

AI4Water

From Assessment to Real-Time Management:
AI-Driven Strategies for Coastal Water Security
in the Annaba Region (Northeastern Algeria)

h 09:00-10:30, April 22, 2026, Sala Consiliare, DII

From Assessment to Real-Time Management: AI-Driven Strategies for Coastal Water Security in the Annaba Region (Northeastern Algeria).



Dr hab. Tachi
Salah Eddine.
Badji Mokhtar
- Annaba
University



Abstract: This presentation addresses the transition from conventional assessment approaches to real-time, data-driven management of coastal water resources, using the Annaba coastal area in northeastern Algeria as a representative case study. It provides a comprehensive overview of the current state of water resources, including the dual aquifer system affected by seawater intrusion and nitrogen-based pollution, as well as the availability and exploitation of surface water resources.

The study further examines irrigation systems, agricultural demand, and water quality constraints, alongside the increasing pressure from industrial activities and population growth. Particular attention is given to the interactions between groundwater salinity, pollution dynamics, and water allocation challenges.

To tackle these issues, the presentation highlights integrated methodologies combining machine learning, deep learning, GIS, remote sensing, and field data acquisition. These approaches aim to improve the modeling of surface water availability, predict seawater intrusion and groundwater pollution, and support the development of real-time decision-making tools.

Short Bio: Dr. Tachi Salah Eddine is an esteemed Algerian researcher and Associate Professor specializing in Earth Sciences and Hydraulic Engineering.

After graduating at the top of his class in Urban Hydraulics, he earned his Ph.D. with distinction in 2017. His academic career advanced at the National Polytechnic School in Algiers, where he achieved his Habilitation (HDR) in 2021 and served as Head of the Hydraulics Department until 2023. He currently teaches at Badji Mokhtar – Annaba University and is head of the Geology department.

Dr. Salah Eddine has published approximately 28 peer-reviewed papers (Scopus/WOS) and participated in over 50 international conferences. His research is particularly innovative for applying Artificial Intelligence and Machine Learning to Earth Science phenomena.

DII Seminar

Organizer: prof. T. Serina

UBMA: Algerian Team



Dr hab Buguerra
Hamza



Dr Bourouga Moncef



Dr Bouchehed Hamza



Prof Emeritus. Djabri
Larbi

Agenda

- Overview of the CCB & SB case study
- Available data and key challenges
- Ongoing and planned research activities
- Open discussion

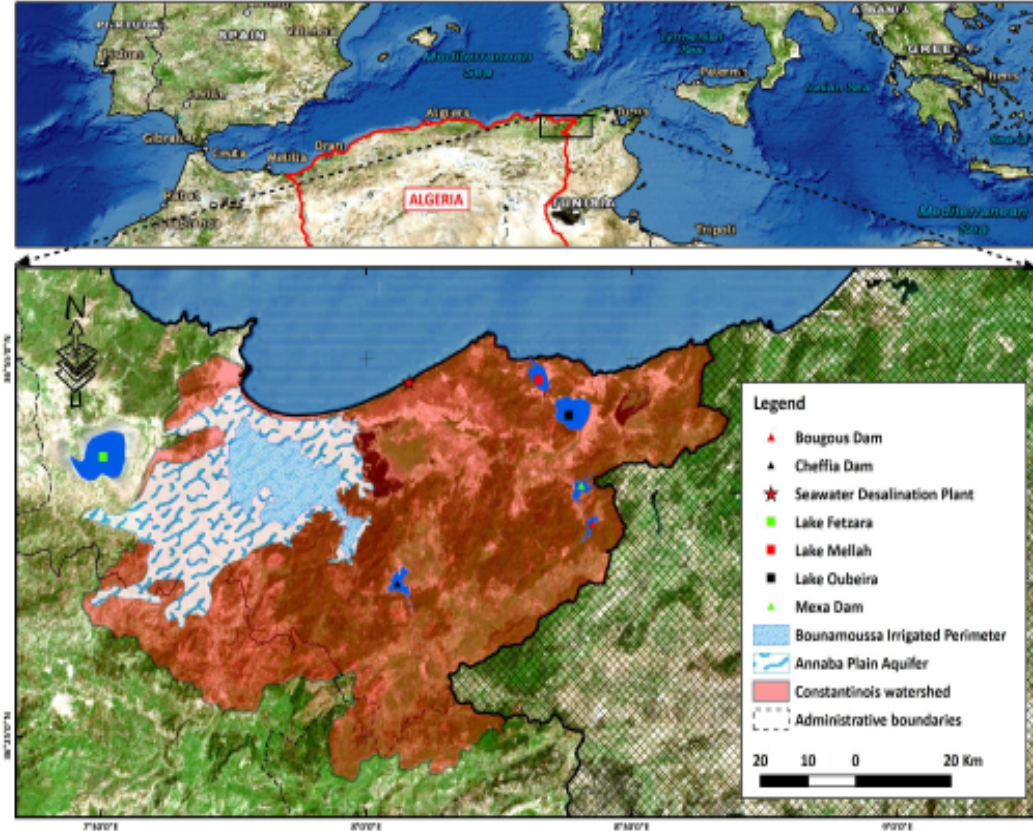
Overview of the CCB&SB case study



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Overview of the CCB&SB case study

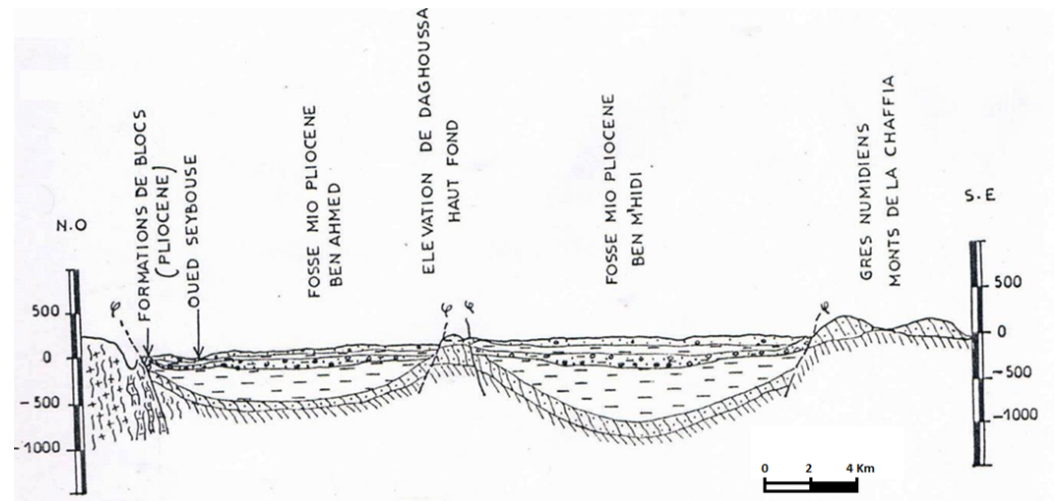
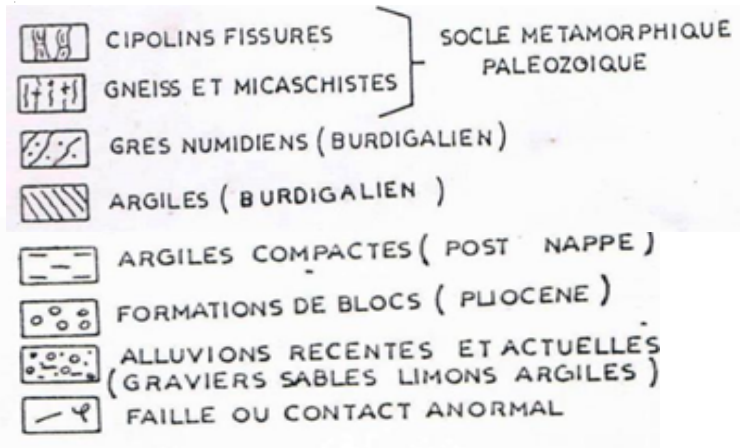
- Mediterranean climate area.
- Population Approx. 1M hab.
- Two (02) main reservoirs.
- Annaba Plain Aquifer.
- Desalination treatment plant 'capacity 300 cubic m/day.
- A main industrial company (SIDER)
- The Bounamoussa irrigated zone (13500ha).



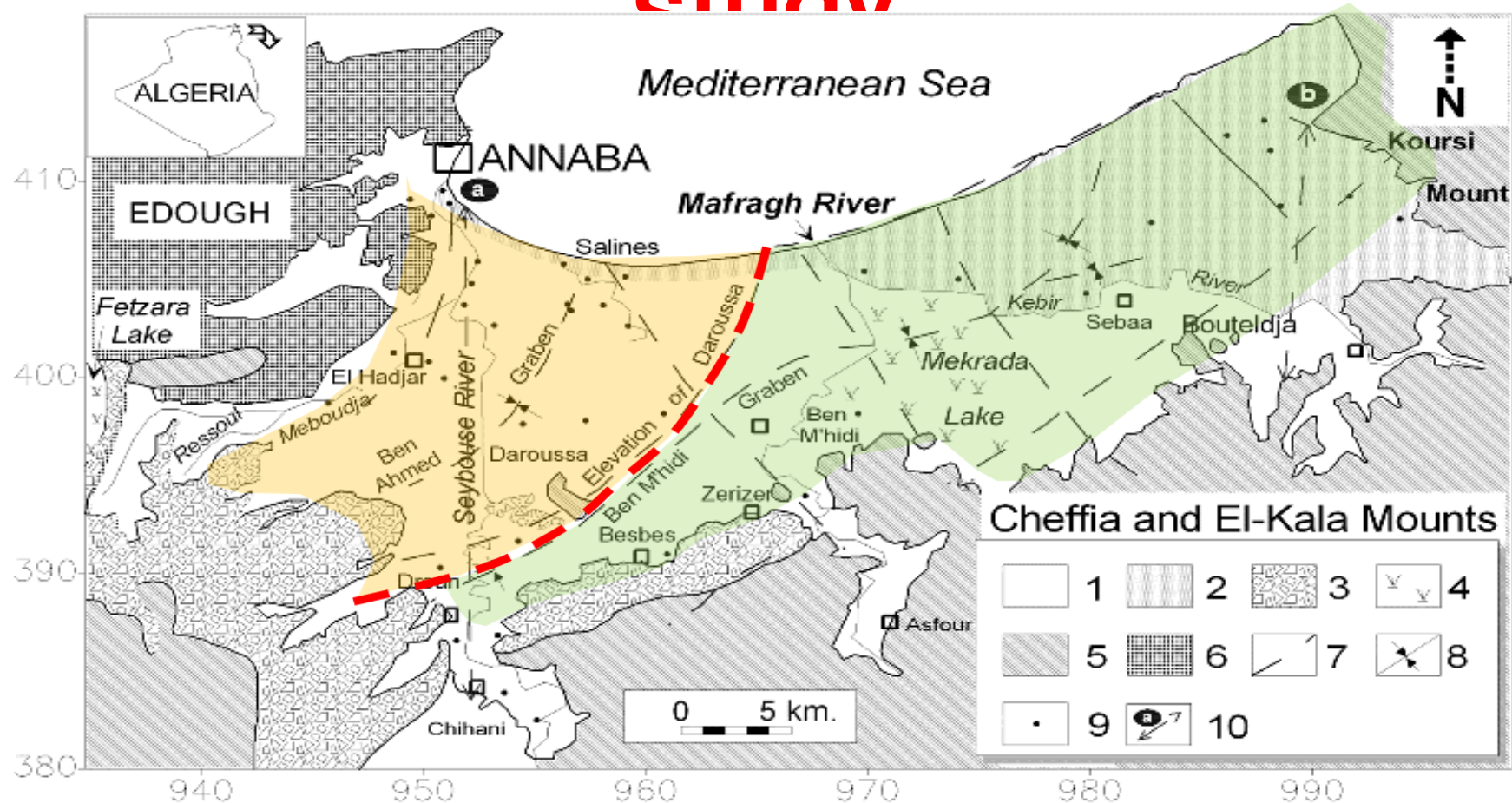
Overview of the CCB&SB case study

Tectonics and paleogeography:

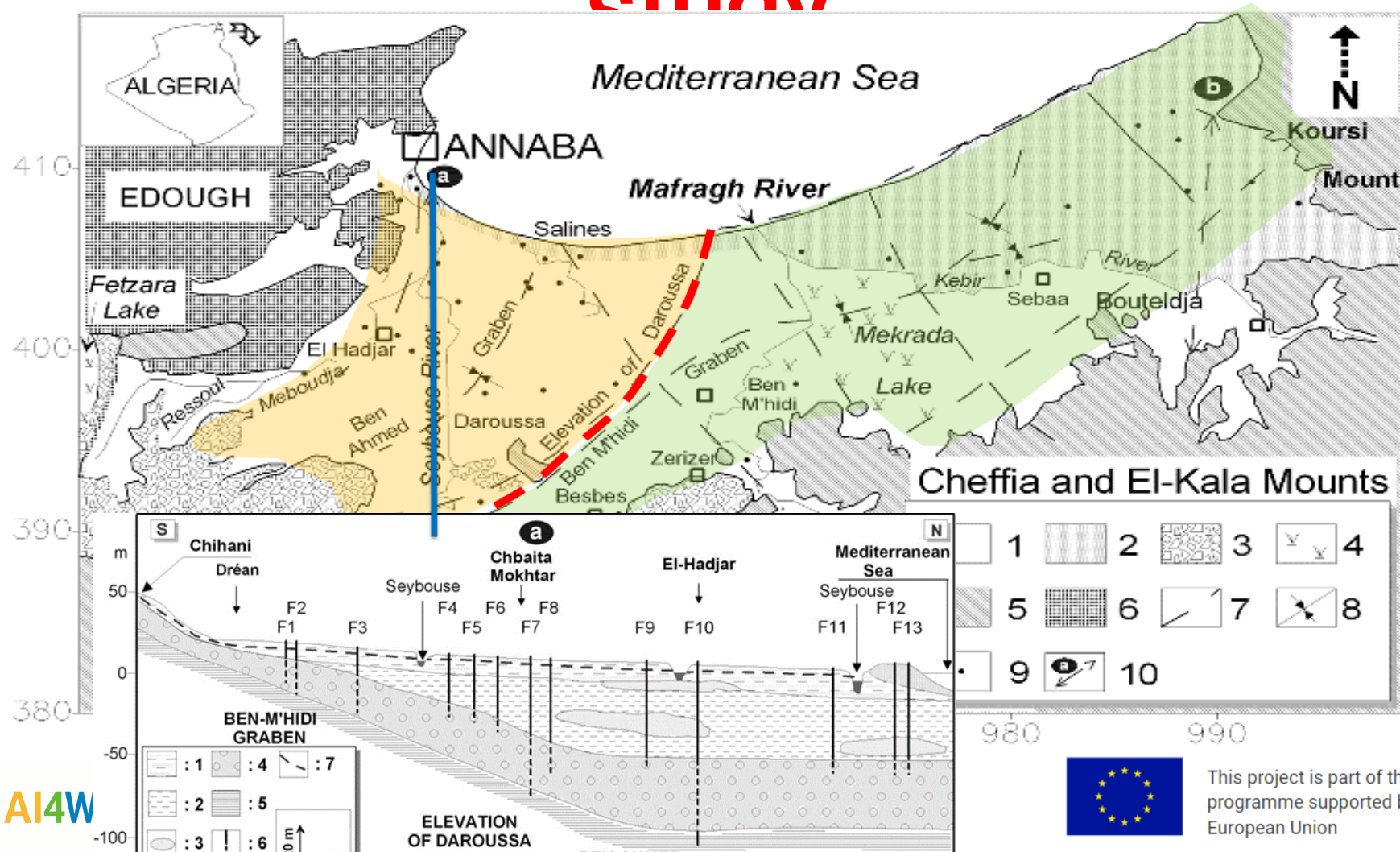
The Annaba plain experienced a tectonic event that caused the gradual subsidence of the Numidian sandstones toward the northwest, up to 300 meters below a formation f II constituting the main aquifer reservoir of the Annaba plain.



Overview of the CCB&SB case study

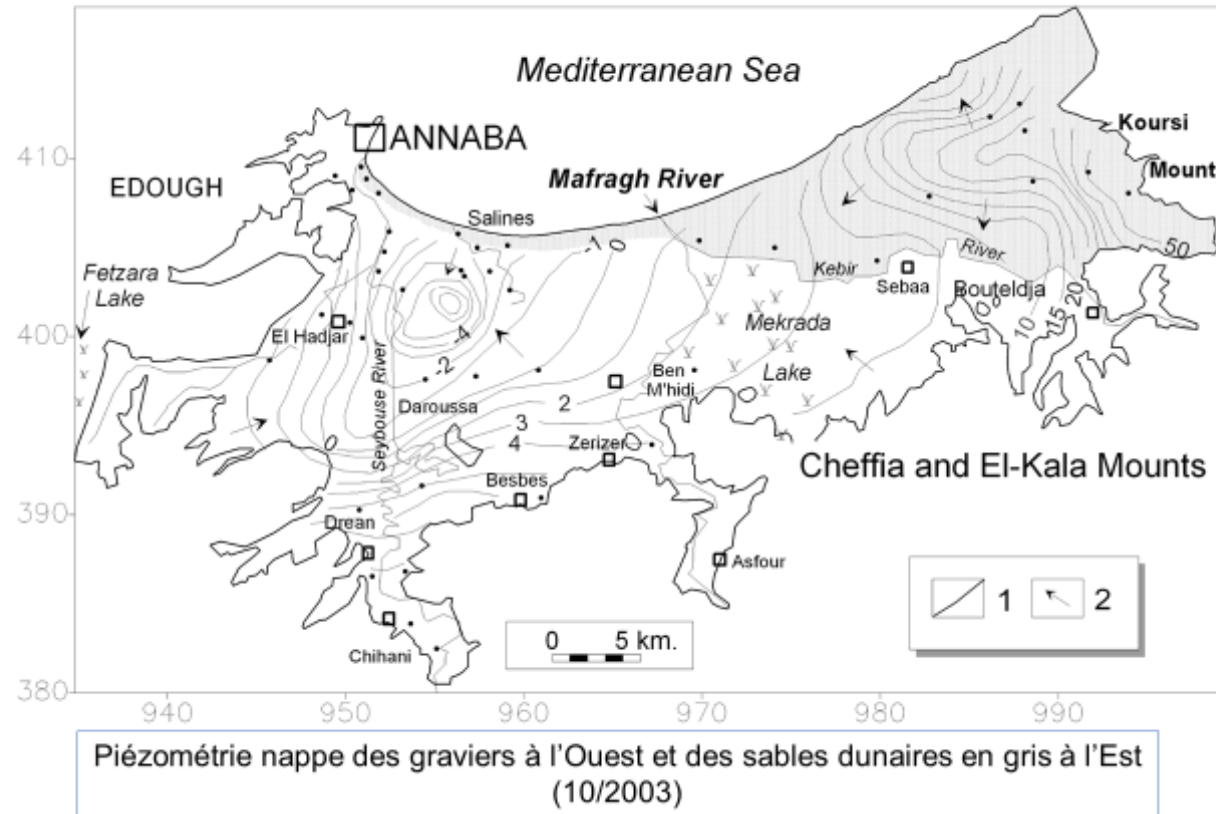


Overview of the CCB&SB case study



Overview of the CCB&SB case study

Piezometry of the gravel aquifer

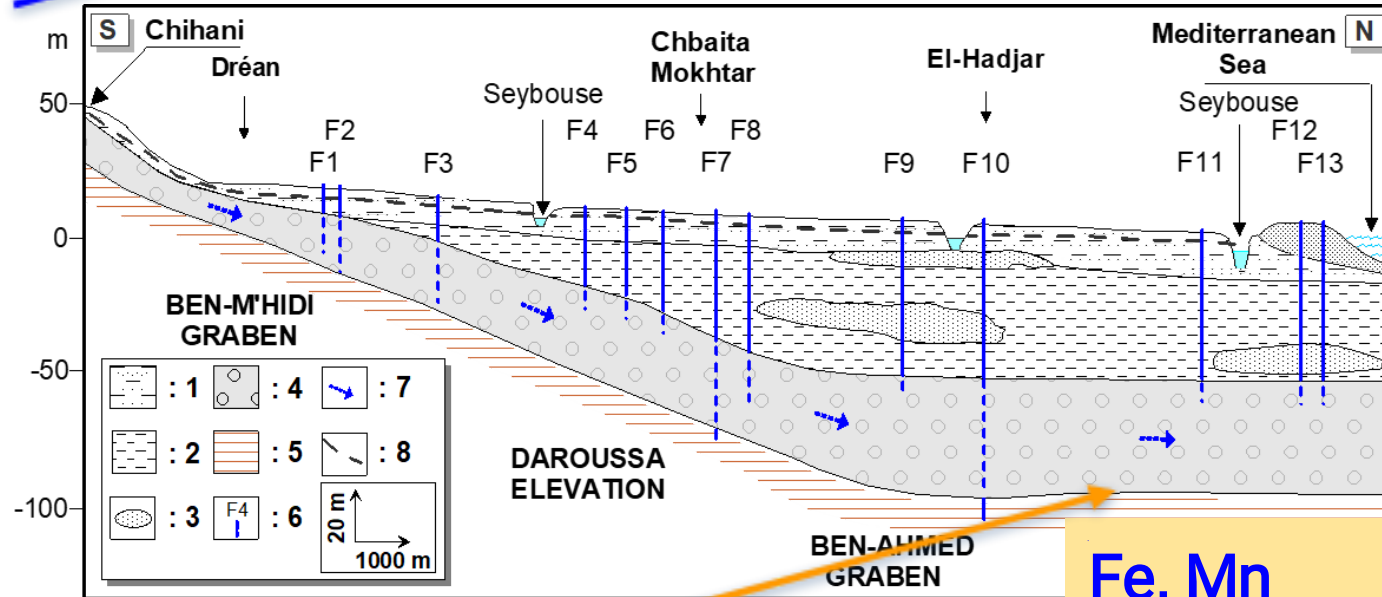


Overview of the CCB&SB case study

Quality of the water in the gravel aquifer:

Ca, Na, CE

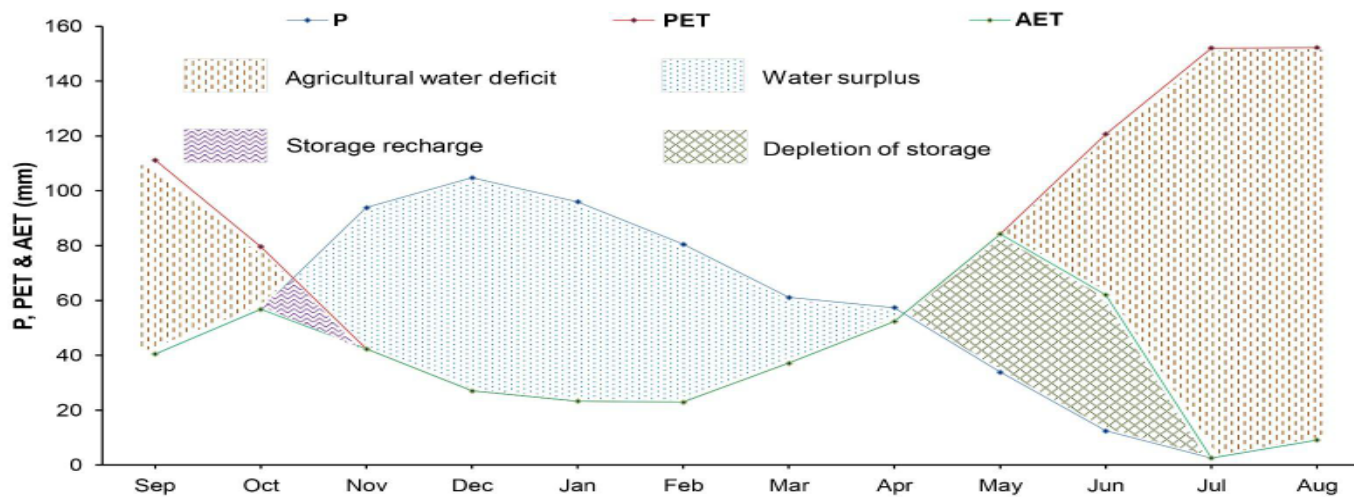
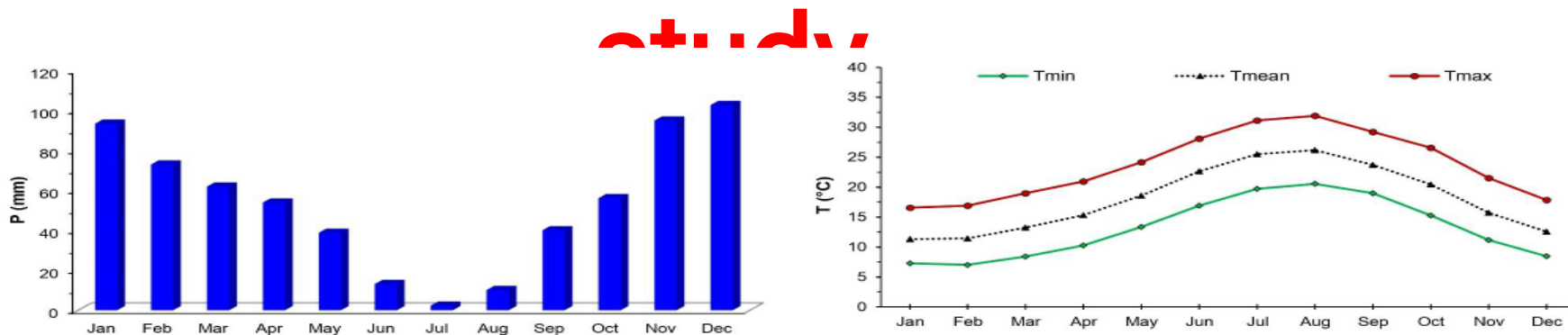
N03, S04, O2



Fe, Mn

Overview of the CCB&SB case

Climatology

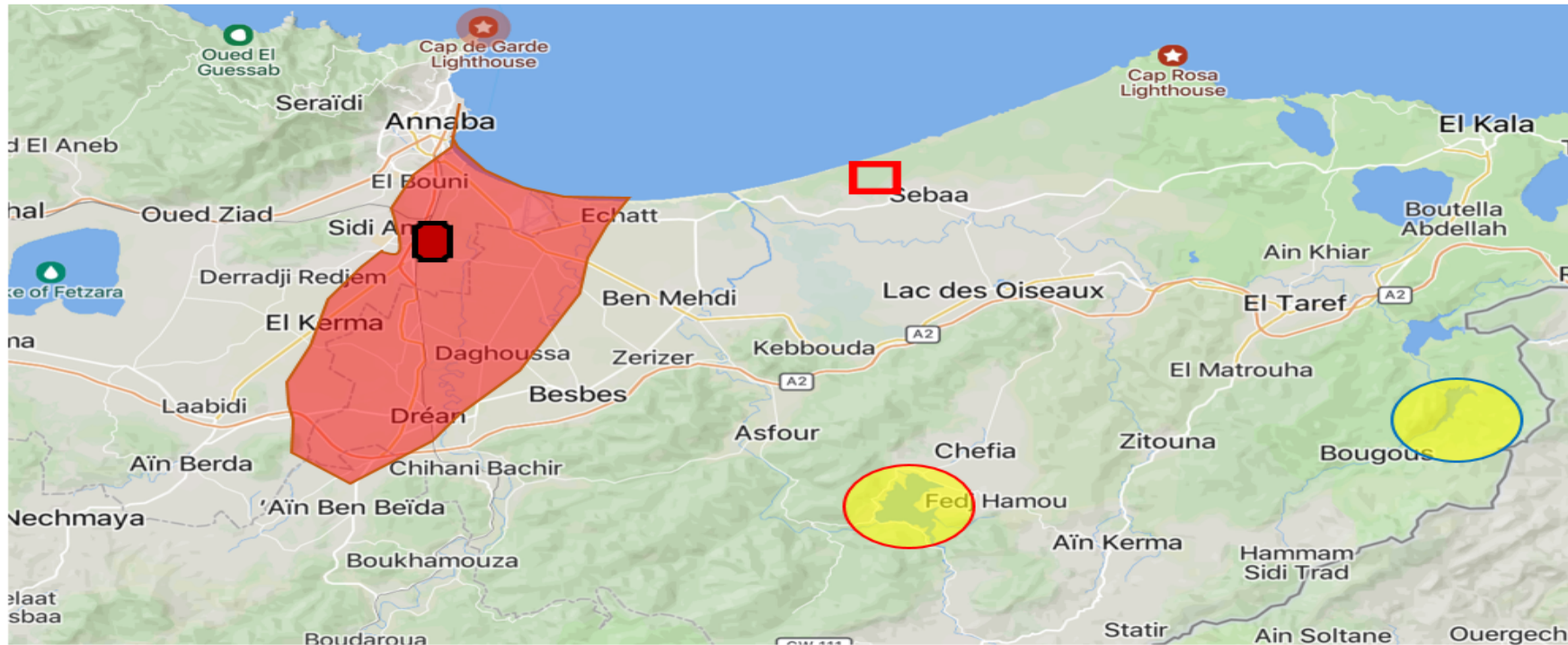


Overview of the CCB&SB case study

Water resources and allocation

Legend

-  Study area
-  Des
-  WWTP
-  Dam
-  SIDER (industrial company)



Available data and key challenges

Available data and key challenges

Data availability and challenges of the Algerian case study coastal aquifer

Objective: from fragmented data to actionable insights



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Available data and key challenges

Why Data Matters?

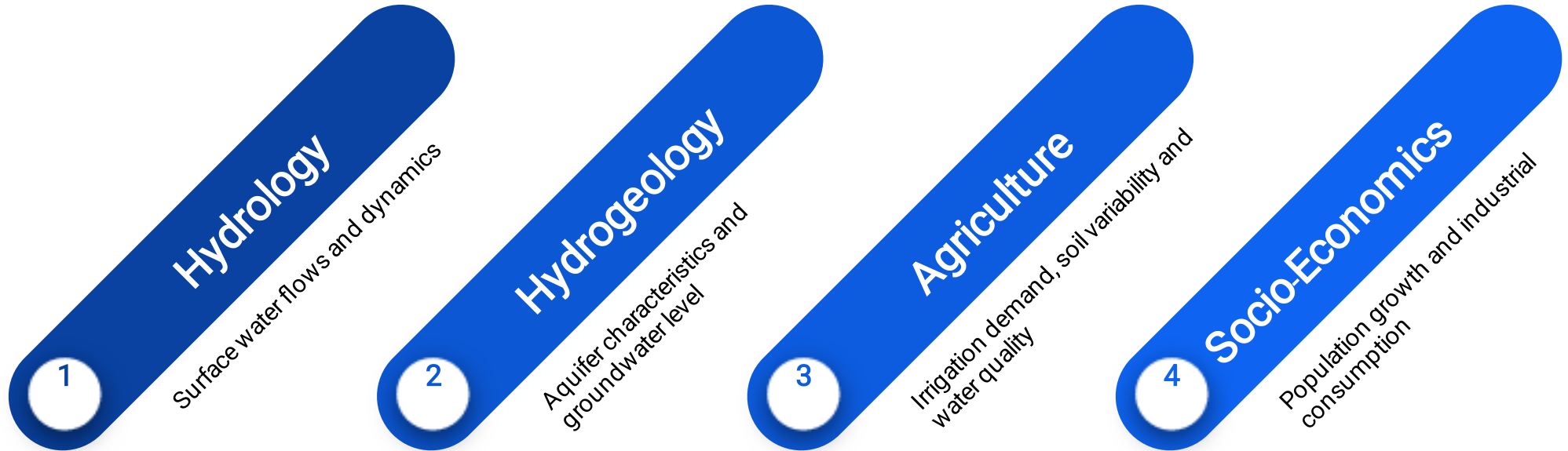
Strategic value: supports sophisticated **modeling, prediction** and evidence-based decision-making for complex coastal ecosystems.

Modernization: Enables the employment of **AI and real-time** management systems to respond to climate variability

Sustainability: Ensures the **equitable allocation** of water resources between industry, agriculture and urban demand

The core challenge: current data is often **fragmented, incomplete** or heterogeneous hindering effective regional planning

Available data and key challenges



Multi-Disciplinary framework

Available data and key challenges

Hydrological data gap and analysis

Data category	status	Observation/Issues
Rainfall & Temperature	Available	Reliable historical records from reliable meteorological stations
Streamflow	Limited	Sparse monitoring stations; many gauges are not functional
Reservoir Storage	Available	Daily records available for Chaffia dam only
Evapotranspiration	Challenging	Calculated estimates; Lack of direct lysimeter data

Available data and key challenges

Aquifer system data (Hydrogeology)

- **Available:** Piezometric levels (Partial temporal coverage) and high quality geological maps.
- **Difficult:** Continues groundwater level monitoring and digitalized layer stratigraphy.
- **Missing:** precise hydraulic parameters (transmissivity, storage).

Key Issue: High cost of field campaigns, **data confidentiality** and limited monitoring wells.

Available data and key challenges

Agricultural data availability scores



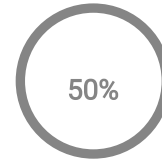
Irrigated Area

The surface of irrigated area
by the Chaffia reservoir



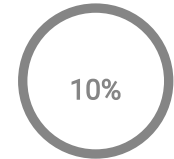
Reservoir Allocation

The dam's discharge for the
irrigation period



Water Demand
estimation

The estimated water demand
for the irrigation area
according to the crops



Pumping rates

No control on private
boreholes

Key issue: Significant data scarcity exists regarding informal water use and soil texture variability across the annaba aquifer Bounamoussa irrigation zone.

Available data and key challenges

SOCIO-ECONOMIC DEMAND ANALYSIS

Regional Water Allocation Profile Annaba Coastal System



Population Demand 40%

Irrigation Perimeter 25%

Urban Expansion & Losses 20%

Industrial Consumption 15%

▲ CRITICAL MANAGEMENT INSIGHT

"Significant data scarcity exists regarding informal water use and soil texture variability across the Annaba aquifer and the

Available data and key challenges

Cross-cutting data challenges

- Heterogeneity
- Temporal resolution
- Real time access
- Institutional gaps
- Monitoring
- Capacity

Available data and key challenges

From Data Constraints to Research Strategy

- Data limitations define research priorities
- Need for integrated and multi-source approaches
- Shift from data scarcity → data exploitation

→ Research designed to:

- Fill data gaps
- Integrate heterogeneous datasets
- Develop predictive tools

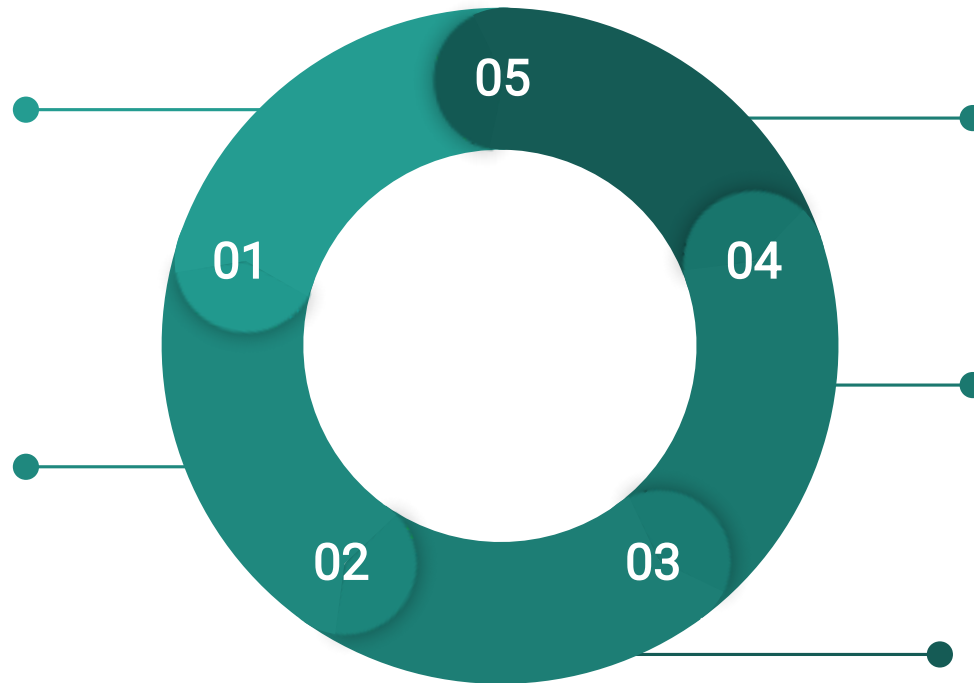
Available data and key challenges

DATA COLLECTION

Field survey + Remote sensing+ historic data collection

DATA INTEGRATION

GIS + Database Structuring



DECISION SUPPORT

Water allocation, Risk mapping

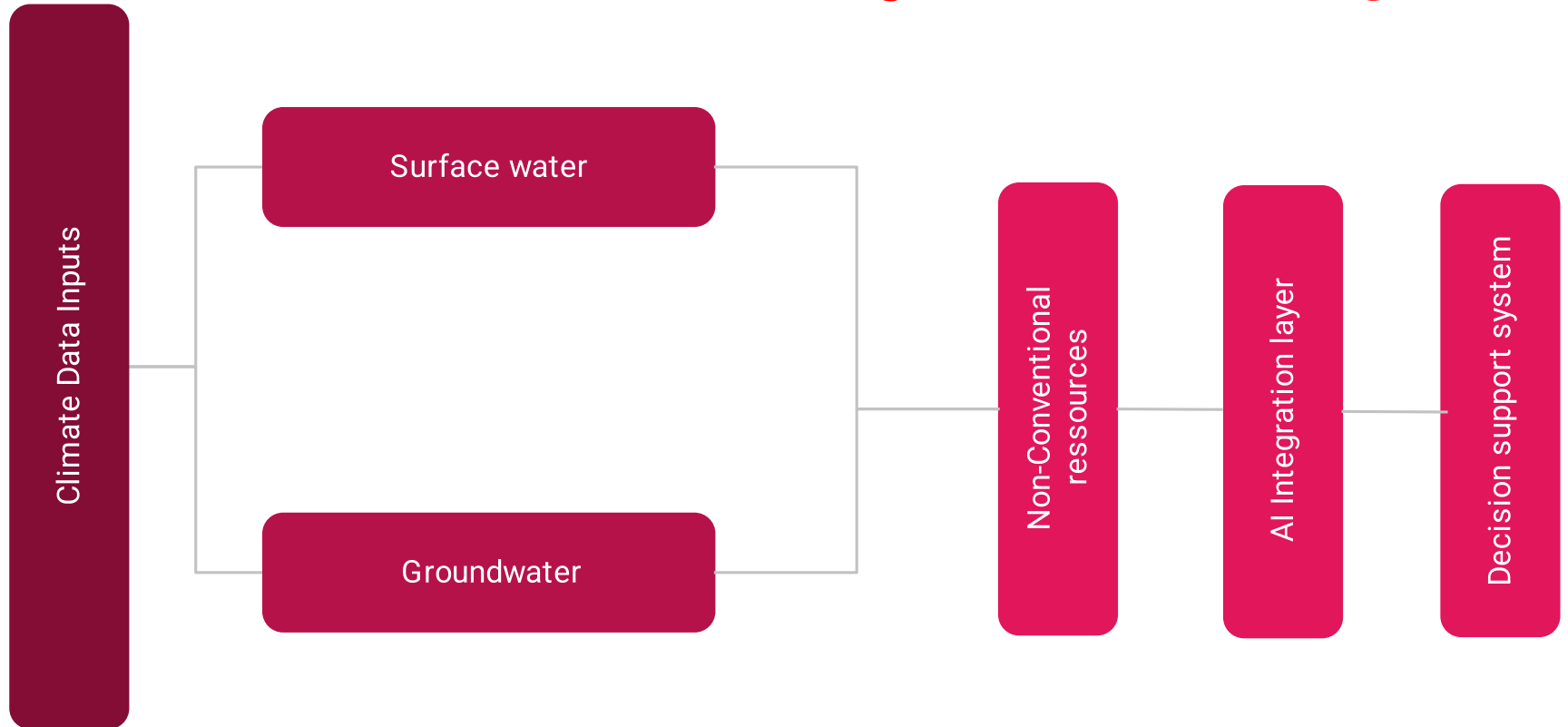
AI & PREDICTION

Machine learning + Forecasting

MODELING

Hydrology, Hydrogeology and Water quality

Available data and key challenges



Ongoing and planned research activities



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Ongoing and planned research activities

From Framework to Ongoing Research Activities

- Research structured into 3 main components:
 1. Groundwater & seawater intrusion
 2. Surface water & hydrolog
 3. Groundwater quality assessment
 4. Non-conventional water resources

Implemented through:

- Master projects
- Habilitation research

Ongoing and planned research activities

Hydrogeology, seawater intrusion, and groundwater quality monitoring:



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Ongoing and planned research activities

Title: AI-Based Mapping of Groundwater Pollution Vulnerability using GIS and Remote Sensing

Objective: Map and predict groundwater pollution vulnerability in the Annaba coastal aquifer.

Ongoing and planned research activities

Data Used:

- Field data (NO_3^- , EC, TDS, Cl^-)
- Land use / land cover
- Remote sensing indicators (NDVI, NDWI, LST)

Ongoing and planned research activities

Methods:

- GIS-based spatial analysis
- Machine Learning (Random Forest, SVM, ANN)
- Integration of field and satellite data

Ongoing and planned research activities

Expected Outputs:

- Groundwater pollution vulnerability maps
- Identification of contamination hotspots
- AI-based predictive model

Ongoing and planned research activities

Title: AI-Enhanced Seawater Intrusion Assessment using GALDIT Method

Objective: Assess and refine seawater intrusion vulnerability in the Annaba coastal aquifer



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Ongoing and planned research activities

Data Used:

- Groundwater levels
- Electrical conductivity (EC), Cl⁻
- Aquifer parameters (hydraulic conductivity, thickness, distance from coast)

Ongoing and planned research activities

Methods:

- GALDIT index (GIS-based vulnerability mapping)
- Machine Learning (Random Forest / ANN)
- AI used to improve accuracy and spatial prediction

Ongoing and planned research activities

Expected Outputs:

- Seawater intrusion vulnerability map
- AI-refined risk zones
- Improved decision-support for coastal aquifer management

Ongoing and planned research activities

These two works are complementary:

- The first addresses salinity and seawater intrusion, while the second focuses on pollution vulnerability.
- Together, they provide a comprehensive understanding of groundwater quality risks which could be highly introduced to the groundwater modelling.”

Ongoing and planned research activities

Hydrology and surface water quality modeling



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Ongoing and planned research activities

Title: Water Quality Assessment of Cheffia Reservoir using Water Quality Indices (WQI)

Objective: Evaluate surface water quality of Cheffia Dam for:

- Drinking water supply
- Irrigation
- Aquatic life

Ongoing and planned research activities

Data Used:

Eighteen (18) Physico-chemical parameters of period of 20 years.

Ongoing and planned research activities

Methods:

- Water Quality Index (WQI) calculation

Classification based on international standards

- Modeling water suitability and characterizing influenced parameters

Ongoing and planned research activities

Expected Outputs:

- Water quality classification
- Suitability assessment (drinking, irrigation, ecology)
- Identification of critical pollution thresholds

Ongoing and planned research activities

Title: Short-Term Rainfall–Runoff Modeling of Cheffia Reservoir using Machine Learning

Objective:

- Model and predict short-term inflow to Cheffia reservoir
- Improve water resource planning and management

Ongoing and planned research activities

Data Used:

- Rainfall time series
- Reservoir inflow / discharge data
- Climate variables (optional: temperature, evapotranspiration)

Ongoing and planned research activities

Methods:

- Machine Learning models:
- Artificial Neural Networks (ANN)
- Random Forest (RF)
- Time-series modeling and prediction (LSTM)

Ongoing and planned research activities

Expected Outputs:

- Short-term inflow prediction model
- Rainfall–runoff relationship analysis
- Tool for reservoir operation optimization

Ongoing and planned research activities

These two studies are complementary:

- The first evaluates **water quality**, while the second models **water quantity**.
- Together, they provide a comprehensive understanding of the reservoir system.

Ongoing and planned research activities

Groundwater Quality Assessment



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Ongoing and planned research activities

Title: Comparative Evaluation of Machine Learning Models for Predicting Groundwater Quality in the Annaba Gravel Aquifer (Irrigation Context)

Objective:

- Predict key groundwater quality parameters using Machine Learning
- Support assessment of water suitability for agricultural irrigation

Ongoing and planned research activities

Methods:

Water Quality Index:

- Weighted Arithmetic Index

Machine Learning models:

- Random Forest (RF) & Adaptive Boosting
- Comparative performance analysis

Ongoing and planned research activities

Expected Outputs:

- Accurate prediction models of groundwater quality parameters
- Identification of the best-performing ML model
- Scientific basis for irrigation water quality assessment

Ongoing and planned research activities

Together, these studies provide a comprehensive assessment of groundwater quality, supporting both **agricultural** and **drinking water** management within the AI4Water framework.



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Ongoing and planned research activities

non-conventional water resources



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Ongoing and planned research activities

Title: Sustainable Reuse of Treated Wastewater for Irrigation and Industrial Applications: Integrated Assessment Using Water Quality Indices-Case Study of El Allelik Wastewater Treatment Plant (Annaba)



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Ongoing and planned research activities

Objective:

1- Evaluate the quality of treated wastewater for:

- **Agricultural irrigation**
- **Industrial reuse**

2- Provide an integrated assessment based on **water quality indices**

Ongoing and planned research activities

Methodology:

- Calculation of Water Quality Indices (WQI)
- Use of irrigation-specific indicators:
 - SAR (Sodium Adsorption Ratio)
 - Salinity hazard indices
- Comparison with international standards for reuse
- Integrated multi-index evaluation approach

Ongoing and planned research activities

Expected Outcomes:

- Classification of treated wastewater quality
- Assessment of suitability for irrigation and industrial uses
- Identification of potential risks and limitations
- Scientific support for sustainable water reuse strategies

Ongoing and planned research activities

This work contributes to integrating non-conventional water resources into the overall water management system, which is essential under increasing water stress conditions.



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Ongoing and planned research activities

Habilitation works is divided into two parts:

- **Drought modelling** at different time scales (**Hydrological, agricultural and meteorological droughts**)
- Develop an **integration water resources management model**

Ongoing and planned research activities

Topic 1: Multi-Scale Drought Monitoring and Prediction using SPEI and Deep Learning (LSTM).

Objectives:

1- Assess and model **drought** at multiple scales:

Meteorological drought; Agricultural drought; Hydrological drought

2- Predict **future drought** patterns using **AI**

Ongoing and planned research activities

Data Used:

- Climate data:
 - _ Precipitation
 - _ Temperature
- Derived indices:
 - _ Potential Evapotranspiration (PET)
- Time series datasets

Ongoing and planned research activities

Methodology:

- Calculation of Standardized Precipitation Evapotranspiration Index at multiple time scales
- Time-series analysis (short, medium, long-term drought)
- Deep Learning model:
 - Long Short-Term Memory for prediction

Ongoing and planned research activities

Expected Outcomes:

- Multi-scale drought maps
- Temporal analysis of drought evolution
- Predictive drought scenarios
- Early warning support tool

Ongoing and planned research activities

Topic 2: Integrated Water Resources Management using Conceptual Modeling (WEAP).

Objective:

- **Develop an integrated water resources management model**
- **Optimize allocation between:**
 - **Domestic use**
 - **Agriculture**
 - **Industry**

Ongoing and planned research activities

Data Needed:

- Hydrological data (surface & groundwater)
- Water demand data (sectoral)
- Climate data (current & scenarios)
- Infrastructure data (reservoirs, desalination, reuse)

Ongoing and planned research activities

Methodology:

- Conceptual modeling using WEAP
- Scenario-based simulation:
 - Climate change scenarios
 - Demand growth scenarios
- System integration (multi-source water system)

Our first field campaigns



Open discussion



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