial data to classify land cover more accurately, robustly, and intelligently.



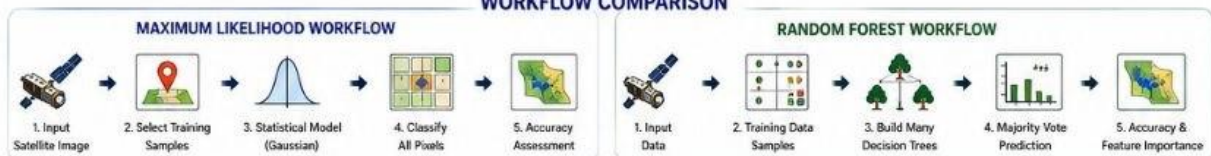
SIDE-BY-SIDE CLASSIFICATION RESULTS



PERFORMANCE COMPARISON



WORKFLOW COMPARISON



OULAD HEDDAR Meriem

PW 10. Collect open-source data for mini-projects and integrate into GIS

1. Starting the Mini-Project

In this part, students practically apply what they have learned. Each student group is required to choose a real environmental issue and define their study area. Then, the following workflows are initiated within **QGIS**:

1. **Creating an organized working folder** containing all spatial data, satellite images, and final outputs.

2. **Collecting Spatial and Satellite Data**

Base layers are downloaded from platforms such as

- *Open StreetMap* (for roads and landmarks).
- *USGS Earth Explorer* or *Copernicus Hub* (for satellite imagery).

3. **Importing Data into QGIS**

Students load **Vector** and **Raster** layers into the software, ensuring a unified **Coordinate Reference System (CRS)**.

2. Data Processing and Analysis

Students begin conducting appropriate analyses based on the nature of the project, such as:

- Calculating the Normalized Difference Vegetation Index (**NDVI**) to assess plant health.
- Executing a **Buffer** analysis to identify areas affected by pollution or an environmental hazard source.
- Applying **Overlay** operations to merge multiple datasets (e.g., soil, water, and vegetation).
- Using **Raster Calculator** tools to derive composite environmental indices.

3. Producing the Final Environmental Map

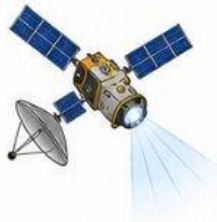
At the conclusion of the practical section, students design a complete map that includes:

- A clear title and scale bar.
- A Legend.

- A North arrow and data sources.
- An appropriate color gradient representing the studied environmental phenomenon.

The map is then exported in **PDF** or **JPEG** format to be included in the final project report.

This stage of the PW represents the point where students begin to think like true environmental analysts. They handle real-world data and produce maps and analyses that can be practically utilized in understanding and managing environmental issues. The following PW will culminate this effort by preparing a comprehensive **final project** that presents the spatial analysis results in a scientific and professional manner.



ENVIRONMENTAL SPATIAL ANALYSIS TECHNIQUES



— TRANSFORMING SPATIAL DATA INTO ENVIRONMENTAL KNOWLEDGE —

GIS and Remote Sensing techniques allow us to analyze environmental information, understand spatial patterns, and support sustainable decision-making.

1 NDVI ANALYSIS

Vegetation Health Monitoring

NDVI (Normalized Difference Vegetation Index) uses red and near-infrared bands to measure vegetation health and density.

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

PROCESS

Satellite Image → NDVI Calculation → NDVI Map

Using Red and NIR Bands

Low Vegetation (-1) High Vegetation (+1)

APPLICATIONS

- Vegetation health assessment
- Drought monitoring
- Agricultural productivity evaluation
- Land degradation detection

EXAMPLE OUTPUT

NDVI Map

- High (0.6 - 1)
- Moderate (0.2 - 0.6)
- Low (-1 - 0.2)
- Water / No Data

2 BUFFER ANALYSIS

Environmental Impact Zones

Buffer analysis creates zones around features to identify areas that may be influenced by a particular source or condition.

PROCESS

Input Feature → Create Buffer → Buffer Zones

Buffer Distance: 500 m, 1000 m, 1500 m

APPLICATIONS

- Pollution impact assessment
- Water resource protection
- Habitat conservation zones
- Infrastructure impact analysis

EXAMPLE OUTPUT

Buffer Map

- 1500 m
- 1000 m
- 500 m
- Input Feature
- River

3 OVERLAY ANALYSIS

Multi-Layer Environmental Assessment

Overlay analysis combines multiple spatial layers to identify areas of high sensitivity, suitability, or risk.

PROCESS

Input Layers: Soil Type, Slope, Rainfall, Land Cover

Overlay Operation → Overlay Result

Common Methods: Intersect, Union, Weighted Overlay

APPLICATIONS

- Environmental risk mapping
- Land suitability analysis
- Watershed management
- Site suitability evaluation

EXAMPLE OUTPUT

Suitability Map

- High Suitability
- Moderate Suitability
- Low Suitability
- Not Suitable

4 RASTER CALCULATOR

Environmental Index Modeling

Raster Calculator is used to perform mathematical operations on raster data to derive environmental indices and indicators.

PROCESS

Input Rasters: Rainfall, Slope, Land Cover

Output Raster

Raster Calculator Expression: $Risk\ Index = (Rainfall * 0.4) + (Slope * 0.3) + (LandCover * 0.3)$

Weighted Combination of Factors

APPLICATIONS

- Erosion risk modeling
- Flood susceptibility mapping
- Drought vulnerability assessment
- Water quality modeling

EXAMPLE OUTPUT

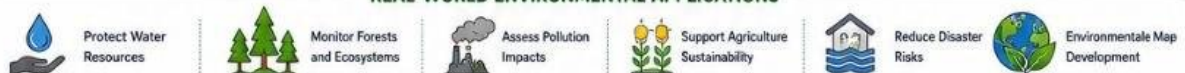
Risk Index Map

- Very High Risk
- High Risk
- Moderate Risk
- Low Risk
- Very Low Risk

HOW THESE TECHNIQUES WORK TOGETHER



REAL-WORLD ENVIRONMENTAL APPLICATIONS



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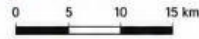
CREATING THE FINAL ENVIRONMENTAL MAP



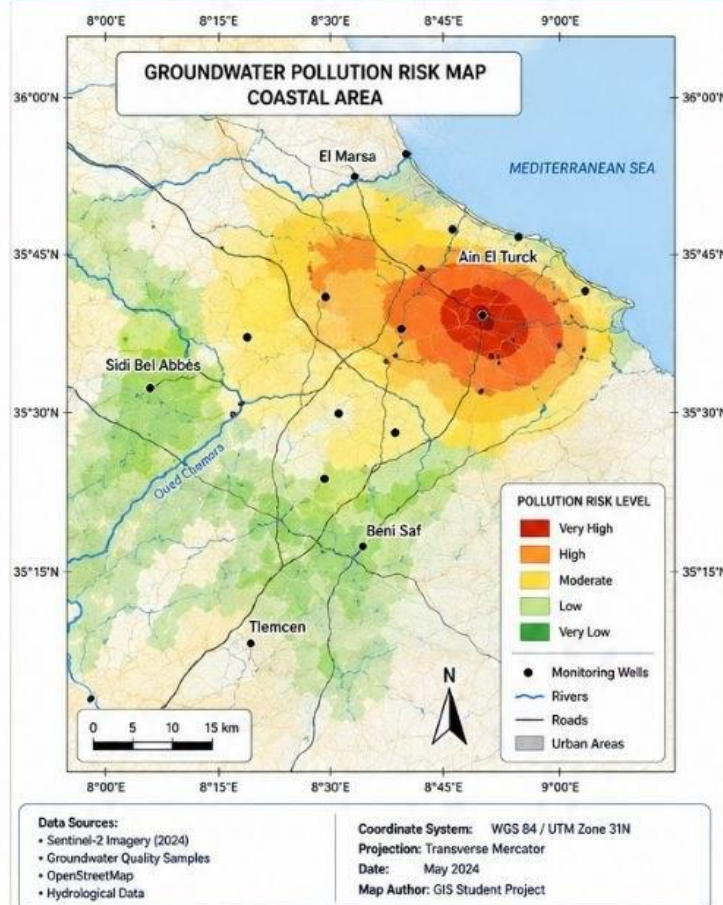
— TRANSFORMING SPATIAL ANALYSIS INTO PROFESSIONAL ENVIRONMENTAL MAPS —

A well-designed environmental map communicates spatial information clearly, supports decision-making, and tells the environmental story behind your analysis.

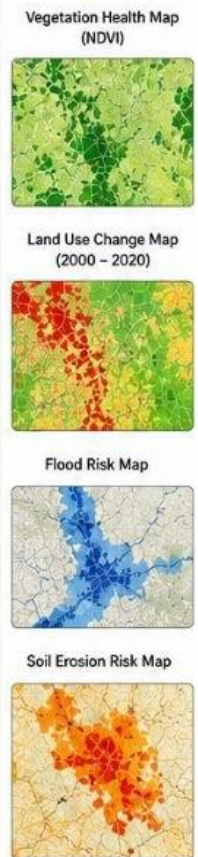
ESSENTIAL MAP ELEMENTS

- 1 MAP TITLE**
 Clear, descriptive, and informative
- 2 LEGEND**
 Explains symbols, colors, and data categories
- 3 SCALE BAR**
 Shows the map scale for distance measurement
- 4 NORTH ARROW**
 Indicates map orientation
- 5 DATA SOURCES**
 Lists data providers and sources
- 6 COORDINATE SYSTEM**
 Defines the map projection and coordinate reference
- 7 SYMBOLS & COLORS**
 Use appropriate symbology to represent environmental data
- 8 ENVIRONMENTAL INTERPRETATION**
 Explain what the map shows and its meaning for the environment

EXAMPLE: GROUNDWATER POLLUTION MAP (COASTAL AREA)



EXAMPLE MAP TYPES



FINAL MAP PRODUCTION WORKFLOW



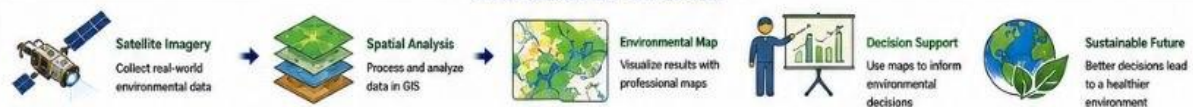
TIPS FOR PROFESSIONAL MAPS

-  **Keep it Clear**
Avoid clutter and use a clean layout
-  **Use Meaningful Colors**
Choose colors that represent data accurately
-  **Use Consistent Symbology**
Maintain consistency across all map elements
-  **Check Accuracy**
Verify data, scale, and coordinates before exporting
-  **Tell a Story**
Your map should communicate a clear environmental message

EXPORT FORMATS



FROM ANALYSIS TO IMPACT



OULAD HEDDAR Meriem

PW 11. Compile results; prepare final report and maps

1. Final Map Output Generation

Students are tasked with consolidating and refining all maps generated during the mini-project within **QGIS**, utilizing the **Layout Manager** functionality. Key steps involved in this process are:

- Setting appropriate map titles.
- Integrating a scale bar and a north arrow.
- Incorporating the project title or institutional logo.
- Exporting maps in high-resolution formats, such as **PNG** or **PDF**.

2. Final Outputs Report Preparation

Students are required to compile their maps and findings into a **formalized scientific report**, utilizing standard word processing software (e.g., **Microsoft Word**, **Google Docs**). The report must encompass the following elements:

- A concise introduction outlining the project's environmental objectives.
- Maps accompanied by brief interpretive descriptions.
- Digital results and relevant data visualizations/graphics.
- A succinct conclusion, along with environmental recommendations.

Emphasis is placed on writing the report in a professional, academic tone, incorporating **in-text citations** in accordance with **APA** 7th edition guidelines.

3. Data Documentation and Review

Prior to project submission, students must meticulously review their data sources to verify accuracy and consistency. A specific review checklist is to be employed, addressing points such as:

- Confirmation that each data layer is adequately documented.
- Explicit mention of the coordinate system employed.
- Verification that all aerial imagery originates from credible sources.
- Correlation of results with any corresponding field observations.

This crucial step reinforces **ethical practices in geographical** research and promotes transparency in spatial data management.



VISUALIZING GIS RESULTS WITH MAPS AND CHARTS



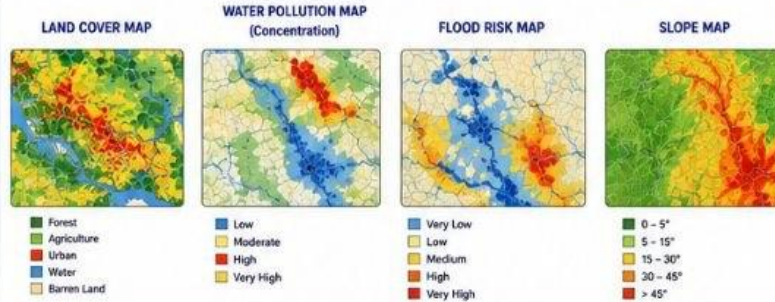
COMMUNICATING ENVIRONMENTAL FINDINGS THROUGH EFFECTIVE VISUALIZATION

Effective visualization transforms complex spatial analysis results into clear, meaningful, and actionable information that supports understanding and decision-making.

1 THEMATIC MAPS

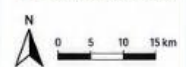
Show the distribution of environmental phenomena.

- Land Cover Maps
- Pollution Maps
- Risk Maps
- Slope Maps
- Soil Erosion Maps



BEST PRACTICES

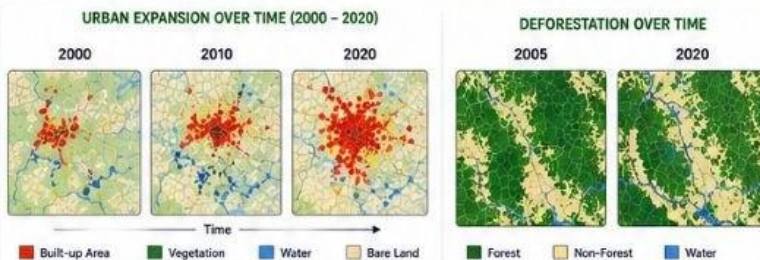
- ✓ Use appropriate color schemes
- ✓ Clear map title
- ✓ Meaningful legend
- ✓ Scale bar
- ✓ North arrow
- ✓ Data source
- ✓ Consistent symbology



2 TEMPORAL MAPS

Show changes in phenomena over different time periods.

- Before & After Analysis
- Time-Series Monitoring
- Change Detection



GOOD PRACTICES

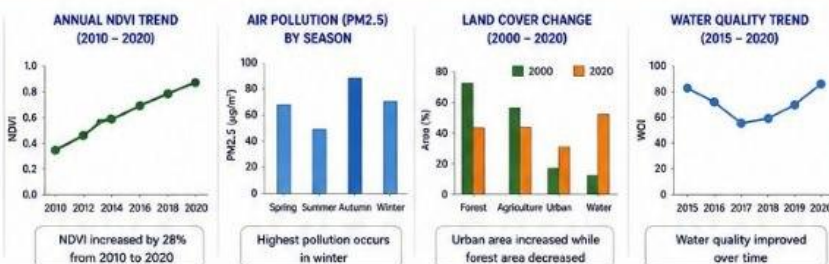
- ✓ Keep the same scale
- ✓ Use consistent colors
- ✓ Show time period
- ✓ Indicate change clearly
- ✓ Add north arrow and scale



3 GRAPHS

Show numerical trends and relationships.

- Bar Charts
- Line Graphs
- Trend Analysis
- Comparisons



GRAPH TIPS

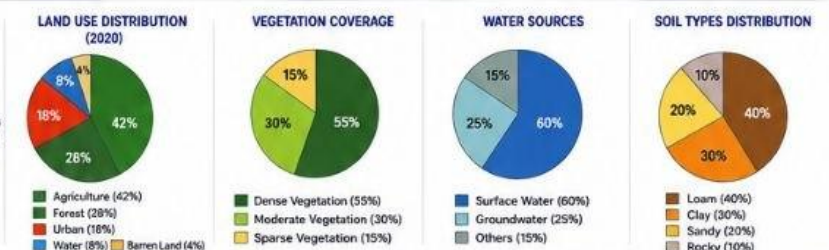
- ✓ Use clear titles
- ✓ Label axes
- ✓ Use units
- ✓ Keep it simple
- ✓ Use consistent colors



4 PIE CHARTS

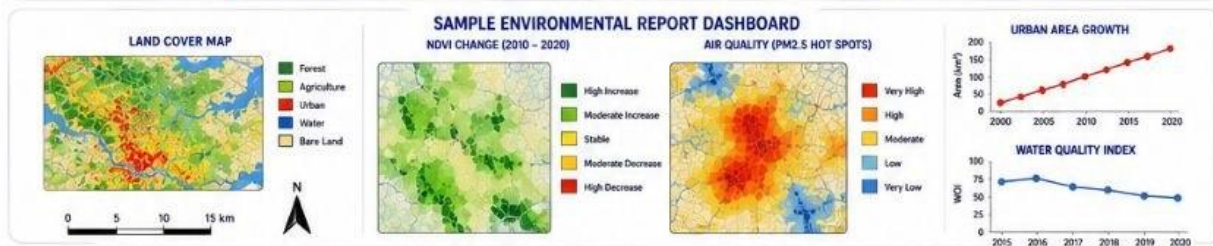
Show proportions and percentages of categories.

- Land Use Distribution
- Vegetation Coverage
- Water Sources
- Soil Types



PIE CHART TIPS

- ✓ Show percentages
- ✓ Use distinct colors
- ✓ Limit to 5-6 categories
- ✓ Add legend
- ✓ Keep labels clear



BENEFITS OF EFFECTIVE VISUALIZATION



Simplifies complex data



Reveals patterns and trends



Improves communication



Supports better decisions



Promotes sustainable actions

SUPPORTED BY



OULAD HEDDAR Meriem



SCIENTIFIC GIS REPORTING AND DATA DOCUMENTATION



— ENSURING TRANSPARENCY, ACCURACY, AND SCIENTIFIC CREDIBILITY —

A well-structured report and properly documented data ensure that GIS and Remote Sensing projects are reliable, reproducible, and valuable for decision-making and further research.

COMPLETE GIS PROJECT REPORT STRUCTURE



DATA DOCUMENTATION CHECKLIST

- ☒ Is every dataset documented?
- ☒ Is the data source clearly mentioned?
- ☒ Is the data type (Raster/Vector) specified?
- ☒ Is the spatial resolution provided?
- ☒ Is the acquisition date mentioned?
- ☒ Is the coordinate system specified?
- ☒ Is the software used documented?
- ☒ Are results validated with field data?

DATA DOCUMENTATION TABLE EXAMPLE

Layer / Dataset	Source	Data Type	Spatial Resolution	Temporal Resolution	Acquisition Date	Coordinate System	Software Used	Purpose
Sentinel-2 Imagery	Copernicus Sentinel Hub	Raster	10 m	5 days	15 May 2023	WGS 84 UTM Zone 31N	QGIS SNAP	Land cover classification
Landsat 8 OLI/TIRS	USGS Earth Explorer	Raster	30 m	16 days	10 Apr 2022	WGS 84 UTM Zone 31N	QGIS	Change detection
DEM (SRTM)	USGS	Raster	30 m	–	Feb 2020	WGS 84 UTM Zone 31N	QGIS	Slope & Elevation
Roads	OpenStreetMap	Vector (Line)	–	–	June 2023	WGS 84 UTM Zone 31N	QGIS	Transportation analysis
Rivers	OpenStreetMap	Vector (Line)	–	–	June 2023	WGS 84 UTM Zone 31N	QGIS	Hydrological analysis
Land Use Polygons	Field Survey + UN FAO	Vector (Polygon)	–	2020	Oct 2020	WGS 84 UTM Zone 31N	QGIS	Land use mapping
Air Quality Stations	Ministry of Environment	Vector (Point)	–	Hourly	2023	WGS 84 UTM Zone 31N	QGIS	Air pollution analysis

SOFTWARE & TOOLS USED IN REPORTING AND ANALYSIS

QGIS
Spatial analysis, mapping, and report production

ArcGIS
Advanced spatial analysis and reporting

SNAP
Satellite image processing and analysis

ENVI
Image processing and remote sensing analysis

Microsoft Word
Report writing and document preparation

Microsoft Excel
Data analysis, charts, and tables

R (Stats)
Statistical analysis and spatial statistics

SAMPLE REPORT LAYOUT PREVIEW

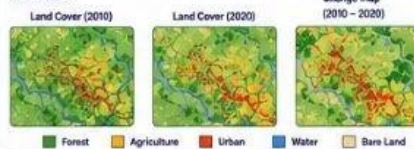
1. Introduction

This study aims to analyze land cover change and its impact on environmental conditions in the study area using GIS and Remote Sensing techniques.

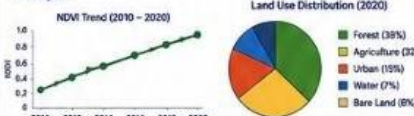
2. Study Area



3. Results



4. Graphs



5. Discussion

Results show significant urban expansion and reduction in vegetation cover. These changes are affecting ecosystem services and increasing environmental risks.

6. Conclusions

- Vegetation decreased by 20%
- Urban area increased by 25%
- Water quality declined
- Immediate management actions are needed

KEY DOCUMENTATION TIPS

- Be Accurate**
Provide exact data and clear descriptions.
- Be Consistent**
Use consistent formats, units, and naming.
- Be Transparent**
Clearly state sources, methods, and limitations.
- Be Reproducible**
Ensure others can understand and reproduce your work.
- Be Ethical**
Respect data licenses and acknowledge all sources.

BENEFITS OF PROPER REPORTING & DOCUMENTATION

Enhances credibility and trust

Supports evidence-based decisions

Improves reproducibility and verification

Facilitates data sharing and collaboration

Ensures compliance with standards

Promotes sustainable environmental management

OULAD HEDDAR Meriem

PW 12. Present final projects; discuss outcomes and environmental insig

1. Final Project Presentations

Each student team delivers their final presentation to a committee comprising the professor, teaching assistants, and their peers.

The presentation consists of:

- Project introduction and environmental objectives.
- Presentation of the data collection and analysis methodology.
- Display of maps, results, and statistical analyses.
- Extraction of environmental recommendations.
- Presentations are strictly supported by visual media (**GIS** maps, satellite images, charts). Students are highly encouraged to utilize **Story Maps** or **Dashboards** via **ArcGIS** Online or Web **QGIS**.

2. Group Discussion and Environmental Recommendations

Following each presentation, an interactive discussion session is opened between the presenting team and the rest of the class, moderated by the supervisor. Focus is placed on analyzing the scientific results and evaluating their accuracy, raising questions such as:

-  Was the data sufficient to explain the environmental phenomenon?
-  How accurate is the applied spatial classification?
-  Are the proposed recommendations practically feasible?

These recommendations are compiled into a final document termed the **Course Environmental Recommendations Plan**, which can be shared with academic or environmental entities.

3. Final Projects Evaluation

Projects are evaluated based on three main criteria:

➤ **Creativity:**

The innovativeness of the idea, the presentation method, and the distinguished use of digital geographic tools.

➤ **Scientific Accuracy:**

The robustness of data analysis, the utilization of scientific references, and the precision of maps and statistical results.

➤ **Environmental Relevance (Applied Value):**

The extent to which the project contributes to addressing a real-world environmental problem or proposes practical solutions to enhance resource management.

Students receive a final grade based on these three criteria, accompanied by detailed feedback to help them advance their future research.



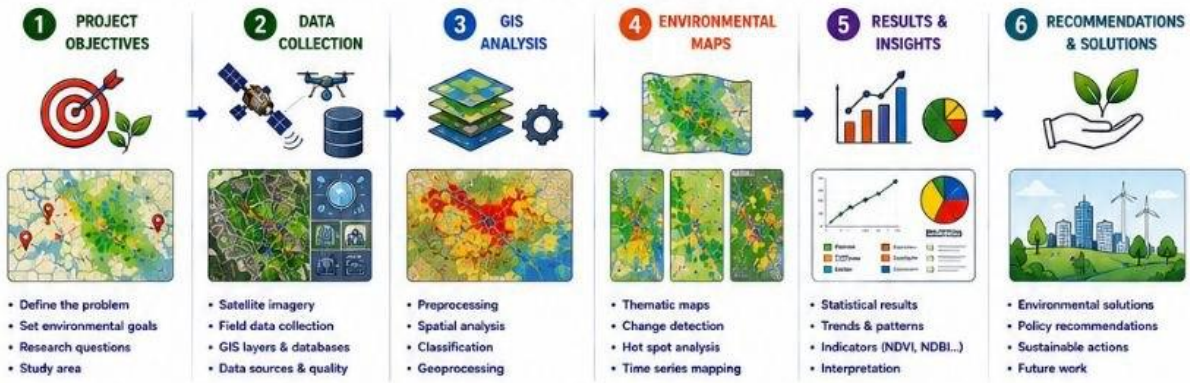
FINAL PROJECT PRESENTATIONS



TURNING SPATIAL ANALYSIS INTO SCIENTIFIC COMMUNICATION

Students present their GIS, Remote Sensing, and GeoAI projects to demonstrate how spatial data analysis can solve real-world environmental challenges.

THE PRESENTATION WORKFLOW



PRESENTATION FORMATS & TOOLS



PRESENT WITH IMPACT



EFFECTIVE PRESENTATION SKILLS



PRESENTATION CHECKLIST

- ☒ Clear objectives & research questions
- ☒ High-quality data & sources
- ☒ Accurate GIS analysis & maps
- ☒ Meaningful results & interpretation
- ☒ Relevant recommendations
- ☒ Professional design & layout
- ☒ Effective time management
- ☒ Confident & engaging delivery

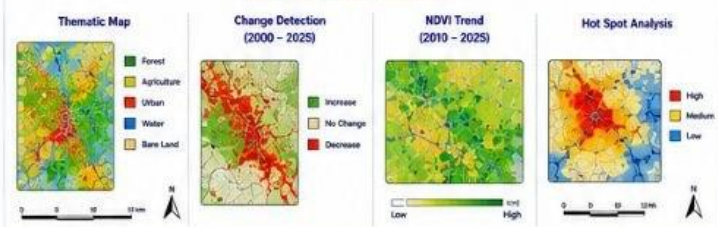
TIPS FOR SUCCESS

- ★ Know your audience
- ★ Practice your timing
- ★ Use consistent colors and fonts
- ★ Highlight key insights
- ★ Be prepared for questions
- ★ Stay confident and passionate

EXAMPLES OF ENVIRONMENTAL PROJECT THEMES



SAMPLE PROJECT OUTPUTS



WHY FINAL PRESENTATIONS MATTER



“ Maps tell stories. Presentations inspire action. Together, we create a better future for our planet. ”

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EVALUATING GIS PROJECTS



MEASURING SUCCESS AND PREPARING FOR THE FUTURE

A comprehensive evaluation ensures high-quality GIS, Remote Sensing, and GeoAI projects that deliver accurate results and real environmental impact.

1 CREATIVITY

Innovation & Originality



Innovation Originality of idea and approach.	Design Quality Visual appeal and clarity of maps and outputs.	Technology Use Effective use of GIS, RS, GeoAI tools.
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SCORING GUIDE (25 POINTS)

Excellent 21–25 pts	Good 16–20 pts	Fair 11–15 pts	Poor 0–10 pts
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2 SCIENTIFIC ACCURACY

Data Quality & Analytical Rigor



Data Quality Accuracy, resolution and reliability of spatial data.	Analysis Reliability Appropriate methods and correct processing.	Results & Maps Accurate results, valid interpretation and cartographic standards.
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SCORING GUIDE (25 POINTS)

Excellent 21–25 pts	Good 16–20 pts	Fair 11–15 pts	Poor 0–10 pts
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3 ENVIRONMENTAL RELEVANCE

Real-World Impact & Sustainability



Real-World Impact Addresses a real environmental problem.	Sustainability Promotes sustainable solutions and resource management.	Practical Solutions Feasible and actionable recommendations.
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SCORING GUIDE (25 POINTS)

Excellent 21–25 pts	Good 16–20 pts	Fair 11–15 pts	Poor 0–10 pts
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OVERALL SCORING SYSTEM



TOTAL 75 POINTS

- Creativity (25 Points)
- Scientific Accuracy (25 Points)
- Environmental Relevance (25 Points)

GRADE SCALE

TOTAL SCORE	GRADE	PERFORMANCE LEVEL
67 – 75	A	Excellent
58 – 66	B	Very Good
45 – 57	C	Good
30 – 44	D	Fair
0 – 29	E	Needs Improvement

PROFESSIONAL COMPETENCIES DEVELOPED



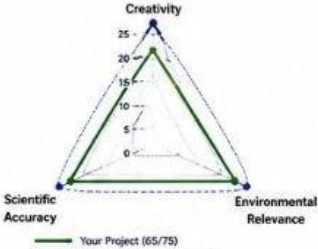
- CRITICAL THINKING**
Analyze complex spatial problems and make informed decisions.
- REMOTE SENSING INTERPRETATION**
Interpret satellite imagery and detect environmental changes.
- SCIENTIFIC COMMUNICATION**
Present results clearly with reports, maps and presentations.
- ENVIRONMENTAL ANALYSIS**
Understand environmental systems and evaluate spatial relationships.
- GIS MAPPING**
Create accurate, professional, and meaningful maps.
- GEOAI APPLICATIONS**
Apply machine learning and AI techniques to extract insights and predictions.

SAMPLE PROJECT ASSESSMENT CARD

Project Title: Urban Green Space Analysis (2025)
Team: Green Earth
Date: 25 / 05 / 2025

CRITERIA	MAX POINTS	SCORE OBTAINED	COMMENTS
1. Creativity	25	22	Innovative approach and excellent map design.
2. Scientific Accuracy	25	20	High data quality and reliable analysis.
3. Environmental Relevance	25	23	Strong real-world impact and practical solutions.
TOTAL SCORE	75	65	
GRADE	B	Very Good	

SCORE DISTRIBUTION RADAR CHART



— Your Project (65/75)
--- Excellent Benchmark (75/75)

PROJECT IMPROVEMENT TIPS

- Enhance innovation and explore new data sources.
- Validate data and improve analysis accuracy.
- Strengthen environmental impact and practical recommendations.
- Communicate results clearly with professional visuals.

GIS ANALYST



Process satellite imagery and extract environmental information.

REMOTE SENSING SPECIALIST



Provide environmental assessments and sustainable solutions.

ENVIRONMENTAL CONSULTANT



Develop AI models for environmental monitoring and prediction.

GEOAI RESEARCHER



Work with big spatial data to generate insights and innovations.

SPATIAL DATA SCIENTIST



Conduct research and contribute to scientific knowledge.

ACADEMIC & RESEARCHER



THE IMPACT OF WELL-EVALUATED GIS PROJECTS



High-quality results and reliable maps



Better environmental decisions and policies



Stronger scientific communication



Innovation and problem solving



Professional growth and career success



Contribution to sustainable future

OULAD HEDDAR Meriem

4. Closing Remarks

The workshop concludes with a speech from the supervising professor, encompassing a summary of the students major achievements throughout the course and encouraging them to **pursue further scientific research in environmental geoinformatics**.

Outstanding projects are showcased on the department's screens, and selected works are nominated for participation in specialized scientific conferences or academic journals.

At the end of the session, symbolic certificates of participation or detailed evaluation reports are distributed to each student.

The ultimate goal is for students to leave the course capable of **designing, executing, and analyzing a comprehensive environmental project using GIS and remote sensing**, bolstered by critical thinking and advanced scientific skills.

With this final gathering, the course concludes not as an end, but as **the beginning of a research and professional** career in the world of digital geography and environmental AI.

Spatial data are not merely numbers, but stories about the Earth; and maps are not just drawings, but powerful tools for protecting the planet and understanding it profoundly.

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