AGIC 5

“Book of Proceedings 5th Atlas Georesources International Congress”

Geosciences and Water Security Challenges under Climate Change

November 8-10, 2024

Hammamet, Tunisia

SCAN ME

WELCOME MESSAGE

Dear Esteemed Guests, Colleagues and friends,

On behalf of the AGIC5 Organizing committee, I am delighted to welcome you to the 5th Atlas Georesources International Congress (AGIC5) which held from 8th November to 10th November 2024 in Hammamet, Tunisia. This 5th Edition of AGIC focuses on serious water challenges facing Tunisia and Mediterrean region. It will cover a wide range of research fields of research from the resource exploration to the application of innovative technologies for monitoring and treatment.

Since its first edition in 2017, AGIC has become an important scientific event. This symposium provided an opportunity for water stakeholders including researchers, experts, Industrials, policymakers to exchange knowledge, share best practices and present the lastest results related to water resources

This edition of the conference has the overall theme **"Geosciences and Water Security Challenges under Climate Change"** and its main sub-themes of :

- ✓ Groundwater management and Surface water monitoring and Groundwater recharge
- ✓ Climate change and water
- ✓ Water treatment and reuse of non-conventional water
- ✓ Pollutant control and Water quality assessment
- ✓ GIS, Remote sensing, and IA applied to water resource
- ✓ Hydro-Hazards and Early warning system
- ✓ Geological Modeling and Resources Exploration

AGIC5 program included plenary sessions, followed by parallel sessions focused on the main sub-themes of the congress. Special sessions will also bring together experts to discuss and find solutions to key water challenges facing society and the environment.

In addition, the poster sessions will offer students and young researchers the opportunity to present their latest findings. A student poster award will also be given to recognize outstanding research contributions.

Last but not least, I would like to express my gratitude to the four co-chairs for their excellent coordination. I also want to thank the volunteers from the organizing committee, the scientific coordinators and reviewers for their valuable work to select outstanding presentations. Finally, I would like also to thank all partners for their support.

Enjoy the AGIC5

Prof. Ammar MLAYAH
Water Research and Technologies Center (CERTE)
Chairman AGIC5

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AGIC5 PROGRAM AT A GLANCE

Day 1 : Friday 8 November 2024		
13 : 00 – 14 : 00	Registration desk Open	
14:00 – 14 :30	Opening Ceremony *Welcome Address by Conference Chairs* *Official Opening of AGIC5*	
14:30 – 16:00	**Plenary Lectures**	
16:00 – 16:30	**Break**	
Parallel Sessions I		
16:30 – 18:00	**Room 1**	**Room 2**
	SubS1 : Groundwater management and surface water monitoring and Groundwater Recharge	SubS1 : GIS, Remote sensing, and IA applied to water resource
18:00-19:00	Workshop : How to write a Scientific paper ?	

Day 2 : Saturday 9 November 2024				
8:30 – 12:00	**Registration desk Open**			
8:30 – 9:30	**Plenary Lectures**			
Parallel Sessions II				
Time	**Room 1**	**Room 2**	**Room 3**	**Room 4**
9:30 – 11:00	SubS1 : Geological modeling for resources exploration	SubS1 : Pollutant control and Water quality assessment	**GGN Event (I)** 1st Geosciences and Environment Interdisciplinary Meetings	**SAFE Event (I)** Bridging the gap between science and society
Parallel Sessions III				
Time	**Room 1**	**Room 2**	**Room 3**	**Room 4**
11:30 – 13:00	Climate change and water	**Treasure Network Event** REUSE opportunities through Treasure Network	**GGN Event (II)** 1st Geosciences and Environment Interdisciplinary Meetings	**SAFE Event (II)** Bridging the gap between science and society
13:00- 14:00	**Lunch**			
Parallel Sessions IV				
Time	**Room 1**	**Room 2**	**Room 3**	
14:00 – 15:45	SubS2 : Geological modeling for resources exploration	Water treatment and reuse of non-conventional water	**GGN Event (III)** 1st Geosciences and Environment Interdisciplinary Meetings	
15:45 – 16:15	**Break + Poster viewing**			
	Room 1& Room 2			**Room 3**
16:15 – 18:00	**Poster Contest / Lighting talk**			**GGN Event (IV)** 1st Geosciences and Environment Interdisciplinary Meetings

Day 3 : Sunday 10 November 2024			
8:30 – 10:00	**Registration desk Open**		
8:30 – 9:30	**Plenary Lectures**		
Parallel Sessions V			
Time	**Room 1**	**Room 2**	**Room 3**
9:30 – 11:00	SubS2 : Groundwater management and surface water monitoring and Groundwater Recharge	SubS2 : GIS, Remote sensing, and IA applied to water resource	SubS2 : Pollutant control and Water quality assessment
11:00 – 11:30	**Break**		
11:30 – 13:00	**Closing Ceremony** Session reports by coordinators / Global Discussion / Poster Awards / Closing remarks		
13:00 – 14:30	**Lunch**		

PLENARY LECTURES

Plenary lecture 1

Water Scarcity: Current Situation and Prospects

Mr. Ridha GABOUJ
Water Expert and former Secretary of State in charge of water resources, MARHP

Mr. Gabouj Ridha is a water management expert who graduated from AgroParisTech and has dedicated his career to the water sector within the Ministry of Agriculture, Hydraulic Resources, and Fisheries (MARHP). From February 2023 to August 2024, he served as Secretary of State for Water Resources after leading the Water Program. His career includes key roles such as General Director of the General Directorate of Rural Engineering and Water Exploitation and Director of Drinking Water. Mr. Gabouj has played a crucial role in developing legislation and policies for the water sector, implementing reforms to enhance governance while addressing various challenges, including climate change. He has coordinated significant infrastructure projects in drinking water supply, sanitation, and irrigation, linked to value chain development, and funded by various donors such as the World Bank, KfW, AfDB, JICA, AFD, and others. He has represented the Tunisian government in numerous international forums and official committees dealing with water and agriculture. Additionally, he has organized international events, including the 5th Mediterranean Water Forum in Tunis, and is an active member of several associations promoting water and environmental conservation.

Plenary lecture 2

Strategic priorities of the water risk in the mediterranean region

Dr. Raoudha GAFREJ
Water Expert,
Univers de l'Eau
IME

Dr Ing. Raoudha Gafrej is a hydraulic engineer graduated from the National Engineering School of Tunis (1988), PhD in Earth Sciences graduated from the Pierre and Marie Curie University Paris VI (1993), specialized in Environmental economics graduated from the Federal Polytechnic School of Lausanne (2006) and in Leadership of public policies, graduate of South Mediterranean University (2019). Dr Gafrej is an international expert in the field of integrated water resources management and adaptation to climate change and a certified trainer in these fields. She was for 18 years a university lecturer and researcher at the University of Tunis El Manar. She participated in the development of various national and regional strategies in the field of water, the green economy, the adaptation of agriculture and ecosystems to climate change, and sustainable development. As a certified trainer, Ms. Gafrej has trained more than 1,500 directors and executives in water, climate change adaptation and other areas. Ms. Gafrej is author and contributor of different publications of World Bank Giz, International Alert, etc. : "Adaptation to a Changing Climate in the Arab Countries" , "Water governance inissues in the media and brings a real advocacy for a sustainable management of water resources under climate change threads

Plenary lecture 3

Groundwater exploitation in the Anthropocene, Day Zero and scientific pathways to water security for Tunisia

Prof. Hakim GABTNI
General Director
Water Research and Technologies Center, Borj Cedria (CERTE)
Tunisia

Professor Hakim Gabtni is a senior geoscientist and full professor at the Georesources Laboratory, currently serving as the General Director of the Centre of Water Research and Technologies (CERTE) in Tunisia. He holds a B.S. degree in geology/geophysics (2000), a master's degree (2002), a Ph.D. (2006), and an HDR (2012), all from Tunis El Manar University. Professor Gabtni specializes in geophysical methods for understanding sedimentary basins and complex geological formations. His work addresses critical areas like groundwater, water resources, energy, geological hydrogen, georesources, and environmental sustainability.

His research focuses on gravity and aeromagnetic investigations, three-dimensional seismic modeling, Deep Electromagnetic survey, and near-surface geophysical techniques, including microgravity, seismic refraction/MASW, and electrical resistivity tomography.

With an extensive background in research, development programs, and consulting, Professor Gabtni is also an active editor, reviewer, and author, contributing numerous publications to international scientific journals.

Plenary lecture 4

Prof. Serge CHIRON
IRD, France

Prof. Serge Chiron is a senior scientist at IRD. He has more than 25 years of experience in environmental chemistry with a particular focus on emerging contaminants. Their analysis and transformation in the environment as well as their remediation at source by applying nature-based solutions are his main research skills. He has been partner in several national and international projects including two projects funded by PRIMA.

Contaminants risks assessment for a safe expansion of reclaimed wastewater reuse and paths for mitigation

Escalating food demands driven by population growth have intensified agricultural practices, placing extraordinary strain on natural resources. The Food and Agriculture Organization predicts a 70% surge in food demand by 2050, paralleling a projected population increase of over 30%. Consequently, strengthening our food systems is becoming essential. Addressing this challenge requires a paradigm shift towards circular economy principles, in which waste becomes a valuable resource. Wastewater emerges as a promising alternative water source for agriculture, provided its characteristics are suitably enhanced. While this approach offers many benefits, this is not without potential risks to human and environmental health that largely stem from the presence of contaminants in the recycled resources (e.g., organic micropollutants, pathogens, antibiotic resistant genes). In this context, different issues and solutions will be discussed including i) contaminants monitoring strategy, ii) regulation and policy as well as iii) water management practices to allow for a safe resource reuse in an effective and replicable way. If needed, contaminants risks must also be mitigated. In rural area, where the capacity of wastewater collection facilities are often underdeveloped, decentralized treatment systems should be prioritized.

Plenary lecture 5

Prof. Jean-François BARDEAU
Director of Research
CNRS, France

Prof.Jean-François Bardeau, Director of Research at CNRS, obtained his PhD in Materials Science at the University of Le Mans in 1997. He specialized in the study of the structural and dynamic properties of different classes of materials such as organic-inorganic hybrid compounds, biomaterials and functional surfaces to focus more recently on the phenomena of electromagnetic exaltation induced on multi−nanostructured metallic surfaces to develop SERS (surface enhanced Raman scattering) sensors. Member of the office of the French Group of Vibrational Spectroscopies (GFSV) since 2015, he is the author of more than 150 publications, 5 patents and has received several distinctions for his work. In march 2024, Jean-François BARDEAU became the new director of the ICMN laboratory (Interfaces, Confinement, Materials and Nanostructures) which is a Mixed Research Unit (UMR n°7374) of the University of Orléans and the French National Center for Scientific Research (CNRS).

Raman Spectroscopy for environmental analysis and monitoring

Jean François Bardeau[1*], *P. Taugeron[1], M. Rahmani[1], Ludovic Douillard[2]*

[1] *Institut des Molécules et Matériaux du Mans – CNRS UMR 6283, Univ. Le Mans, Le Mans, France*

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[2] *CEA, IRAMIS SPEC - CNRS UMR 380, Université Paris-Saclay, Gif-sur-Yvette, France*

**Jean-Francois.Bardeau@cnrs.fr*

Surface-Enhanced Raman Spectroscopy (SERS) is an exceptionally powerful and non-invasive optical technique, increasingly used for the detection and identification of trace-level molecular analytes. Despite its immense potential, one of the key obstacles to the widespread quantitative application of SERS lies in the reproducible fabrication of substrates that exhibit consistent, high enhancement factors. These factors are intimately linked to the formation on the surface of "hot spots", regions of intense electromagnetic field enhancement. In response to this challenge, we successfully developed an efficient and inexpensive approach for fabricating metallic SERS substrates through thermal evaporation. In our recent work, we developed a bilayer gold substrate based on a primary layer approximately 100 nm thick, overlaid with an additional evaporated gold layer. During the deposition process, the metal clusters gradually coalesce, initially forming irregular nanoscale structures with small asperities before merging into a continuous film. This controlled evolution allows for fine-tuning of the interparticle spacing, creating an extended percolation network — ideal conditions for the generation of abundant hot spots.However, a critical question remains: how does the surface quality of the primary layer influence the spatial distribution and density of hot spots, and consequently, the overall SERS enhancement factor of the substrate? To address this, we conducted numerical simulations, creating model surfaces and by using the Finite Element Method (COMSOL Multiphysics®), we mapped the distribution of hot spots, elucidating thus the influence of the base layer's topographical irregularities on the substrate's plasmonic behavior. Our findings were further validated by experimental results obtained using PhotoEmission Electron Microscopy (PEEM), which confirmed the critical influence of the primary gold layer's morphology on the plasmonic properties and overall SERS performance. Our optimized nanorough Au substrates enabled the detection of crystal violet (CV), a chemical dye and antifungal agent classified as a biohazard and potent carcinogen, at a concentration of 5.10^{-9} M, highlighting the potential of such substrates for applications in environmental monitoring.

Plenary lecture 6

Prof. Abdelaziz MRIDEKH
Ibn Tofail university,
Faculty of sciences,
Natural ressources and
Sustainable laboratory
Morocco

Prof. Abdelaziz Mridekh is a professor of Applied Geophysics at Ibn tofail university, ''Géosciences des ressources naturelle''. He is head of research unit ''Géophysique et hydrosystèmes''. He earned his DEA in 1994 (at the university of Tunis El Manar) and Doctorat national at Ibn Tofail University in 2002. He worked for 3 years in water exploration for GéoAtlas, one of leader in hydrogeophyics in Africa. He specializes in hydrogeophysics and petroleum basin exploration, sequence and seismic stratigraphy, wire-line logging and GIS. He is currently conducting many research programs, consulting and is the author of several international publications and a reviewer in international journals.

Energy Transition: Nord African Perspectives and Challenges

Abdelaziz Mridekh[a], Rachidi Samir[b], Nouhail Nabil[b], Achraf Essalih[c], Ibtihal El Aichouni[a]
a) Ibn Tofail university, Faculty of sciences, Natural ressources and Sustainable laboratory
b) Institut de rechecrche en energie solaire et energies nouvelles
c) Société Marocaine de Stckage Souterrain

The energy transition is a crucial issue of the21st century, driven by the need to reduce carbon emissions and promote sustainable energy sources. Globally, this transition significantly influences the economy, redefining investments and energy policies. In Africa, the energy transition presents considerable opportunities for sustainable development but also faces unique challenges, such as limited access to technology and financing. Morocco possesses significant fossil energy potential, with production zones in the Gharb region and numerous offshore projects. These resources offer an opportunity to balance the energy mix while transitioning towards more sustainable sources. In parallel, Morocco stands out as a regional leader in adopting renewable energies, with ambitious initiatives like the Noor solar complex in Ouarzazate, one of the largest in the world. The country has implemented an energy strategy aiming to increase the share of renewables to 52% of its energy mix by2030. Additionally, Morocco is actively developing its green hydrogen policy, recognizing its potential to decarbonize industry and transport. In this context, Morocco is exploring underground storage sites, with ongoing projects like MELHY, which aim to enhance energy security and stability by addressing the intermittency challenges of renewable energies. This underground storage presents numerous technical challenges, requiring the integration of diverse scientific disciplines such as geomechanics, geophysics, and reservoir modeling to ensure effective and safe implementation. We examine the role of the energy transition in the global economy and its impact in Africa, emphasizing the importance of an energy mix tailored to the specificities of each country. In conclusion, it highlights the necessity of a personalized and collaborative approach to ensure a successful energy transition, beneficial for both Africa and the rest of the world.

Plenary lecture 7

Prof. Joanna DOUMMAR,
American University of Beirut
IAH, Lebanon

Prof. Joanna Doummar is the Chair of the Department of Earth Sciences and an associate professor of groundwater hydrology at the American University of Beirut. Joanna's research focuses on water quality and quantity assessments in Mediterranean, semi-arid, and snow governed karst and fractured aquifers. Her research projects include the high-resolution monitoring and collection of time series data, subsurface characterization, and development of numerical groundwater flow. This approach is essential to drive, using science-supported evidence, policy and infrastructural interventions for GW protection and sustainability on pilot scale. She has supervised many undergraduate and graduate students in research topics in hydrogeology that culminated in various publications. She is the Vice president (MENA Region) of the International Association of Hydrogeologists and an elected member of the IAH Karst Commission. She has been also been elected in the World Economic Forum Young Scientists Community- Class of 2020

Data and modeling in karst systems: potential application to groundwater management and policy in semi-arid regions

The presentation will present work undertaken in an experimental poorly studied semi-arid region in Lebanon: the Nahr El Kalb surface water/ aquifer system composed of limestone and dolostones of Jurassic to Cenomanian age. A high-resolution monitoring is taking place since 2014 to characterize the subsurface, understand spring responses, conceptualize flow and transport in complex systems, and simulate flow in variably heterogeneous systems of Mount-Lebanon. Different methods have been applied for the characterization of flow and transport in different types of karst systems with variable heterogeneities, hydrodynamic conditions, and climatic input: 1) snow-governed versus rain governed springs, 2) fissured karst aquifers, 3) highly complex heterogenous karst with little knowledge of the subsurface, and 4) highly complex karst with a cave access. Such utilized methods include times series analysis, tracer experiments, micropollutants sampling campaigns, stable isotope studies etc. The presentation will present briefly selected models such as distributed integrated hydrological, lumped linear reservoir, 2-D dual continuum, discrete fractured network models, and recently machine learning applications that have been tailored to simulate flow in the investigated spring catchments to account for the degree of karstification and varying hydrodynamic responses. In sum, the talk will illustrate a long-term methodology that allows to assess water quality and quantity in Lebanon in particular. This approach can be upscaled to the region for a better sustainable karst groundwater management, testing of alternative methods for enhanced recharge, and policy development and implementation in poorly studied catchment areas.

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Groundwater Management and Surface Water Monitoring and Groundwater Recharge

Groundwater Management and Surface Water Monitoring and Groundwater Recharge

Oral

GR-Or-01

Fractures analysis in the Takelsa basin (Northeastern Tunisia) using field data and automatic extraction for groundwater investigation

Sabra Dhouioui[a], Houcem Mzali[a], Kalthoum Hafsa[a]

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Introduction/Objective

The study region is represented by the Takelsa basin situated in the Northeast of Tunisia, in the Cap Bon peninsula. This region is characterized by a semi-arid Mediterranean climate with annual precipitation of 600 mm (from 2009 to 2021) and a mean annual temperature of 20,1 °C. It exhibits a blend of urban, agricultural and natural features. It is characterized by hills and mountains cloaked in a tapestry of shrubs and grasslands that play a pivotal role in erosion control. Considering the topography of the region reveals a patchwork of agricultural fields, with olive groves, citrus orchards, vegetables, cereal and vineyards. For this reason, the Takelsa region relies heavily on water for irrigation. One of the major problems that contributed to the water crisis is the extensive use of fertilizers and pesticides in order to increase the agricultural production in the region. This practice led to soil degradation, nutrient imbalances and groundwater contamination. Furthermore, climate change has led to irregular rainfalls and prolonged droughts. For these reasons, sustainable water management practices, such as drip irrigation, rainwater harvesting and improved water distribution systems are adopted to ensure the long-term viability of agriculture. Dams, for example, serve as essential infrastructure for water storage, irrigation and flood control. The most important dams in the region are Wadi Abid and Wadi Bezirk with a storage capacity of 10 Mm3, 6 Mm3 respectively. However, even though the region relies on dams, groundwater remains an important reserve of water in the study region. The major threat to the region's groundwater reserves is the over and uncontrolled exploitation by the region's various economic sectors. This has led to a severe water table drawdown and water quality degradation.

The available literature reveals that several hydrogeological studies carried out in the Takelsa region to determine the different aquifers (Mzali et al., 2016) and to examine the source of water quality variation and the major geochemical processes controlling the groundwater evolution (Ghouili et al., 2021). The present study aims to: 1- Determine the potential water reservoirs after the fracture analysis. 2- Determine the fractures that are affecting the consolidate sandstone of Beglia and Saouaf formations. 3- Identify the dominant and secondary directions and length of all fractures within the study area.

Methodology

This study is based on field investigation and the automatic extraction of fractures.

The field study subject of this paper has been carried out by measuring the dip and orientation of fractures that affect the sandstone of Beglia and Saouaf formations. Thirteen field stations have been located by a GPS device. Each station is represented by several measures of the fracture geometry. In order to obtain the stereograms of fracture directions and the rose diagrams, the researchers processed the measures of each station using "Win Tensor" software (Delvaux, 2008).

The automatic extraction of fractures has been carried out in several steps: 1: Image processing procedures were achieved by the Sentinel S2MSI2A image. 2: a Multi-Spectral Instrument (MSI) has been used. 3: Edge detection has been assured by the Canny algorithm. 4: The edge strength image is thresholded to produce a binary edge image. 5: Automatic extraction of lineaments.

Result/Discussion

This study is carried out on the Takelsa Basin. It enabled the research team to reveal two main water reservoirs, which are respectively 180-meter sandstone layer of Saouaf Formation, and 200-meter consolidated sandstone of the Beglia Formation. The fractures' field measurements, the interpretation of NW-SE seismic profile and the automatic extraction of these fractures carried out by satellite imagery (Sentinel S2MSIL2A imagery) demonstrate that the reservoir layers of the Takelsa basin (Saouaf and Beglia formations) are affected by a high density of fractures at the surface and subsurface levels. These fractures increase the porosity and permeability of the water reservoirs, facilitate the flow of the groundwater through interconnected fractures, and facilitate the groundwater recharge. The fractures' automatic extraction is performed by MSI (Multi Spectral Instrument), composite band, Canny algorithm, enhancement algorithm and GIS (Geographic Information System). The direction rose diagrams show that the principal fractures' (Faults') directions are NW-SE, E-W, NE-SW and N-S. The length rose diagram shows that the longest fractures are oriented almost E-W.

Conclusion

Two important water reservoirs have been distinguished for their lithology and thickness. The first water reservoir, of the Saouaf formation, is composed of sandstone with a 180-meter thickness. The second water reservoir, of the Beglia formation, consists of consolidate sandstone with a 200-meter thickness. These two water reservoir are affect by a high density of fractures where the principal directions are NW-SE, E-W, NE-SW and N-S. These fractures are characterized by interconnected fractures with low and high dips. This allows the continuous recharge of the water reservoirs and assures the groundwater flow. The fractures network play a significant role in increasing the porosity and the permeability of water reservoirs.

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Keywords: water reservoir, basin structure, fractures, automatic extraction, GIS, Tunisia.

GR-Or-02

Recharge Mapping and water availability analysis for the Zaghouan Karst aquifer (Northeastern Tunisia)

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Introduction/Objective

In the southern Mediterranean, especially in semi-arid zones, assessing karstic aquifers is crucial for sustainable water supply due to challenges like population growth, agricultural expansion, and climate change. These pressures increase water demand and make karstic aquifers, which are vulnerable to contamination and overuse, vital to evaluate (Hssaisoune et al., 2020; Bagherzadeh et al., 2018). In Tunisia, where karst aquifers account for over 13% of groundwater, climate change and overexploitation pose significant threats (Hamed et al., 2023). This study assesses the Jebel Zaghouan aquifer in Northeast Tunisia, focusing on groundwater availability and recharge. Using data from boreholes and methods like APLIS, the research aims to equip decision-makers with tools for sustainable management of this critical resource

Methodology

Study Area

Jebel Zaghouan, located approximately 50 kilometers from Tunis, is a pivotal Jurassic formation within the Zaghouan massif, spanning roughly 19.6 km². The region experiences an upper semi-arid to subhumid climate, with an average annual rainfall of 467 mm and significant temporal fluctuations, and an average annual temperature of 17.7°C.

APLIS Method and Water Budget Estimation

The APLIS method, used to estimate annual recharge of carbonate aquifers in Mediterranean climates, was applied. This GIS-based method factors in altitude, slope, lithology, infiltration, and soil type to create a recharge map. Variables were scored, and recharge rates calculated using QGIS. Water budget analysis relied on calibrated and validated models from Djebbi et al. (2001) and Sagna (2000), which assessed the water balance and aquifer storage.

Drought Analysis

The Standardized Precipitation-Evapotranspiration Index (SPEI) and the Standardized Groundwater Level Index (SGI) were used to analyze drought conditions. These indices consider both surface water and groundwater dynamics, providing a comprehensive understanding of drought impacts on the aquifer.

Result/Discussion

The analysis showed severe groundwater depletion in the Zaghouan region, mainly due to overexploitation from urban expansion. Despite occasional wet periods, recharge remained minimal. Statistical analysis confirmed a steady decline in groundwater levels, indicating a shift in hydrological patterns post-2011. Most of the study area exhibits moderate infiltration rates, with over 73% falling within the 40% to 42.5% range using the APLIS method, consistent with

previous reservoir modeling. Recharge for the aquifer was estimated at 207 mm, or 45% of the median year's rainfall. MEDKAM results supported this, showing a recharge volume of 162 mm, or 35% of median annual rainfall.

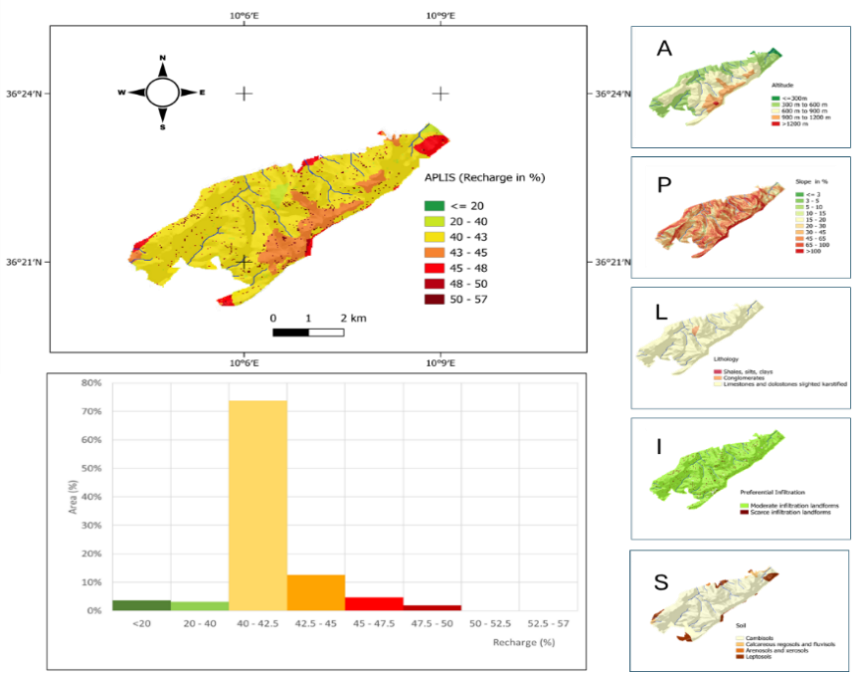

Figure 1: Groundwater recharge distribution by the APLIS

Conclusion

The assessment of the Jebel Zaghouan aquifer revealed severe groundwater depletion requiring urgent implementation of sustainable strategies to ensure long-term resilience. Although there were some measurement uncertainties, the APLIS method yielded consistent recharge rates, highlighting the need for further validation. Future strategies should focus on integrated monitoring, stakeholder engagement, adaptive management, and resolving conflicts related to urbanization and water use

Keywords: Karst Hydrodynamic, APLIS, SPEI, SGI, Drought

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GR-Or-03

Groundwater recharge estimation for Mornag aquifer using SWB code

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Introduction

In Northeastern Tunisia, the scarcity of water resources is a significant problem that is exacerbated by the effects of climate change. To address the risk of imbalance between water demand and supply, Tunisian water authorities are urged to explore new groundwater resources and improve their management. In water resources management the estimation of groundwater recharge is of great importance. Accurate estimation requires a good understanding of the hydrological processes in the studied area (Nolan et al., 2007). Choosing the right technique from the various available methods is always a challenging step, several factors need to be considered when selecting a groundwater recharge assessment method. The study area, Mornag aquifer (Northeastern Tunisia), is of vital importance for drinking water supply and agricultural irrigation; the intensive use of the aquifer levels threatens the sustainability of these waters. The estimation of aquifer recharge is a crucial issue for its sustainable management. The Soil Water Balance (SWB) code was chosen to assess the recharge of the Mornag aquifer. Satisfactory results in other study area are among the criteria for applying this model.

The Mornag plain is part of northeast of Tunisia, Ben Arous Governorate, covering an area of about 250 km^2 (Fig. 1). It is characterized by a semi-arid climate with an average temperature of 20°C and an average precipitation around 452 mm (1965-2022). The study area is bounded by the Mediterranean Sea to the north-east, the Jebel Bougornine structure to the east and the Rades and Megrine regions to the north-west. The plain is drained by the Oued Miliane, which flows from the southwest to the north, and Oued El Hma flowing from the south-east and reaching Oued Miliane in the centre of the Mornag plain. Geologically, the Mornag plain is a depression filled with fluvial-continental deposits of Plio-Quaternary age, consisting mostly of sand and clay over the majority of the aquifer.

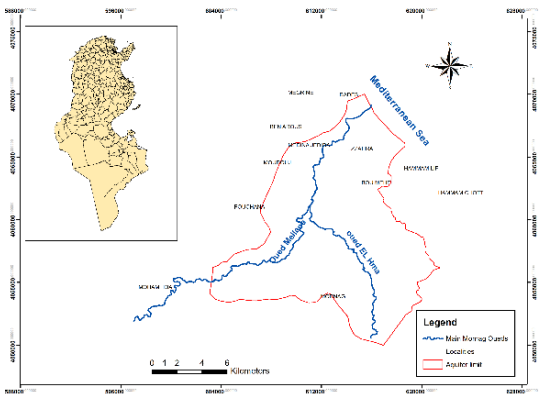

Figure 1: Study area

Methodology

The SWB is a computer code developed by the USGS (Westenbroek et al., 2010). It calculates groundwater recharge by using the commonly available geographic information system (GIS) data layers in combination with tabular climatological data. This code has no user interface, but only a control file with associated data. This code calculates the components of the water balance at a daily time step based on a modified version of the Thornthwaite-Mather approach (Thornthwaite and Mather, 1957) according to the following equation: $R = P\text{-}I + SN_{melt} + DR_{in} - DR_{out} - ET_{sm} - \Delta S$

Where R, P, I, SN_{melt}, DR_{in}, DR_{out}, ET_{sm} and ΔS correspond to recharge, precipitation, interception, snowmelt, direct runoff into the grid cell from upslope grid cells, direct runoff out of the grid cell, evapotranspiration, and change in soil moisture, respectively.

Result and Discussion

The simulated results from SWB model for the year 2005, showed recharge values ranging from 0 to 400 mm/year, with an average of 73.10 mm/year. It represents 15.3% of the annual precipitation. The spatial distribution showed that low recharge values are observed in areas with impermeable soil. Moderate recharge covers almost the entire aquifer as it is characterized by a low slope and the presence of dense vegetation cover and permeable soil (Quaternary alluvium). The Khledia hills, Jbel Tella, and the Bir El Kassaâ and Radès-Megrine hills play an important role in the recharge of this aquifer system they are considered as preferential zones for aquifer recharge.

Conclusion

Any rigorous assessment of groundwater resources requires effective estimation of groundwater recharge, this latter is the primary key for most of the approaches used to assess and manage the sustainable use of groundwater resources. For the Mornag aquifer, results highlight the significant contribution of precipitation to the recharge of the aquifer. It also underscores the importance of judiciously managing water resources and considering climate variability to ensure a reliable and sustainable water supply in the Mornag region.

Keywords: Groundwater recharge, Mornag, SWB, semi-arid climate.

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GR-Or-04

Precise delimitation of the 'SASS' reservoirs (Southern Tunisia). Well logging contributions

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Introduction/Objective

Southern Tunisia belongs to the Sahara desert, one of the driest regions of the world, where groundwater research is crucial to satisfy the water demand. Based on petroleum wells and their corresponding logging, the present study aims a better characterization of the Triassic-Miocene aquifer system in Tataouine-Medenine region in view to develop a water resources rational exploitation program.

Methodology

The study area is covered by 25 petroleum wells at depths 1000–4000 m, crossing the Triassic-Miocene formations. These wells contain, gamma ray, sonic, spontaneous polarization and resistivity logs, which allow for a precise delimitation of the 'SASS' réservoirs in Tataouine-Medenin région.

The gamma ray (GR) log is an excellent tool to distinguish between shales and non-shales because shales emit more gam ma rays than other sedimentary rocks (Bassiouni 1994). The sonic or acoustic logs measure the interval transit time (Δt) of an elastic wave through the formation. They can also be used to calculate seismic velocity (Desbrandes 1985). The sensitivity to changes in mineralogy and porosity make them a useful tool for lithological identification. High Δt values (low velocities) usu ally indicate shale and coal ; a middle Δt values specifies sand and evaporate, and a low Δt value marks carbonate (Rider 1996). The spontaneous polarization or potential (SP) and the resistivity logs, commonly recorded together, are widely used in determining the aquifer layers and the salinity of the formation water. The SP is a natural potential that appears opposite porous and permeable layers when the salinity is different between the interstitial water and the mud filtrate (Serra 1984). The mud filtrate is usually less saline than the water formation ; thus, a deflection towards the negative potential, to the left, occurs in the aquifers. The existing resistivity logs comprise the deep induction (ID or ILD) and medium induction (IM or ILM) measurements. The ILD is used to provide the uninvaded zone resistivity (Rt), whereas the ILM, which has a shallower penetration depth (Schlumberger 1989), gives the invaded zone resistivity (Bassiouni 1994). The ILD and ILM curves indicate the high resistivities of the permeable formation containing freshwater (Chapellier 1992 ; Cuddy and Glover 2000).

Result/Discussion

Well logs and lithological columns are used to precisely determine the position and composition of the known water reservoirs and to identify others able to produce good quality water. They show that the sandstone formations: Sidi Stout, Kirchaou and Touareg and the dolomitic formations : Mekraneb and Rehach are the main reservoirs of the Triassic aquifer system. The permeability of these reservoirs mainly depends on the degree of fracturing and the clay content. Their interconnection is limited by the gypsum and clay layers separating them.

The Jurassic aquifer layers consist of Krachoua limestones, Techout sandstones, and Foum Tataouine limestones and dolomites. These aquifers are important in the West and Southwest, and are rich in clays and evaporates, while towards the East and Northeast, they are progressively enriched in carbonates and their thickness decreases.

The lower Cretaceous aquifer system (CI) is a multilayer aquifer composed of Boulouha, Douiret, Chenini, and Oum Diab sandstones. The Boulouha and Douiret reservoirs are developed in the Southwest and are rich in clays, while towards the Northeast, they are progressively depleted in clays and their thickness decreases. The Chenini and Oum Diab sandstones gradually change to carbonate from south west to northeast without significant variation in thickness.

The Gattar limestones, Abiod limestones, Ain Ghrab limestones and Oum Dhouil sandstones are the main Upper Cretaceous-Miocene (CT) reservoirs.

Well logs analysis highlights many permeable layers that could play an important role in the groundwater circulation.

Conclusion

The present study yielded to interesting results that may contribute to a better management of groundwater resources in southern Tunisia. It can be also a reference of other scientific research dealing with the Northern Sahara Aquifer System (SASS). Moreover, this study can be an international reference of a successful use of petroleum data for hydrogeological purposes.

Keywords: ‘SASS’, Southern Tunisa, Triassic-Miocene formations, Well logging

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GR-Or-05

Hydrochemical and geophysical study of the spatial extent of marine intrusion in the Oualidia coastal aquifer, Morocco

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Introduction/Objective

Semi-arid regions face water stress due to climate change and intensive exploitation of groundwater resources, contributing to marine intrusion. This phenomenon represents a major challenge for the sustainability of water resources in these areas. This study aims to assess the spatial extent of marine intrusion in the Oualidia coastal aquifer in 2024.

Methodology

To achieve this objective, a geophysical methodology involving ETR electrical tomography profiles (positioned perpendicular to the shoreline), combined with hydrochemical analysis of 75 wells during July. These groundwater samples are distributed across the study area in such a way as to maintain a maximum mesh size of two kilometers. Statistical analysis was also adopted to check data homogeneity and correlations (figure 1).

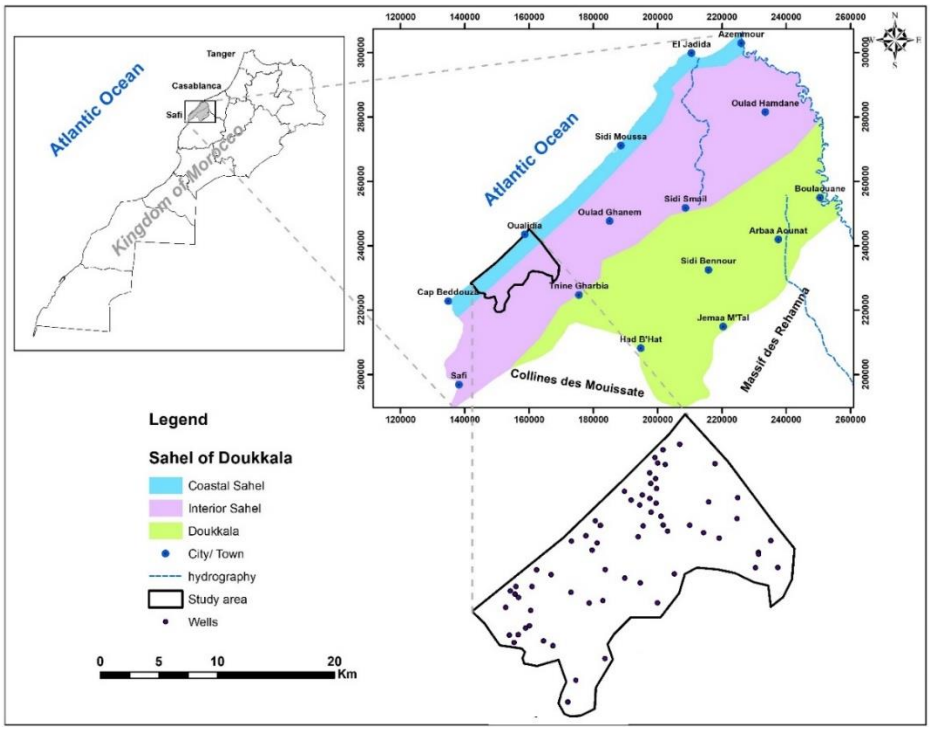

Figure 1 : geographical location of the study area

Result/Discussion

The results obtained from two tomographic profiles reveal the presence of a conductive layer characterized by a particularly low resistivity, below 45 Ω-m, indicating seawater intrusion. In addition, hydrochemical analysis of groundwater samples highlights that the area most affected by marine water is mainly located within the first kilometer of the ocean, showing high levels of electrical conductivity over 5 ms/cm as well as significant concentrations of Na^+ and Cl^- ions. As one moves away from this coastal zone, the degree of mineralization progressively decreases to reach much lower levels.

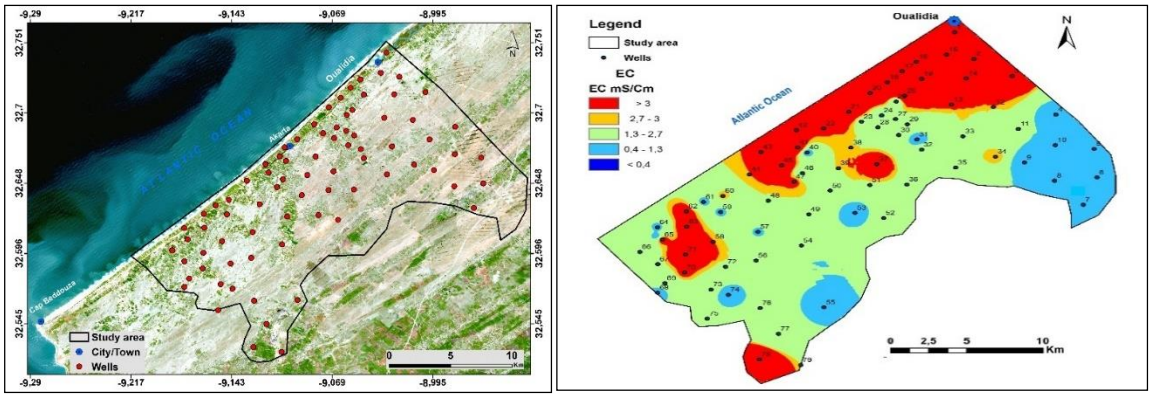

Figure 2 : distribution of wells in the area and spatial distribution of electrical conductivity EC

Conclusion

By integrating the data obtained from ETR tomography, hydrochemical analysis, and electrical conductivity values, it is established that the extent of mineralization in the region mainly influenced by marine waters is concentrated within the first kilometer of the ocean, suggesting a weak progression of the salt bevel towards the mainland compared with the results of previous studies.

Keywords: Groundwater, seawater, hydrochemistry, salt bevel, ERT.

GR-Or-06

Analyzing the Hydrodynamic Patterns of Zaghouan's Karst Springs: A Comparative Evaluation of ANN Models Using Historical Data

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Introduction/Objective

Karst aquifers, supplying 25% of global drinking water, are formed from carbonate rock dissolution and have complex flow paths, making them difficult to model (Ghasemizadeh et al., 2012). Hydrogeological models, whether lumped or physical, are essential for managing these resources (Jourdes & Wang, 2023). Artificial Neural Networks (ANNs), though considered a "black box," are increasingly used to improve karst hydrodynamic modelling without detailed knowledge of geometry. This study examines the Jebel Zaghouan karst system in Tunisia, assessing ANNs to better understand its hydrological processes. The research also evaluates the potential of ANNs to be applied to other karst systems under anthropogenic and climate pressures, contributing to sustainable management of these vital water resources.

Methodology

Data pre-processing

Historical data on rainfall, temperature, pressure, and discharge for the Jebel Zaghouan karst system from 1915 to 1944 were sourced from archives and hydrological surveys. Data preprocessing included scanning, OCR conversion, manual error correction, and standardization. Missing data were addressed using interpolation, conditional univariate distribution filling, and ANNs. Statistical analyses, including correlation coefficients, cross-correlation, and autocorrelation, were conducted to explore hydrological dynamics and relationships.

ANN Modelling

Three ANN architectures—MLP, CNN, and LSTM—were tested with hyperparameters fine-tuned using Bayesian optimization, grid, and random search. The data was split into 70% training, 15% validation, and 15% test sets. Models were trained on the training set, with validation set performance used to prevent overfitting. Model effectiveness was evaluated using MAE, RMSE, NSE, and cross-validation to determine the best architecture for simulating hydrological processes.

Result/Discussion

The three models reproduced the karst dynamic (Figure 1). However, the MLP and CNN overestimate the discharges. The best model is LSTM. It reproduces the dynamic and the discharges. Indeed, this model presents the best highest coefficients: KGE= 0.67; NSE= 0.42 and R^2=0.59.

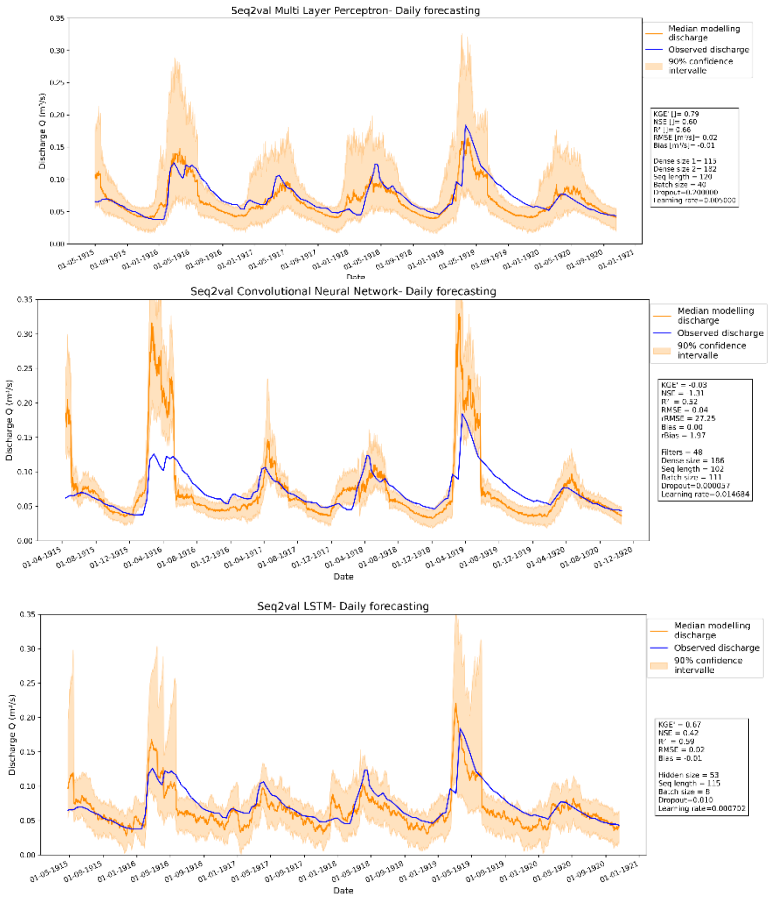

Figure 1 : Test set at daily scale from (a) MLP (b) CNN and (c) LSTM models

Conclusion

This study reveals that the lag time between rainfall and discharge in the Jebel Zaghouan karst system varies from 4 to 6 months, emphasizing the need for long-term monitoring. Daily scale data is crucial for capturing short-term variations, while LSTM models excel on a weekly scale, effectively handling temporal dependencies. ANNs prove reliable for forecasting and modeling complex karst hydrology, highlighting their potential for improving future hydrodynamic models and sustainable water resource management.

Keywords: Karst Hydrodynamic, Artificial Neural Networks, Long Short-Term Memory

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GR-Or-07

Surface water quality for irrigation and dominant hydrogeochemical mechanisms in a Mediterranean wetland ecosystem, North-East Algeria

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Introduction/Objective

The Fetzara Lake is one of the most important wetlands of the extreme northeast of Algeria. It is located 18 km southwest of the city of Annaba, covers an area of about 18600 hectares, it extends over a length of 17 km and a width of 13 km. In 2002, it was officially classified as a wetland of international importance by the "Ramsar" convention. The waters in its watershed are affected by salinity, which influences their suitability for irrigation. The aim of this study is to determine the chemical elements responsible for spatio-temporal variations in water quality in all tributaries of the Lake Fetzara watershed, and to assess the suitability of these waters for irrigation purposes.

Methodology

In order to identify the factors influencing the quality of these surface waters in the Lake Fetzara watershed, geochemical and statistical analyses were carried out on the basis of the results of chemical analyses of 51 samples taken, during two monitoring campaigns (Februry and November), from the tributaries of the watershed that supply Fetzara lake, as well as from the main drainage channel and the wadi Meboudja that drain the lake.

The hydrogeochemical characterization and evaluation of irrigation suitability for surface waters in the Lake Fetzara watershed employed a multifaceted approach, integrating graphical techniques, multivariate statistical analyses, and geochemical indices. This comprehensive methodology aimed to elucidate dominant facies, hydrogeochemical processes, and water quality parameters relevant to agricultural applications and environmental management.

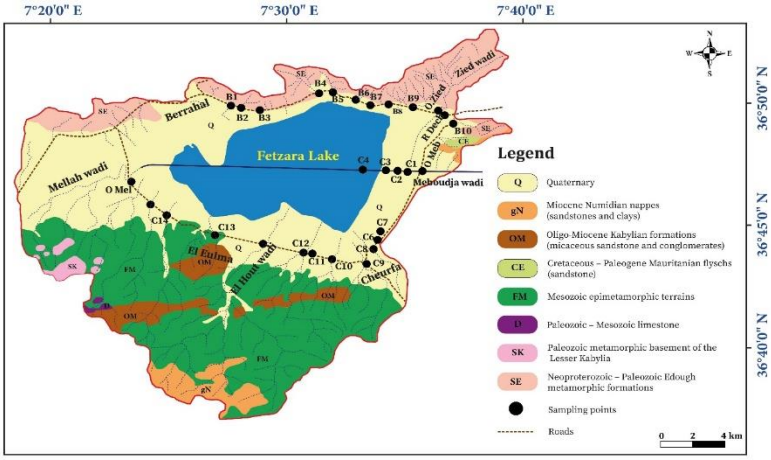

Figure.1 Geological map with sample location points of Fetzara lake watershed (Vila, 1978)

Result/Discussion

Multivariate statistical analysis (PCA), conventional graphs and irrigation water quality indices, applied on surface waters of the Fetzara watershed, identified three distinct water categories: highly mineralized waters with Na-Cl facies in the downstream areas, weakly mineralized oxidizing waters, and moderately mineralized waters influenced by local geology with Ca-Mg-Cl and Ca-Mg-HCO_3 facies. This categorization reflects the complex interplay of evaporation, lithology, and hydrological processes characteristic of Mediterranean wetlands in shaping water chemistry. The observed salinization, affecting both surface and groundwater, poses risks to soil quality in irrigated areas (Zahi et al., 2022), a phenomenon observed in other Mediterranean wetlands. Temporal variations in water quality, particularly at the lake outlet, underscore the need for careful management of irrigation practices, especially during the Mediterranean dry seasons (Djitli et al., 2021). While this study provides valuable information on the mechanisms controlling the hydrogeochemistry of the Fetzara wetland, it has limitations in temporal resolution, spatial coverage, and consideration of anthropogenic influences, ecological impacts, and climate change effects on this Mediterranean ecosystem (Leberger et al., 2020). Comparisons with other Mediterranean wetland studies highlight both common challenges and unique features of the Fetzara wetland. The results of this study provide a crucial baseline for future research and management strategies in Mediterranean wetlands. In addition, it identifies key areas of concern, particularly salinization trends and their potential impacts on irrigation practices, which are essential for preserving the sustainable management of water resources in this Mediterranean wetland.

Conclusion

This study revealed the existence of three distinct chemical facies groups in water samples from two campaigns: Na-Cl facies (55.17% and 22.73% of the samples), Ca-Mg-Cl facies (27.59% and 40.91% of the samples), and Ca-Mg-HCO_3 facies (13.79% and 36.36% of the samples). The prevalence of Na^+, Cl^-, and SO_4^{2-} in the water is attributed to mineral dissolution, potentially generated by water evaporation and the dissolution of evaporite formations in the southern part. Conversely, the presence of Ca^{2+}, Mg^{2+}, and HCO_3^- is linked to silicate weathering in the Edough region and surrounding carbonate formations.

Multivariate statistical analysis (PCA) identified three water types: highly mineralized, weakly mineralized and moderately mineralized waters. The study of irrigation water suitability, using various indices (SAR, %Na, RSC, and KR), revealed that water from the majority of the tributaries (64.71% of samples) has acceptable quality for irrigation. However, a slight degradation in water quality was observed during the second campaign, especially at the lake outlet, where 36% of the samples were deemed unsuitable for irrigation. The use of such water for irrigation could adversely affect the quality of irrigated soils.

Keywords: Water quality; Hydrogeochemical mechanisms; Irrigation purpose, Wetland.

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GR-Or-08

Hydrogeological Significance of Mediterranean Geoparks In the Framework of the UNESCO IGCP-730 Project

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Introduction/Objective

Mediterranean geo-heritage sites are variable in their related water sources conditions due to humanity careless actions and climatic changes. They are enriched by spring complex system emerging through geological complex stratigraphy. The majority of them are still in use in their cold and thermal temperature kinds. The spring water suitability is influenced by different geological, climatic change and hydrogeological factors. The water cycle evolution that affected the interactions of the Geopark sites to their related hydrogeological aquifers has to be determined to address their water availability and affordability.

Methodology

The project will focus on the hydrogeological settings of the Geoparks water in the Mediterranean countries of Tunisia, Morocco, Spain, Palestine, Jordan, and Egypt. The study will bring results in the water resources management integration from quantitative and qualitative point of views. The hydrogeological complex settings around their water sources will be determined in order to check their potentiality for initiating Geological touristic bases for strengthening the Geopark's role in their societies. The project will focus to topics addressing critical issues for the future sustainability: Water provision issues associated with climate change: hydrogeological water availability, groundwater quality and health. The innovative project results will support in achieving global water sustainability.

Result/Discussion

These results are part of the project "Hydrogeological significance of Mediterranean Geoparks (IGCP-730)" funded by UNESCO's Geological Sciences Program, which plays an important role in the conservation of the geoheritage due to their scientific and touristic interest.

Conclusion

The project Hydrogeological significance will be impacted in increasing the awareness of the local population and decision makers regarding the need for sustainable use and management of geoheritage sites in particular for the benefit of local socio-economic sustainable development targets through the promotion of both geotourism and the creation of unique geoparks. In regards to their cultural design and structural similarities reflecting the ancient civilizations settled in different geographical areas around the Mediterranean, there are variability of hydrogeological significances to their used water sources. These sites and fountains are preserved against climatic change resistance and strugling against the damage caused by humans. The water resources sustainability per time is a function of hydrogeological variables. The geological outcropping as well as hydrogeological processes reflecting the emerging of the springs image. The springs are playing the based important element for the first thinking of settlement of ancient civilizations. The spring water sources are different from place

to place according to geological and hydrological parameters. The weathering processes reflecting the natural changes for the geological outcropping around these springs. The climatic change parameters cause the variability of springs discharge per time. The human activities around these water resources cause negatively qualitative changes. The effect of climatic change to the underground resources is the major objective of the research hydrogeological-heritage proposal. The hydrogeological phenomena of the water sources heritage sites in the targeted countries will be defined and characterized from quantitative and qualitative point of views. This will be identified through hydrogeological and water quality assessments through Groundwater modeling techniques. This will bring results to the integrated water resources management of the water sources geoheritage around the geocultural study areas. The natural and human effects will be determined in order to create a protection base policy that will help the decision makers in the management planning of increasing the geotourstic volubility of these sites. This will increase the society cohesion to these sites. It is an interdisciplinary project combining Geology, hydrogeology, Geography, Environmental Science and geocultural heritage. The project makes a major contribution to informal and formal geo-education by sharing scientific, historical and geocultural knowledge, skills and values with students and teachers.

Keywords: Hydrogeologyl, Mediterranean Geoparks, Springs, Geocultural Heritage.

GR-Or-09

Multi-tracer and isotopic investigation of seawater intrusion in the Lebna plain (Cap-Bon, Tunisia)

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Introduction/Objective

The Korba aquifer in Northest Tunisia, a characteristically overexploited Mediterranean coastal aquifer, is experiencing severe groundwater depletion due to intensive pumping and recent drought (2020-2024). This study focuses on the Plio-Quaternary plain downstream of the Lebna dam, particularly vulnerable to seawater intrusion in the first kilometers, causing a qualitative deterioration of the groundwater.

Methodology

The aim of this study is to characterize the current hydrodynamic state and salinization processes in this region, considering the influence of seawater intrusion and recharge from the Lebna Dam. A multi-tracer approach, encompassing piezometric monitoring, geochemical analyses, and stable isotope composition studies ($\delta^{18}O$, $\delta^{2}H$), was employed in the Lebna region from 2019 to 2023.

Result/Discussion

Piezometric data revealed significant drawdown in the Plio-Quaternary aquifer downstream of the Lebna Dam, suggesting influence from both the Lebna Wadi and the Mediterranean Sea, indicative of saltwater intrusion.

Geochemical and isotopic analyses were utilized to assess the impact of marine and Lebna Wadi estuary saltwater intrusion on groundwater quality. Waters exhibited a shift towards sodium chloride and calci-sodium chloride-sulphate facies, with increasing chloride and sodium concentrations seaward. Mineralization patterns aligned with groundwater flow, and high electrical conductivity (up to 9.7 mS/cm) indicated significant marine influence. Statistical analyses (PCA and HCA) supported these findings. The isotopic analysis identified three distinct groundwater types: 1) less evaporated groundwater, the 2) groundwater aligned with the evaporation line , likely influenced by the recharge from Lebna Dam, and 3)groundwater enriched in oxygen-18 and deuterium, indicative of seawater intrusion.

Conclusion

The main contribution of this work is to highlight the role of the Wadi Lebna estuary in the salinization of the coastal aquifer near the Lebna dam. In fact, a recharge area from the Wadi is defined, where the water has salinity levels significantly higher than that of seawater. Additionally, this study revealed a piezometric drawdown of -9 m.a.s.l, indicating that the influence of marine intrusion extends more than 3 km from the sea.

Keywords: seawater intrusion; hydrochemistry; aquifer salinization; coastal aquifer; climate change; Lebna Dam.

GR-Or-10

Optimization of the strategy for exploiting underground water resources at the University of Bondoukou site (north-east of Côte d'Ivoire)

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Introduction/ Objective

Faced with a crucial drinking water supply problem, Côte d'Ivoire is putting in place solutions to meet the needs of its population. As part of the university decentralization program (PDU), the government has invested in infrastructure to improve living conditions for students, in particular access to drinking water and electricity. In Bondoukou, a new university has benefited from 13 boreholes to supply its population. Assessing the aquifers exploited is therefore essential to ensure sustainable management of groundwater resources. The aim of this study was to propose a strategy for the optimal management of groundwater resources for the supply of drinking water to the people who will be using the University site in the town of Bondoukou (north-east of Côte d'Ivoire). The specific objectives are firstly, to identifying the type of underground aquifer, then assessing the hydrodynamic and hydraulic parameters using the Pumping Interpretation Assistance Tool (OUAIP). Secondly, to estimate the practical scope of productivity using geostatistical analysis and kriging of the transmissivity of the aquifers tapped. Finally, to strategize for optimizing groundwater production was simulated on the basis of the intrinsic properties of a productive borehole layout to cover the progressive programming of the drinking water consumption needs of the population living on the University site.

Methodology

The methodological approach consisted, firstly, of identifying the type of aquifer on the basis of stratigraphy, and secondly, assessing the hydrodynamic and geological parameters based on stratigraphy, followed by an assessment of the hydrodynamic and hydraulic parameters hydraulic parameters using the pumping interpretation support tool (OUAIP) and then estimating the productivity regionalization through geostatistical analysis and kriging of the transmissivity of the transmissivity of the ten aquifers tapped. Finally, a strategy for optimizing the groundwater production was simulated based on the intrinsic hydrodynamic properties of a drilling of a productive borehole and the progressive programming of coverage of the drinking water consumption drinking water needs of the population living on the University site.

Results/Discussion

The results show that ten of the boreholes tap discontinuous aquifers containing confined groundwater. These boreholes deliver an average flow rate of 6.81 m^3/h of groundwater from aquifers characterized by an average specific flow rate of $0.53 m^2/h$ and an average transmissivity of $2.63 * 10^{-4}$ m^2/s. The geostatistical analysis depicted that transmissivity behaves as a regionalized variable with a practical range of no more than 150m. From the optimization simulation, the results showed that it is not necessary to operate all the boreholes

on the site simultaneously however, to choose a single borehole identified as F17 operated at a flow rate of 12m^3/h for 12 hours each day to cover the water needs of the people who will be attending the University of Bondoukou for the first five years.

Conclusion

The study concludes that ten boreholes tap discontinuous, confined aquifers, with an average flow rate of 6.81 m^3/h and a specific flow rate of 0.53 m^2/h. Transmissivity, regionalized over 150 meters, has an average of $2.63*10^{-4}$ m^2/s. Optimization simulations show that it is not necessary to operate all the boreholes simultaneously. Borehole F17, operating at a flow rate of 12 m^3/h for 12 hours a day, can cover the water needs of the University of Bondoukou for the first five years. In this way, the operating optimization strategy is helping to make considerable savings on the initial cost of the drinking water supply budget for the university site.

Keywords: aquifer, transmissivity, drinking water supply (DWS), Bondoukou.

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GR-Or-11

Application of multiple approaches to investigate the hydrochemistry evolution of salt in an arid region, sabkha En Noual, Southern Tunisia

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Introduction/Objective

In a closed basin under an arid climate, several factors contribute to the accumulation and distribution of evaporites, including climate, surface and groundwater connections, and the types of rocks present (Wood et al, 2002, Warren, 2010). Furthermore, the accumulation of salts directly affects surface and groundwater as well as the nearby recent terrains surrounding the Sabkha. An investigation of major ions in 34 water samples was performed using graphical methods, ionic ratios, and geochemical modeling. This study aims to understand the processes responsible for the accumulation of salts in the depression considering the hydrological, and hydrogeological conditions.

Methodology

Sabkha En Noual is a high saline basin, with an area of approximately 154.2 km^2, situated in the south of the governorate of Sidi Bouzid. The annual average rainfall and evapotranspiration reach 220 mm and 1397 mm/year respectively. Thirty-four samples were conducted in 2019. The chemical composition of groundwater resources, as well as water-rock interactions and ion exchange processes, were assessed using ionic ratios, correlation analysis, Gibbs diagram, and Piper trilinear diagram. Ion speciation and saturation indices were assessed using the USGS program, PHREEQC v3.3.7 (Parkhurst and Appelo, 1999) along with the Pitzer database (Pitzer, 1973). Simulations determine mineral precipitation sequence in the catchment area of the sabkha.

Result/Discussion

Shallow aquifers, situated in Plio-Quaternary geological formation, show the highest value of salinity whereas deep groundwaters, located generally in carbonate formations, present the lowest value of salinity variations. The TDS value of meteoric and sabkha samples ranged from 64820 mg/l to 87284 mg/l. Water samples are classified into three hydrochemical groups: recharge area (Na-K-Cl-SO_4), saline depression (Na/K-Cl), and deep groundwater (Ca-Mg-Cl). The saturation index values showed that the sabkha was supersaturated with bloedite ($Na_2Mg(SO_4)_2$ $4H_2O$) and Goergeyite ($K_2Ca_5(SO_4)$ $6H_2O$. The results of the mixing simulation under evaporation conditions indicate that the sabkha geochemistry consists of a mixture of groundwater, deep aquifer water, and meteoric water. The application of graphical methods, ionic index and geochemical modeling provided a first comprehensive understanding of the hydrochemical characteristics of sabkha En Noual. The most important hydrogeochemical

processes that control brine evolution in the sabkha along the flow path are evaporation, gypsum dissolution, mixing and ionic exchange on clay minerals.

Conclusion

The hydrogeochemical analysis indicates that water chemistry is controlled by water-rock interactions, evaporation, the dissolution of evaporites, and ionic exchange. Modeling results from PHREEQC show that bloedite is the predominant salt mineral in the sabkha, at approximately 80 kg/m³, followed by Goergeyite, which ranges from 2 to 4 kg/m³. Future studies will focus on additional experimental and field studies to explore the processes that govern the chemical composition of water in the Sabkha El Noual catchment area and to evaluate the overall reserves of precipitating minerals during brine evolution.

Keywords: arid climate, brine, sabkha, geochemistry, evaporation

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GR-Or-12

Modeling Approach to Groundwater Processes and Pollution: A Hydrogeochemical Assessment of the Grombalia Aquifer in Northeast Tunisia

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Introduction/Objective

The Grombalia region's groundwater Northeast of Tunisia, has been extensively studied, particularly its geochemical and isotopic composition. Research has focused on natural water-rock interactions and the anthropogenic impacts of irrigation water returning to the aquifer, contributing to water salinization (Ben Moussa et al. 2010). This study aims to build on previous research by examining the hydrogeochemical processes (such as mineralization, alteration, and pollution) and human activities that influence groundwater quality in the Grombalia region using various methodologies.

Methodology

Several approaches were applied to achieve our goals, namely: multivariate statistical analysis (principal component analysis (PCA) and cluster analysis (CA)), visual interpretation diagrams (Piper, dispersion), calculation of several indices (hydrogeochemical chloro-alkaline index (CAI), groundwater pollution index (GPI) and nitrate pollution index (NPI)), and mapping using a geographic information system (GIS).

Result/Discussion

The findings indicate that the chemical element concentrations in most samples surpass WHO standards. The groundwater, characterized by a Cl–Ca–Mg hydrochemical facies, results from a mix of natural and human-induced processes. Multivariate statistical analysis, including principal component analysis, Pearson correlation, and hierarchical cluster analysis, identified agricultural activities and the dissolution of evaporitic formations as primary factors affecting groundwater chemistry.Additionally, the nitrate pollution index (NPI) shows that most groundwater samples are highly polluted (NPI > 3), likely due to anthropogenic activities such as irrigation water return and untreated urban waste (Fig.1). The suitability of groundwater for drinking was assessed using WHO guidelines and the Water Quality Index (WQI), revealing that the Grombalia aquifer has poor to very poor water quality for drinking purposes (Fig.2).

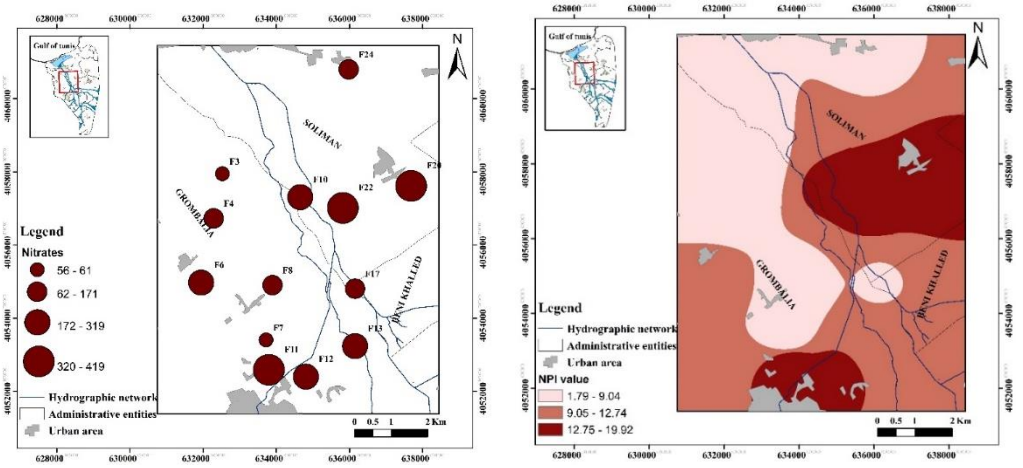

Figure.1 Spatial distribution of **(**A) Nitrate, (B) NPI

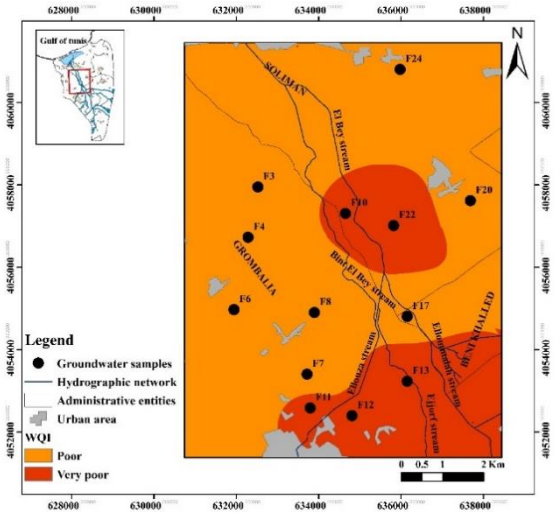

Figure. 2 Spatial distribution of Water quality index (WQI) in the Grombalia aquifer

Conclusion

These data suggest the impact of human activities as well as natural processes on groundwater quality. This work will help the public understand groundwater quality and assist decision-makers in developing strategies for the sustainable management and protection of the Grombalia shallow aquifer from pollution.

Keywords: Hydrogeochemistry, Groundwater, Factorial analysis,Water–rock interactions, Nitrate contamination, Grombalia

Acknowledgements This research was supported by INWAT project, PRIMA section 2.

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Groundwater Management and Surface Water Monitoring and Groundwater Recharge

Poster

GR-Po-01

Hydrogeophysical study of the relationship between the Sfax and Regueb aquifers in the Tunisian Sahel (Mediterranean arid region)

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Introduction/Objective

The Sfax aquifer called the «deep» of the Upper Miocene and its continuity relationship with the Regueb aquifer have always raised the question of fossil or recharged aquifer and what they are its recharge zones, in particular its northwestern and western parts.

This research article aims to study the relationship between Regueb's aquifer and the Sfax one in the Tunisian Sahel based on geological, hydrogeological, and hydrogeophysical (seismic and gravity) approaches. The outcomes of this research clarify and give a deep understanding of this relationship to contribute to the sustainable management of groundwater potential in this region.

Methodology

The methodology of this study consists of geological, hydrogeological, and geophysical data such as the water and oil wells, seismic and gravity data consecutively to reveal the relationship between the Regueb deep aquifer and the Sfax one. In addition, we use software such as Corel Draw, Oasis Montage, ZondGM3D, Surfer, and ArcGIS to process and generate the needed maps.

Result/Discussion

The Segui formation of the Plio-Quaternary age is correlated with the water well (W1) with a sounding depth of 800m and the other oil wells, and also the Oum Douil formation of the Middle-Upper Miocene demonstrates the thickness and the spread of the formation throughout the study area. The relationship between the Regueb and Sfax aquifers is linked to the tectonic inversion of an ancient Cretaceous horst. Further, the Regueb aquifer is related to folding while the Sfax aquifer is related to faulting. The outcome of gravity shows the amplitude tendency of the study area. Major lineaments direction NE-SW, N/S, and minor lineaments direction N/S, NE-SW, E/W, and SE-NW. The piezometer sense goes from Regueb's deep aquifer towards Sfax.

Conclusion

The interpreted seismic profile reveals subsurface geological structure, and the faults networking, and highlights the extension of the Mio-Plio Quaternary aquifers. Lithostratigraphic correlation proves the Segui formation is the thickest and spreads throughout Regueb's aquifer and the Sfax one. The gravity filters show lineaments' directions and location and disclose the hidden faults and their subdivision. The relationship between both aquifers is a recharge relationship, Sfax's aquifer is the recharged aquifer from the Regueb one due to the high altitudes and the piezometric level.

Keywords: Regueb, Sfax, Tunisian Sahel, Seismic, Gravity, aquifers, Hydrodynamic.

GR-Po-02

Geophysical Characterization of Karst Aquifers in a Semi-Arid Environment: A Case Study of the El Houdh Basin (Northwestern Tunisia)

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Introduction/Objective

In Tunisia, karst systems represent a significant water resource of economic interest. The complexity of karst hydrosystems leads to a lack of knowledge that limits their exploitation. A geophysical approach was applied in the El Houdh basin (central Tunisia, Mediterranean basin) to map the structure of a tectonically controlled aquifer system in a semi-arid region where the demand for water for agriculture and mineral water bottling plants is increasing. TDEM (Time-Domain Electromagnetic Method) and ERT (Electrical Resistivity Tomography) data were used to image the saturated and unsaturated karst zones by studying the relationship between the Epikarst and the endokarst.

Methodology

The complete survey consisted of 19 TDEM soundings and 2 ERT profiles calibrated with outcrop and borehole data. Based on the 1D inversion of the TDEM soundings, we propose to study the lateral resistivity distribution through 5 cross-sections that intersect the El Houdh basin (Northwestern Tunisia) to explore the different exposed Eocene formations and the Quaternary deposits at depth. Electrical resistivity tomography measurements were conducted to better visualize and assess, in high-resolution 2D, the extent of fractured Eocene limestones and the Epikarst/endokarst relationship.

Result/Discussion

The 1D TDEM technique was primarily used to locate the unsaturated karst zone associated with the high-resistivity layer corresponding to the Epikarst. Additionally, we located the transition zone and the saturated zone corresponding to the endokarst due to the decrease in limestone resistivity caused by the presence of water.

The 2D models reveal the surface hydrogeological aspects within the Houdh basin. The resistivity disparities can be used to delineate the potential of the aquifer system in the Houdh syncline and the recharge and discharge zones of this aquifer, thereby improving the understanding of infiltration processes. The NE-SW ERT 1 and ERT 2 electrical profiles, located respectively on the flanks of Jebel El Houdh and Jebel Gabli, provided a finer characterization of the aquifer geometry and confirmed the results obtained by the 1D and 2D TDEM methods.

Conclusion

The TDEM approach has proven to be a rapid and reliable method for estimating the resistive layers and characterizing the geometry of karst aquifers in semi-arid environments. By mapping both the lateral and vertical variations in electrical resistivity, we could delineate the preferential pathways for deep infiltration and understand the relationship between the Epikarst and Endokarst in the El Houdh region. The integration of 2D Electrical Resistivity Tomography (ERT) provided a more detailed characterization of the aquifer's geometry, confirming and expanding upon the results obtained with the TDEM method. These findings enhance our understanding of karst aquifer systems in tectonically active regions and provide a valuable framework for the sustainable management of water resources in semi-arid environments.

Keywords: Karst; TDEM; ERT; Aquifer; Tunisia.

GR-Po-03

Modelling Dam - aquifer exchanges under climate change: Impact of Dam construction on groundwater recharge of Lebna plain downstream (Cap Bon, Tunisia)

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Introduction/Objective

Climate change combined with increasing human activities, is significantly impacting coastal aquifer systems worldwide, particularly, in the Northeast Tunisia. In the Lebna watershed, the human activities are manifested by high agriculture and hydraulic constructions. Since the Lebna dam building in 1986, its reservoir has contributed to groundwater recharge through leakage in the sand and sandstone layers along the lake's banks (Ouhichi et al, 2022). While numerical groundwater models are essential for sustainable long-term groundwater management under changing future scenarios, few studies investigated the modelling of dam-aquifer interactions.

Methodology

In this study, Modflow code was used to understanding the aquifer evolution and assess the impact of Lebna lake leakage on aquifer recharge. The Lebna Dam - aquifer exchanges modelling was established taking in account the piezometric monitoring of 181 wells covering a 5-year period (2019-2023), the results of 69 SEVs, and 10 pumping tests carried out in the region.

Result/Discussion

The model boundary conditions are principally influenced on one end by the varying Lebna Dam water level and on the other end, by the Mediterranean Sea, which impose fixed head boundaries (h=0m).The hydrodynamic behavior of the water table was significantly correlated to the recharge on the Northwestern side of Lebna Dam. Steady-state modelling confirmed that the dam leakage value was related to the water altitude in the Dam. Under scenario-1 (before the Dam construction), computed groundwater flow was estimated at approximately 2.2 Mm^3/year. In contrast, under scenario-2 (an average dam level of 16.3 m.a.s.l), total flow increased to 4.1 Mm^3/year.

Conclusion

In the latter scenario, the Lebna Dam contributed approximately 1.9 Mm^3/year to upstream aquifer recharge. The rise in dam level also led to a piezometric rise downstream, concentrated along the right bank, exceeding 12 m locally. The average volume of Dam leakage can be reduced by several factors including increased water demand in upstream basin, or/and a decreased rainfall.

Keywords: Climate change; groundwater rise; human activities; Lebna Dam; modflow.

GR-Po-04

Mapping regional discontinuities and identification of their role in underground fluid flow in reservoir: case study of the of Sidi Jdidi region (North-Eastern Tunisia)

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Introduction/Objective

Outcrops of fractured hard rock in Northeastern part of Tunisia provides a fundamental environment for studying recent tectonics and its role in fluid flow functioning of fractured reservoir. In the Bouficha region, particularly in the Sidi Jdidi city, outcrops of fractured hard rock of the Ain Grab formation characterize the area. Indeed, fracturing can enhance the quality of a reservoir. This study aims to investigate a methodology to map regional discontinuities in this formation, based on a measurement of fractures in the field, to assess if they play a noticeable role as groundwater flow paths or oil and gas reservoir.

Methodology

The visited outcrops are located in Northeastern of Tunisia (Sidi Jdidi region). Our study area requires a well-defined methodology for conducting a detailed study on fracturing. This methodology includes the following Steps:

-Adaptation of a specific sampling method: In our case, we will use the linear method, consisting of a decameter throughout the process.

-Measurement of fractures in the field using a compass: Measurements include orientation, direction, dip, type of filling, etc (Fig.1). All measurements will be recorded on a fracture note sheet.

-All measurements will then be displayed on software that allows the display of fractures according to their frequencies. For example, we can mention the Grapher software, which is a scientific graphics software that enables the user to import data in many formats, create and combine a wide variety of 2D and 3D plot types, and customize plots with an infinite number of details.

-For qualitative analysis, we will use Win Tensor software, which allows us to display the measurements obtained from the field on a grid to display the stress tensor appropriate to each study area.

-Establishment of a chronology of deformation events with the results obtained by following a logical scenario.

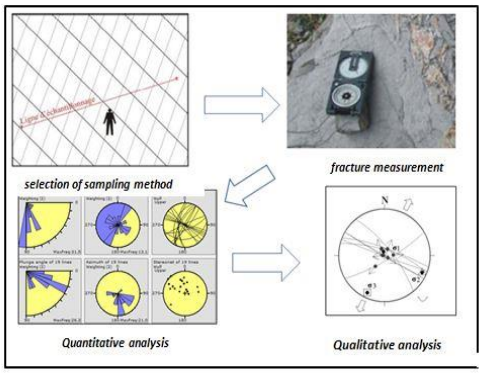

Figure 1: The steps involved in conducting a fracturing study in a given study area.

Result/Discussion

Several fracture families affect the study area: N50, N30, N120, N130, N150 and N-S (Fig.1). Following the interpretation of the various measurements taken in the study area and verification of the different formations in the two flanks of the Jebel Harbi-Jebel Menchar anticline, we note the absence of the Korbous term of the Fortuna formation in the SE flank and the absence of the Messiouta formation in the NW flank. We can clearly explain the syn-sedimentary control of these deposits by the N50 fault, consistent with the distensive regime that characterizes this period. During the Oligocene-Serravallian, NE-SW distension reactivated the N50 fault in normal play, causing thickness variations on either side of the fault. This distension also activated the N120 fault in normal play, which explains the existence of microtectonic evidence of this fault in the Korbous and Haouaria formations. During the Tortonian, atlasic compression reactivated the NE-SW reverse strike-slip faults, setting up the Sidi Jdidi folds. In addition, this compression reactivated the N120 fault, which caused the thickness of the Ain Grab formation to vary in the study area. However, during the Plio-Quaternary, Villafranchian compression reactivated the NW-SE faults in play with an inverse component, as can be seen in the Ain Grab formation, where the NW-SE fractures always offset the NE-SW fractures. This compression has accentuated the NE-SW folds. Quantitative analyses have shown that (i) the Ain Grab Formation was affected by fractures whose two dominant directions are NW-SE and NE-SW (ii) the N120 map fault played a role at the time of deposition of the Ain Grab Formation (iii) NW-SE fractures are the most recent and were reactivated during a major tectonic phase. Qualitative analyses show that the Ain Grab Formation was affected by two major compressive tectonic regimes that were responsible for the reactivation of NW-SE and NE-SW trending fractures in the Sidi Jdidi area. The microtectonic evidence of the N120 and N50 faults at JEBEL Harbi indicates that these faults played a normal role during the Lower Oligocene, with the synsedimentary control of the Fortuna formations on the SE flank and the absence of the Messiouta formation on the NW flank being ensured by the N50 fault. During the Tortonian, reactivation of the N120 fault-controlled sedimentation of the Ain Grab formation in the Sidi Jdidi block, and during the Plio-Quaternary, reactivation of the NE-SW and NW-SE faults accentuated folding in our study area. An economic interest of this work is that these well-localized dense fracture zones located in often subtle zones of dip changes of folded horizons could have a major influence on the dynamic properties of folded reservoirs. Articulation related fracture zones could be expected to act as good parallels to axis fluid drains. Further works allowing to predict the presence and the location of these articulations in folded and fractured reservoirs could thus be very helpful in defining fluid flow models in fractured reservoirs.

Conclusion : This study focused on the Ain Ghrab formation through the study of fracturing, which is concerned with how fractures in rocks influence the movement and storage of fluids. This analysis can be indispensable for groundwater or oil and gas reservoir. Using the data obtained from this study of the Ain Ghrab formation to identify and analyze surface fractures, and integrating seismic data from wells operating in the region, we can image fractures at depth, leading us to establish a fluid flow model and a detailed understanding of fracture networks.

Keywords: Ain Grab formation, Microtectonics, fractures, quantitative analysis, qualitative analysis, North-eastern Tunisia.

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GR-Po-05

Deep structure of the Mesozoic series in Southern Tunisia. Hydrogeological Implications

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Introduction/Objective

This study aims to reconstruct the geometric configuration of the Mesozoic series in Southern Tunisia focusing on the aquifer levels they contain. This reconstruction represents a major step in understanding the system aquifer functioning. The identified structures can play an important role in the relationships between hydrogeological units and may allow for a better understanding of groundwater circulation.

Methodology

Both surface and subsurface data were used. Surface data consists mainly of results deduced from previous structural and sedimentological studies based on outcrops observations, whereas subsurface data includes water and petroleum boreholes as well as 2D seismic reflection profiles.

The lithological logs were correlated according to different directions to approach the Mesozoic series geometry by following their lateral evolution. The established correlations are not sufficiently precise to define the tectonic structures in Mednine-Tataouine region, hence the need exploitation of seismic reflection data. The seismic interpretation was made easier by using SMT software. Seismic calibration was performed using the relation of time and depth in petroleum wells. Then, the reflectors corresponding to the Triassic, Jurassic, Lower and Upper Cretaceous were identified and picked on seismic profiles all over the area. The correlation between the interpreted profiles achieved to isochrone, isobath and isopach maps.

Finally, a synthetic block diagram integrating available geological data and seismic interpretation has been elaborated to elucidate the influence of the reconstituted geometry on the Mesozoic aquifer system functions and characteristics.

Results and Discussion

The correlations of the lithostratigraphic logs have provided important results regarding the distribution of reservoirs, as well as variations in their thicknesses, facies and depths.

The Triassic series is complete, thick, deep, and rich in clays as it extends from the West to the East of the Jeffara domain. Along the eastern sector of the Dahar domain, the Upper Triassic is absent, and its base describes high and low zones. In the western sector of this domain, the Triassic series is reduced, and it is primarily its basal part that is missing. These formations decrease in depth and thickness until they disappear in the direction of Tebaga of Médenine.

The Jurassic deposit depths and thicknesses decrease towards the Tebaga of Medenine Permian outcrop, which reflects the Hercynian orogeny phase effect on the study area. The absence of the Jurassic deposits in the Jeffara domain can be explained by erosion due to domain uplift

caused by the Barremian or Upper Aptian compression. The Jurassic deposits of the Dahar structure reveal a gradual decrease in depth towards the East ; the notable variation in thickness suggests synsedimentary tectonic deformation.

Lower Cretaceous series are absent in the Jeffara domain. Along the Dahar domain, the Lower Cretaceous series present a gradual deepening and thinning from the South to the North.

The absence of the Upper Cretaceous in the Jeffara domain may be due to erosion or a phase of non-deposition.

The confrontation of information derived from the lithostratigraphic correlations analysis, the seismic sections interpretation, and the previous geological studies dealing with the Mesozoic series in southern Tunisia allowed the definition of different tectonic features influencing the geometry of the Triassic-Cretaceous deposits in the Mednine-Tataouine region. The absence of some formations in the Jeffara domain and the variations of depth, thickness, and composition in the Dahar domain are the consequences of diverse tectonic deformations. The extensional deformations are mainly induced by NW–SE to NNW-SSE and E-W normal faults whose synsedimentary normal activity in the Dahar domain dated back to Permian and continued during the Triassic, Jurassic, and Lower Cretaceous epochs. Their reactivation during the later extentional events occurring in the Saharan platform has certainly contributed to the structuring of these series in raised and subsided compartments.

Compressive deformations are mainly manifested by the Hercynian discordance, intra-Triassic discordance of Sidi Stout, and Austrian discordance. They are responsible of the absence of Lower Cretaceous reservoirs in different localities in the Mednine-Tataouine region.

The delineated tectonic features structuring the Mesozoic permeable layers may also influence the water circulation and characteristics. Indeed, the NW–SE to NNW-SSE normal faults inducing the deepening and thickening of the Triassic-Lower Cretaceous series towards the Dahar southwestern part may promote the groundwater flow in this direction. Further, they may promote the vertical communication within the different aquifers.

In the Jeffara where Jurassic and Lower Cretaceous aquifers are absent, NW–SE to NNW-SSE normal faults favor the interconnection between the Upper Cretaceous aquifers and Triassic aquifers. Moreover, the synthetic bloc diagram shows that the actual recharge of the Mednine-Tataouine Mesozoic aquifer system may be directly by infiltration in the outcropping Lower Cretaceous permeable sediments and/or indirectly though the lateral communication of these sediments with the Dogger permeable deposits corresponding to the most raised outcrop in the Dahar structure and to the main continental divide in Tataouine region.

Conclusion

This study, integrating borehole and seismic reflection data, enhanced significantly the understanding of the Mesoizoic aquifer system in a large part of Southern Tunisia. The methodology used in the present study may apply easily and successfully to other hydrogeological research aiming to investigate deep aquifers in the‘‘Sahara’’ and other arid zones worldwide.

Keywords: Southern Tunisia, Mesozoic series, Petroleum Wells, Water boreholes, 2D Seismic reflection, Hydrogeological implications.

GR-Po-06

Integrated Hydrogeological and Geophysical Approaches for Characterizing the Sahel Aquifer System

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Introduction/Objective

Water stress has become a critical worldwide issue, especially in semi-arid and arid regions where the gap between water supply and demand is growing. This problem is shown by the Mahdia Ksour Essaf coastal aquifer, which is under extreme water stress brought on by environmental factors and unsustainable extraction methods. Groundwater withdrawals from this aquifer increased to 202% of its renewable capacity between 1980 and 2022 (DGRE, 2022), resulting in a serious imbalance that jeopardizes the aquifer's long-term survival. The Pliocene marine shelly sandstones and Tyrrhenian oolitic limestone sandstones make up the aquifer in the coastal zone. Beyond this coastal region, it is primarily composed of sandy-clay deposits that are confined by significant East-West and North-South fault corridors. This study highlights the most role that hydrogeological investigations play in addressing water scarcity. Specifically, our aim is to evaluate groundwater resources in highly stressed areas, which will provide guidance for sustainable management strategies in areas where water security is vulnerable. This complex geological structure complicates the understanding of the aquifer's dynamics and geometry.

Methodology

A multidisciplinary strategy that included hydrogeological, geophysical, and geological techniques was used to solve these issues. Interpreting gravity anomalies is made more difficult by the research area's prominent N-S and E-W structural tendencies, which are impacted by both compressional and extensional tectonic processes. In order to get around this, sophisticated gravity data processing which included the use of many filtering techniques was implemented in order to precisely identify important aquifer properties and subsurface structures. The integration of these geophysical findings with hydrological correlations highlights the important role played by local tectonic structures and provides a comprehensive picture of the lateral and vertical evolution of the hydrological systems. A thorough grasp of the water balance of the area was also obtained by analyzing data on well extraction and water quality.

Result/Discussion

Gravimetric studies reveal the complexity of tectonic movements that have shaped the folded graben, suggesting significant discontinuities in the aquifer distribution. Uneven saturation of groundwater can result from variations in the permeability and deformation of the rock strata inside the graben. Notably, faulted and fractured zones may function as barriers, impeding groundwater movement, in the El Jem and Sidi Alouane regions. A significant fault, specifically, has the potential to divide a graben zone from a horst zone, limiting hydraulic connection and producing an aquifer distribution that is discontinuous. Hydrogeological correlations, combined with gravimetric parameters, show that geological formations in the region vary significantly in permeability. While less permeable rocks usually restrict the presence of groundwater in the horst, more permeable geological elements are frequently found inside the graben, facilitating the existence of an aquifer. The distribution of aquifers may become unequal as a result of certain places receiving greater recharge than others. An interesting association may be shown

by superimposing structure patterns with salinity and chemical composition distribution. There is a significant difference near the Mahdia graben's southern edge. The main cause of the sodium chloride-dominated water to the east is maritime intrusion and over-extraction. On the other hand, the water to the west is primarily made up of sodium sulfate due to gypsum deposits. Greater structural permeability may make it easier for groundwater to migrate, including incursions from seawater. Given that such intrusions are encouraged by the geological structure in the northeast, this might account for the high saline levels seen there. Lower permeability zones, on the other hand, function as barriers, restricting the movement of groundwater and perhaps concentrating dissolved salts, which might be a factor in the higher salinity levels seen in some areas of the region. The complicated geological structure of the folded graben and the permeability and impermeability of the water combine to significantly explain the observed spread of salinity in the Mahdia Ksour Essaf aquifer.

Conclusion

The tectonic structures in the Mahdia Ksour Essaf region significantly influence groundwater quality through a complex interplay of factors. Groundwater salinity is primarily caused by marine intrusion, which is made worse by seasonal and climatic fluctuations. This highlights the necessity of continuous monitoring and control. The overuse of aquifers due to saline intrusion from coastal regions and growing demand for water for household, industrial, and agricultural purposes further worsens salinity. Furthermore, ions and chemical compounds are released into the surrounding rock as a result of reactions between groundwater and that rock. Because of the geological faults and cracks that have sculpted the region's hydrodynamics, salt water may more easily migrate into places that were not previously affected. Developing efficient management techniques in this geologically complicated region requires an understanding of the complex interaction between groundwater flow and tectonics.

Keywords: coastal aquifer, salinity, Gravimetric, permeability.

GR-Po-07

Reconstitution of the geometry of the Mio-Plio-Quaternary aquifer system in the Sousse region

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Introduction/Objective

In the last years, the Sousse governorate, located in the Tunisian Sahel, has known significant water scarcity due to socio-economic activity development as well as the remarkable decrease in precipitation. To ensure equilibrium between water needs and water availability, a better management of the water resources is necessary. In this context, the present study aims for an enhanced knowledge of the Mio-Plio-Quaternary aquifer system in the Sidi Bou Ali-Kalaa Kebira region through the analysis and interpretation of borehole data, vertical electrical soundings (VES) and satellite imagery.

Methodology

The characterization of the Sidi Bou Ali-Kalâa Kébira aquifer system was achieved using data from 142 water boreholes, including well logs, hydrodynamic and hydrochemical measurements, 123 vertical electrical boreholes (VES) and a Landsat 8 satellite image. Available lithological columns and their corresponding well logs were analyzed to identify the different Mio-Plio-Quaternary groundwater reservoirs. Hydrodynamic and hydrochemical characteristics were studied using piezometric and water salinity measurements. VES are qualitatively and quantitatively interpreted to determine the water reservoirs arrangement. The satellite imagery allowed the identification of superficial lineaments affecting the Sidi Bou Ali-Kalaa Kebira region that may control the aquifers geometry and recharge.

Result/Discussion

The restitution of lithological columns using well logs allowed a better delimitation of aquifer layers. Many clay and coarse layers, which are indistinguishable in the available lithological column, are identified. The established piezometric map exposes groundwater flows towards the north and south of the Kalaa Kebira anticline. The water salinity map indicates a progressive increase (1 to 5 g/l) in the same directions as groundwater flows. The apparent resistivity maps show high values at the Kalaa Kebira anticline, indicating its richness in coarse deposits. The geoelectrical cross sections revealed that the Mio-Plio-Quaternary deposits contain at least one coarse formation showing variations in depth, thickness and resistivity. Many discontinuities that may correspond to tectonic accidents controlling the arrangement of the Mio-Plio-Quaternary permeable layers have been highlighted. Several superficial lineaments were determined from the Landsat 8 satellite image. Numerous of them correspond perfectly to geoelectrical discontinuities. This coincidence confirms the tectonic influence on the Sidi Bou Ali-Kalâa Kébira aquifer geometry.

The detected faults generate the deepening of the water reservoirs on either side of the Kalaa Kebira anticline, while inducing groundwater flows in opposing directions, towards the north and the south of this structure.

Conclusion

The confrontation of indirect methods such as geophysics and remote sensing associated with water borehole data allowed the identification and the characterization of the Mio-Plio-Quaternary aquifer system in the Sidi Bou Ali-Kalaa Kebira region. The obtained results have brought more precision to the hydrogeological scheme of the study area and may contribute to groundwater management in the Sousse governorate. Furthermore, it serves as an example that satellite images and electrical prospection are useful not only for initial research into the implantation of water boreholes but also for effectively reconstructing the geometry of an aquifer system.

Keywords: Sousse, Aquifer, Well logs, Vertical electrical soundings, Satellite imagery.

Climate Change and Water

Climate Change and Water

Oral

CC-Or-01

Time propagation from meteorological to hydrological drought

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Introduction/Objective

Drought is one of the most catastrophic natural phenomena, causing scarcity and lack of water resources in reservoirs and severely affecting the majority of the population economically, socially and environmentally. The aim of this study is to contribute to a better understanding of the time propagation from meteorological to hydrological drought.

Methodology

In this study, two meteorological drought indices (Standardized Precipitation Index : SPI and Standardized Precipitation Evapotranspiration Index: SPEI) and one hydrological drought index (Standardized Hydrological Index : SHI) were used to explore the two types of drought at different time scales (1, 2, 3, 6, 9, 12 and 24 months) at eight dams in Tunisia. The Pearson Correlation Coefficient (PCC) and the Directional Information Transfer Index (DITI) are used to determine the propagation time from meteorological to hydrological drought, while considering linear and non-linear dependencies, respectively. In addition, the relationships between drought characteristics such as duration and severity were examined for both types of droughts.

Result/Discussion

Results indicate the information theory based analysis such as DITI and mutual information together with classical linear relationships is a prominent approach for assessing meteorological drought propagation into hydrological drought.

Conclusion

Drought warning and prevention require a thorough understanding of the linear and non-linear mechanisms in the propagation process from meteorological to hydrological drought. In this research, DITI and mutual information are used to study drought propagation time, in order to build, for the first time, a drought assessment model and correlations between duration and severity of meteorological drought and hydrological drought in dams in Tunisia.

Keywords: Information theory, Meteorological drought, Hydrological drought, Drought propagation, dams, Tunisia.

CC-Or-02

Hydrological and meteorological drought characterization in Lebna and Oued el Bey Basins, Cap Bon, Tunisia

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Introduction/Objective

Over the past decades, Tunisia like the majority of Mediterranean countries is facing an intensification of drought conditions characterized by significant rainfall deficit. This is the case of the Cap Bon Peninsula, with its sub-humid to semi-arid climate, particularly vulnerable to water shortage due to its high climatic variability. Therefore, this study aims to analyse the impact of climate change on drought frequency and intensity in Cap Bon, providing quantitative information on meteorological and hydrological droughts, including a vulnerability map for the study area.

Methodology

To analyse precipitation anomalies, The 6-month and 12-month Standardized Precipitation Indexes (SPI-6 and SPI-12) were calculated using rainfall data in several rain gauges collected from Lebna and Oued el Bey basins over a period of 43 years.

The SPI calculation, at monthly scale, was done through Gamma distribution function, defined by its frequency or probability density function as follow:

$$f_\gamma(x/\alpha,\beta) = x^{\alpha-1}.\frac{1}{\beta^\alpha.\Gamma(\alpha)}.e^{\frac{-x}{\beta}};x \geq 0;\alpha,\beta > 0$$

The computation of the SPI involves fitting a gamma probability density function to a given frequency distribution for total precipitation. The maximum likelihood solutions are used to optimally estimate α and β. Moreover, satellite data were used to calculate the vegetation and water indices (NDVI and NDWI) to assess the impact of drought on vegetation and on surface water resources.

Results/Discussion

Preliminary results indicate a notable increase in the frequency and intensity of drought events in Cap Bon over recent decades. The SPI indices reveal prolonged drought periods (Figure 1), correlated with significant decreases in precipitation and surface water storage that was noticed mainly in our case study where the Lebna dam was completely empty in 2023.

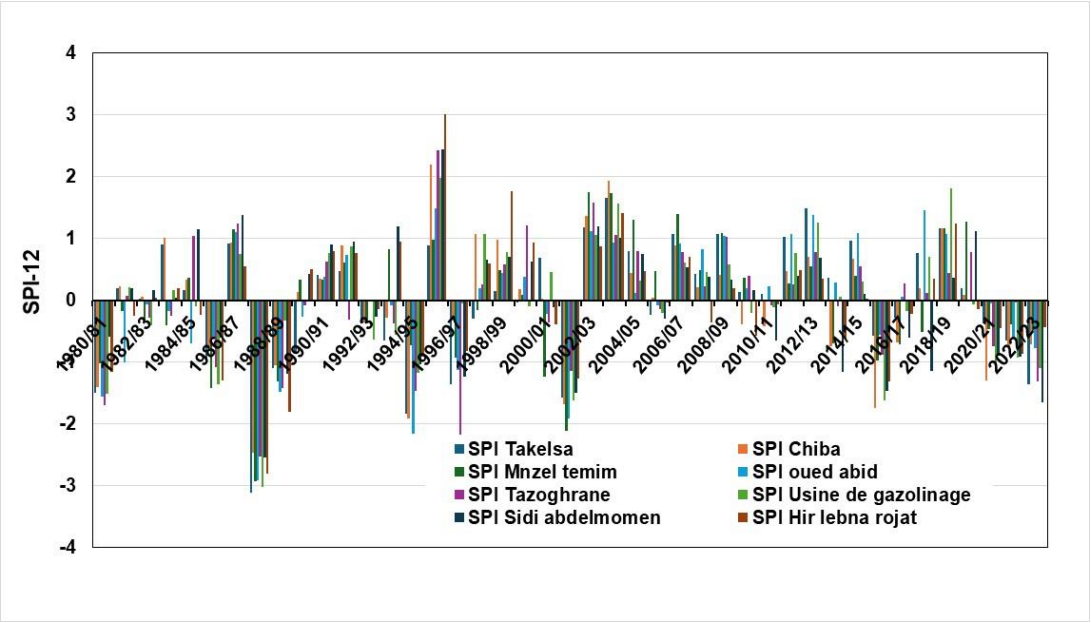

Figure 1. SPI variation in some representative rain gauges in Lebna basin (1980 - 2023)

Analysis of satellite data shows vegetation degradation and a reduction in surface water resources.

Conclusion

The finding highlights the critical impact of climate change on drought events in Cap Bon, Northeast Tunisia. By providing detailed information about the time-space characteristics of droughts and identifying vulnerable areas, this research will be useful for an efficient development of water management strategies, to mitigate and reduce effects of droughts on water resources, agriculture and economy.

Keywords: Climate change, SPI index, Vegetation index (NDVI), Water index (NDWI).

CC-Or-03

Comparison of High-Resolution Satellite Precipitation Products and a Reanalysis in a Semi-Arid Region

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Introduction/Objective

Precipitation is an important component in hydrologic processes. It is useful for hydrological modeling and water resource management. However, many areas face limited data availability due to a lack of ground-based rain gauge networks.

Methodology

The main objective of this work is to compare other sources of rainfall data, such as remote sensing data (CHIRPS, PERSIANN, and GPM) and a reanalysis (ERA5), to ground-based data, which could provide complementary rainfall information in the case of Tunisian semi-arid catchment (Haffouz catchment), for the period 2000-2018. Twelve rain gauges and two different interpolation methods were used to provide a set of data as interpolated precipitation reference. Several statistical metrics were used to evaluate the performance of these products at daily, monthly, and yearly timescales, as well as spatial scale.

Results

The results demonstrated that the two interpolation methods produce comparable precipitation estimates at Haffouz catchment. Based on the different statistical criteria, CHIRPS produced the best results, followed by PERSIANN, which performed well in terms of correlation but underestimated precipitation spatially across the watershed. GPM significantly underestimates precipitation, yet it provides satisfactory performance temporally. ERA5 performs very good at the daily, monthly, and annual timescales, however it is unable to represent the spatial variability distribution of precipitation in this catchment.

Conclusion

In conclusion, the satellite-based precipitation products and the reanalysis data used in this work can be valuable in semi-arid regions and data-scarce catchments.

Keywords: Precipitation, Satellite-based precipitation products, Spatial interpol

CC-Or-04

Impact of Land Use Change on the Hydrological Response: Two Cases Study in Tunisia

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Introduction

Several countries in the Mediterranean region, namely Tunisia, are increasingly faced with serious rainy episodes causing significant damages. It was the case in North Eastern Tunisia which has undergone flooding in September 2018. The prediction of flows at the outlet of a watershed by hydrological modeling seems interesting to better understand the processes and to aid in decision-making.

Methodology

Land use is a necessary input in hydrological modeling. Thus, its update can significantly influence the response of hydrological models. The impact of changes in land use on the hydrological response of watersheds is an essential research area for understanding hydrological dynamics in an ever-changing context. Alterations in land distribution, whether resulting from urbanization, deforestation, expansion of agricultural areas, or other anthropogenic interventions, significantly affect hydrological processes.
The aim of this study is to update the land use map for two river basins and compare the hydrological modeling results using the 2000 and an updated land use map.
The adopted methodology involves applying the SWAT model to the study watershed between 2000 and 2020 using the land use map derived from the 2000 agricultural map as input. The simulation is repeated with the same inputs, except for the land use map, which is replaced by an updated map obtained through supervised classification.

Results

For the new land use map, there have been significant changes in the practiced crops. Some have shown progress, such as olive trees, while others have seen a reduction, notably vegetable and cereal crops. The application of this new map has led to improvements in the key processes of the hydrological cycle, including infiltration, evaporation, and runoff. The model has also showed different results both before and after calibration, particularly for the NSE and PBIAS.

Conclusion

Land use land cover change (LULCC) have profoundly influenced the hydrological response of the watershed indicating a rise in surface runoff and water yield

Keywords: River basin, Hydrological modeling, Land Use, SWAT model.

CC-Or-05

Projections of cereal production in Tunisia under climate change

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Introduction/Objective

Climate change impacts on socioeconomic development of Tunisia will keenly be expressed in reduced agriculture production due increased temperature, land use change, and reduced water resources. Yet vulnerable to climatic variability, cereal production in Tunisia will be likely threatened by climate change. However, theses impacts are not well investigated so far.

Methodology

In this study we propose an approach based on combined climate change projection with artificial intelligence-based model to project cereal production changes in Béja, Siliana and Jendouba regions. We developed and trained a Feedforward Artificial Neural Network (FFNN) using historical wheat production data while considering precipitation (P), temperature (T) and potential evapotranspiration (PET) as inputs. Then, an ensemble of CORDEX climate model projections were used to provide future timeseries of P, T and PET under RCP4.5 (Regional Concentration Pathway) to project changes in wheat production over the selected regions.

Result/Discussion

Our results showed that wheat production is likely to be reduced in the future under climate change.

Conclusion

The proposed approach revealed that combining historical data and climate model projection together with FFNN is a prominent and reliable approach for assessing the impact of climate change on future wheat production in Tunisia.

Keywords: Wheat production; Climate change; Artificial Intelligence; Tunisia.

CC-Or-06

COMSOL Multiphysics Model Applied to Simulate Soil Water and Salt Content in the El Haouareb Irrigated Area - Central Tunisia

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Introduction/Objective

Global changes affect hydrological processes and consequently the water resource quantitatively and qualitatively. Thus, a good forecast of the future water quality and quantity is mandatory to help decision-making actions and to avoid damages and shortages mainly due to climate change. This is only possible with sophisticated and performant numerical tools.

In arid areas, water and soils resources are threaten by scarcity and degradation, especially due to climate changes. Interlinked, those resources affect each other from the point of view of quality during the path of water through soils pores until reaching the aquifer (saturated zone) bringing with it the minerals of the soil. For this reason, it is useful to monitor the dynamic of water and the behaviors of the transfer of salts crossing the soils. This process make possible understanding the hydrologic system in order to reinforce the human effort and improve the management of the resources. This control is only possible with advanced technologies and the intervention of digital tools. This study aims to predict water flow and salt transfer in a 2 m monolith of soils extracted from Merguellil area, Kairouan city at Central of Tunisia.

Methodology

The experiment has been going through different atmospheric conditions. Indeed, water content and electrical conductivity have been monitored during 18 months. Thus, the experiment has been composed of 5 phasis; internal drainage, natural atmospheric conditions, irrigation with different water quality (distilled water, borehole water and saline water).

In this context, Comsol Multiphysics software has been used. This software, based on finite element method, offers the possibilities to solve Partial Differential Equation (PDE) of different mechanisms/processes. Therefore, Richards and dispersion-advection equations have been used to simulate water flow and salt transfer respectively. In order to get efficient results, the model has been executed taking into account the sodium chloride (NaCl) as tracer. Meanwhile, the calibration has been assessed during the 5 phasis of the experiment in order to get efficient results.

Result/Discussion

Computed results have been compared to measurement data for the parameters of water and NaCl contents. In fact, the root means square error (RMSE) seemed fairly low. This index varied between 0.0183 and 0.0891 m3/m3 for water content and between 1.5557 and 51.2864 mol/m3 for NaCl content. The model has shown its performance while foreseeing future behaviors of water dynamics.

Conclusion

Results seemed promising and will be extended to predict climate change impact on soil and aquifer. The monitoring of water content, water tension and electrical conductivity under various climatic conditions gave a consistent à priori information about the hydrodynamic system behaviors toward climate hazards. Results still subject of enhancement and model calibration is continuously processing.

Keywords: Numerical modeling, Comsol Multiphysics, Climate changes, Haouareb, Central Tunisia

CC-Or-07

Impact of Climate Change on Areas vulnerable to Water Erosion : Case of the Boulajraf Watershed, Morocco

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Introduction/Objective

Water erosion is a multifaceted issue that poses risks to property, people, and agriculture, making it a critical concern globally and the leading cause of soil degradation in Morocco. In the pre-Rif regions, such as the southern Rif corridor, this erosion heightens vulnerability in sensitive areas. The focus on utilizing new technologies aims to monitor and manage this environmental challenge and explore innovative solutions to mitigate its effects on agriculture, ecosystems, and water resources. Numerous studies have addressed water erosion in Morocco (Rahhou, 1999; Sadiki et al., 2004; Faleh, 2004; El Garouani, 2008; Abahror, 2009, Tribak et al., 2009; Sbai et Kaouass, 2011; Elhafid et al., 2012; Markhi et al., 2015; Chaaouan,2013, 2015; Briak et al., 2016; Farris et al., 2016; Iaaich et al., 2016, Laaraj, 2022; Arari, 2023), highlighting the Oued Boulajraf watershed, which faces exacerbated issues due to its gentle topography and climate change. Previous research has used quantitative methods and experimental techniques to analyze water erosion risks, and future efforts will contribute to developing new mapping methods that integrate geotechnical approaches to identify fragility factors in specific areas.

Methodology

In the present study, a multivariate methodology is adopted based on the chosen objectives. Drawing from a literature review, a precise descriptive approach to erosion forms and soil degradation served as the foundation for the mapping approach, which utilized satellite images and Google Earth to create maps of erosion types and land use. Additionally, topographic, geological, and pedological maps were necessary for mapping the factors. Finally, the empirical approach focused on fieldwork (sampling and result validation) and laboratory work (geotechnical analyses).

Result/Discussion

The cartographic analysis of erosive phenomena in the Boulajraf basin, combining Google Earth data with field observations, reveals significant erosion activity, including forms like sheet erosion, rill erosion, badlands, and deeper rill erosion. The study confirms that no single factor fully determines the presence of specific erosion types; rather, it is a combination of multiple factors. Soil vulnerability to degradation is mainly low to moderate, with over 90% of the area experiencing this level of erosion. The RUSLE model estimates average soil loss due to sheet erosion at 23.06 t/ha/year for 2022, with a notable increase from 2008. Key factors influencing water erosion include soil erodibility (K), topographic factor (Ls), and erosivity (R). Additionally, the EPM model qualitatively classifies the basin as moderately to lightly eroded, while the quantitative estimate shows an average soil loss of 59.44 t/ha/year, peaking at 117.68 t/ha/year in the south. Major contributors to water erosion include slope (Ja), soil sensitivity (Y), and precipitation (H).

Geotechnical tests (XRD, calcimetry, Atterberg limits, and grain size analysis) conducted to assess soil and subsurface conditions in areas prone to landslides and pseudo-karst have ruled out swelling clay minerals like smectite as a cause of the observed landslides. A significant finding indicates that the pseudo-karst in sandy-clay soils is primarily due to the dissolution of carbonates, contrary to the initial hypothesis suggesting crystallized salts in the clays or sands. Additionally, XRD analysis did not identify the presence of such saline or swelling minerals.

Conclusion

The research on water erosion is crucial for preserving our natural resources and environment. This study aimed to understand the mechanisms, causes, and consequences of water erosion, along with sustainable soil management perspectives. While our findings significantly contribute to understanding this phenomenon, limitations exist that must be addressed for a more comprehensive approach to future soil management. Continuing to explore this topic is essential for contributing to the preservation of our environment and natural resources.

This study on water erosion in the Oued Boulajraf watershed revealed several indicators of the natural environment's vulnerability to this phenomenon. These indicators were highlighted through various aspects explored in the research, including physical characteristics, detection of erosion forms, modelling, and geotechnical testing.

Keywords: Morocco**,** Taza-Guercif Corridor, Oued Boulajraf Watershed, Water Erosion, RUSLE, EPM, Geotechnics.

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Climate Change and Water

Poster

CC-Po-01

Changes in Extreme events in a semi-arid context: Drought and Annual Maximum Daily Rainfall over the past decades (Merguellil basin)

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Introduction/Objective

Due to the climate change and variability, the characterization and assessment of extreme values become one of the prior interests for scientists, researchers and stakeholders. Effects of climate variability become more visible with the increase of flooding and drought in some regions around the world.

Central Tunisia regions, especially Merguellil basin, is highly vulnerable to extreme hydro-climatic events and known with a strong space-time variability of rainfall (flood and drought). Annual rainfall values vary between 200 and 500 mm and measured evaporation varies generally between 1500 and 2000 mm/year. This study aims **1)** to provide quantitative information on extreme rainfall and meteorological and hydrological drought **2)** to assess aspects related to the changing trends of these extremes in Merguellil basin.

Methodology

We investigated the appropriateness of using statistical methods to assess drought events and extreme precipitations (Annual Maximum Daily Rainfall). we consider a subset of the long-lasting (1980-2021), homogeneous, quality-checked rainfall national Tunisian database for eleven rain gauges in the basin.

The Standardized Precipitation Index (SPI) was used for drought identification and monitoring in Merguellil watershed. The drought index values were obtained for the time scale of twelve and six months (SPI-12 and SPI-6).

Rainfall trend for the Annual Maximum Daily Rainfall (AMDR) was also assessed using the non-parametric Mann–Kendall test and Sen's slope estimator. Also, a frequency analysis was applied to estimate extreme rainfall quantiles in such Mediterranean climate.

Result/Discussion

The statistical analysis showed an irregular space-time distribution of rainfall and an inter-annual variability was marked by wet and dry year's fluctuations.

The assessment of drought indices revealed that the basin suffered from a succession of dry years in the past specially in the decade (1980-1989), accompanied by sever and moderate years.

About trends, findings showed that generally there was an increasing for the AMDR (figure 1): the tendency marked a dominant upward in ten studied raingauges, but statistically significant in just four stations. The increase varies from 0.4 to 0.6 mm. year^{-1}.
The Log normal value distribution was used to extract the 10, 20, 50 and 100-year return levels. Also, the space distribution of calculated quantiles was assessed to localize the most exposed area to these extreme events.

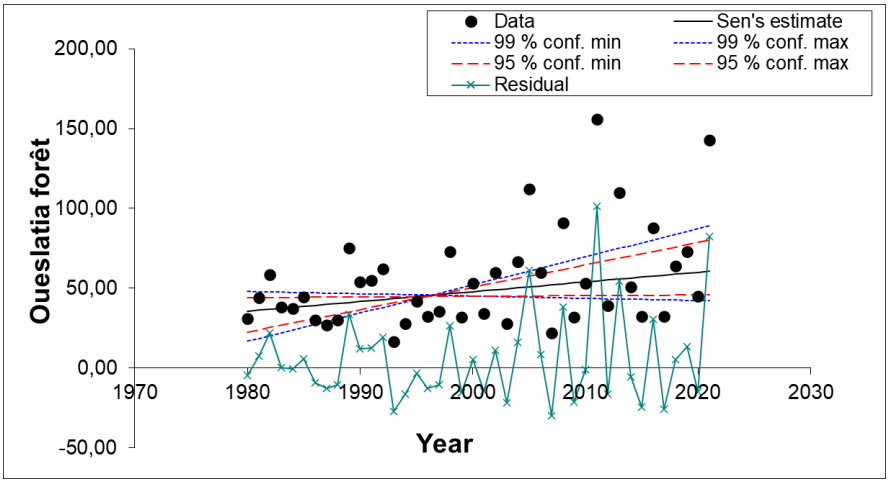

Figure 1. Annual Maximum Daily Rainfall trend (Oueslatia forêt station)

Conclusion

Understanding and assessing the past rainfall changes and variations, in the last four decades, is a necessity because the entire water resources system is influenced by hydrological processes driven by the rainfall. For this reason, results of this study can be helpful: knowledge of the SPI and the AMDR may be very useful to well monitoring the hydrological behaviour of Tunisian semi-arid region and to facilitate the water resources management against the future climate change.

Keywords: Drought, SPI, Maximum Daily Rainfall, Merguellil watershed, climate variability.

Water Treatment and Reuse of Non-Conventional Water

Water Treatment and Reuse of Non-Conventional Water

Oral

WTR-Or-01

Synthetic and textile wastewater based cationic dye treatment using local iron tailing waste

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Introduction/Objective

In the framework of wastewater treatment and environmental protection, the overall aim of this work is to study the potential of iron oxide of a mining waste MW from northern Tunisia in dye treatment from aqueous solutions: a synthetic solution of methylene blue and textile wastewater sample, using dual adsorption and Fenton process

Methodology

Two solutions, a synthetic methelyne blue (MB) and textile wastewater (TW), were treated using iron mining tailing. Iron tailing sample (MW), was used as adsorbent and catalyst inadsorption and AOP processes, respectively. This by-product (MW) is mainly composed of geothite, hematite, quartz, kaolinite, illite and calcite. It was thermally activated at 400 °C for 3h well time (RM400).

Experimental parameters (pH, initial concentration, catalyst dosage, thermal activation, H_2O_2 dosage, and contact time) were investigated in order to access the optimum discoloration conditions.

Result/Discussion

Thought adsorption technique, by using 0.1 g of raw MW and calcined MW400, removal efficiency in MB solution achieved 90% and 83%, respectively, after 120 min of contact time. The effect of pH medium (neutral pH 7, acidic pH 3 and alkaline pH 9) on MB dye removalshowsa relatively high discoloration efficiency obtained at pH 3 with 89%. While, wastewater sample (TW), by using 0.02g of MW and MW400, the discoloration values was 22 % and 16 %, respectively.

With the same amount of catalyst (0.02g of MW400) and 20ml of H_2O_2, the MB removal reached 90 %. On other hand, under the same conditions, the discoloration of (TW) was 79%. This is related to the complex composition and presence of other auxiliaries and chemical reagents in the textile effluent (compared to the synthetic MB solution) that could challenge the complete wastewater dye degradation.

Conclusion

On both synthetic (MB) and textile effluent (TW), the experimental kinetic data exhibited a very good fit with the pseudo-second order model (R^2superior to 0.997 using MW400).

Valorization of iron rich by-product overrides chemical adsorbent and catalyst application and good results were achieved compared to other research studies.

Keywords: Iron mining tailing, MB solution, textile wastewater, adsorption, Fenton Process.

WTR-Or-02

Phosphate sludge-metakaolin foamed geopolymers and their application in dye removal

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Introduction/Objective

This study addresses the environmental impact of phosphate sludge from mining activities, focusing on recycling it into materials for water treatment. Using alkali-activated metakaolin and calcined phosphate sludge, the research aims to create sustainable geopolymers. The geopolymers were prepared with two forms: foamed and unmodified and were evaluated for their ability to adsorb contaminants and immobilize heavy metals, offering a potential solution for reducing pollution.

Methodology

Geopolymers were prepared by mixing an alkali-activating solution with 40% of calcined El Mdhilla phosphate sludge. Foamed metakaolin/phosphate sludge geopolymers were prepared with the same formula, but with the addition of 5 ml of hydrogen peroxide to the mixture once it was poured into the molds. Mineralogical and chemical characterization of phosphate sludge and metakaolin was conducted. Additionally, XRD (X-ray diffraction) and FTIR (Fourier-transform infrared spectroscopy) analyses were performed, along with assessments of the compressive strength and physical properties of the geopolymers. To study the immobilization of heavy metals by geopolymers, leaching tests were conducted.

Result/Discussion

The sludge sample from the El Mdhilla phosphate laundry was found to contain particles of carbonate, silicate, and residual fluorapatite but lacked alumina, highlighting the need for metakaolin to ensure sufficient aluminate content in the geopolymer mixture. XRD and FTIR analyses of the geopolymers indicated partial reactivity within the alkaline solution. Calcite traces were observed in the samples, while quartz remained inert. Physical properties analyses revealed that the inclusion of calcined phosphate sludge enhances the specific surface area and porosity of the geopolymers. However, the compressive strength of unmodified geopolymers decreased upon the addition of hydrogen peroxide to the geopolymeric mixture. In contrast, the specific surface area of foamed geopolymers with calcined phosphate sludge experienced a significant increase. This augmented surface area enhances the adsorption capacity of the materials, resulting in a remarkable 99.9% removal of methylene blue dye within 20 minutes. The adsorption behavior of methylene blue fits the Langmuir isotherm and pseudo-second-order kinetic models, indicating robust chemical and monolayer adsorption characteristics. Overall, these findings underscore the potential of using hydrogen peroxide in raw phosphate sludge-based geopolymers for efficiently purifying industrial effluents and immobilizing leached heavy metals within their unique 3D porous geopolymeric structure.

Conclusion

Geopolymers exhibit significant potential as adsorption materials for methylene blue, with adsorption performance and mechanisms that warrant particular attention in contaminated water treatment applications. Utilizing this valorization pathway will help reduce the environmental impact of phosphate sludge, thereby paving the way for more sustainable management of these residues.

Keywords: Phosphate sludge, foamed geopolymers, adsorption, methylene blue.

WTR-Or-03

Green synthesis of zinc oxide nanoparticles using Albizia procera leaf extract: Degradation of methylene blue dye via Advanced Oxidation Process and Box–Behnken Design

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Introduction/Objective

Through this research, zinc oxide nanoparticles (ZnO NPs) were successfully synthesized via easy route "green process" using plant extract of Albizia procera.

Methodology

The purpose of this research is to investigate the degradation of methylene blue (MB) dye via advanced oxidation process (AOP) in the presence of Hydrogen peroxide (H2O2) and the ZnO photocatalyst under visible light irradiation.

Result/Discussion

The X-ray diffraction (XRD) results confirmed that the ZnO NPs had a hexagonal wurtzite structure. The dynamic light scattering (DLS) showed a range of sizes 23 nm. This study aims to analyze the influence of operating parameters and their interactive effect on the overall removal efficiency of the targeted component by response surface methodology (RSM). The Box–Behnken design (BBD) in RSM was used to optimize several process variables. In order to optimize the responses of MB elimination rate, parameters such as pH (A: 3–11), molar ratio [H2O2]/[ZnO] (B:1–3), concentration dye (C: 10–30 mg L−1), and contact time (D:30–70 min) were used as independent factors. The values obtained from the experiment and model predictions were discovered to be in adequate approval, and the model equation's performance confirmed the experimental observation with only a small divergence

Conclusion

These results confirmed the efficient environmental remediation of heterogeneous photocatalytic process thanks to ZnO NPs.

Keywords: Green process, Zinc oxide nanoparticles, Albizia procera, Box–Behnken design, H_2O_2 oxidation, Methylene blue.

WTR-Or-04

Enhanced Water Reuse for Irrigation: Synergy of Macrophytes and AOP in Urban Wastewater Treatment

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Introduction/Objective

Urban wastewater management poses significant challenges, especially in areas facing water scarcity. Effective treatment methods are essential for recycling wastewater and reusing it in agricultural applications. This study aims to explore the integration of macrophytes and Advanced Oxidation Processes (AOP) using hydrogen peroxide (H_2O_2) , iron (Fe) and solar irradiation for wastewater treatment. The primary objective is to assess the efficiency of this combined approach in reducing organic pollutants and pathogens, and to evaluate the suitability of the treated water for turnip irrigation, focusing on germination and growth performance.

Methodology

The treatment process involved two main stages. Initially, macrophytes were employed to treat the urban wastewater, targeting the reduction of organic matter and improving water quality through natural filtration and nutrient uptake (Khan et al, 2023). Following the macrophyte treatment, Advanced Oxidation Processes (AOP), specifically the Photo-Fenton reaction, were applied to further degrade organic contaminants (Huang et al 2020; Khan et al 2022). The AOP utilized hydrogen peroxide and iron in the presence of sunlight to enhance the breakdown of chemical oxygen demand (COD) and to eliminate pathogens.

Result/Discussion

The results indicated a significant reduction in COD levels. The COD decreased from 160 mgO_2/L to 141 mgO_2/L after the macrophyte treatment, and further to 65 mgO_2/L following the application of AOP. This demonstrates the effectiveness of the combined treatment approach in reducing organic pollution. Pathogen analysis revealed complete removal of total coliforms, fecal coliforms, and streptococci during the AOP stage, confirming the efficiency of the process in ensuring microbiological safety.

The treated water was then tested for its suitability in turnip irrigation. The results showed excellent performance in seed germination and plant growth, indicating that the water quality was adequate for agricultural use. This suggests that the combined use of macrophytes and AOP not only improves wastewater quality but also provides a sustainable solution for irrigation in water-scarce regions.

Conclusion

The study demonstrates that integrating macrophytes with AOP, particularly Photo-Fenton process, is an effective method for urban wastewater treatment. This approach significantly reduces organic pollutants and eliminates harmful pathogens, making the treated water suitable for agricultural irrigation. The successful application of this method for turnip irrigation highlights its potential for broader agricultural applications, providing a viable strategy for water reuse and contributing to sustainable water management practices.

Keywords: Macrophytes, AOP, Wastewater treatment, Pathogen removal, Sustainable irrigation

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WTR-Or-05

Enhanced Photocatalytic Degradation Activity of Amido Black Dye by Electrodeposition of $BiVO_4$ nanostructures on TiO_2 nanotubes

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Introduction/Objective

For water treatment, conventional ways are undeniably in a disadvantage with the constantly immerging Advanced Oxidation Processes (AOP). These methods are designated to the removal of organic materials by way of reaction with Reactive Oxygen Species (ROS) such as superoxide free radicals $(O_2°)^-$ and hydroxyl radicals (OH°) which are highly oxidative to the point of utter degradation or mineralization of the mentioned pollutants [1]. As these methods continues to evolve throughout the years and diverse in terms of energy sources for the generation of free ROS in aqueous solution including sonocatalysis, electrocatalysis, photocatalysis and piezocatalysis [2], the catalysts also evolve in terms of type, state, morphology and size. One of the most exploited photocatalysts is TiO_2, with its excellent properties and its band edge positioned in an adequate potential for radical generation. In this work, an effective approach for fabricating Z-scheme photocatalysts and a heterojunction of $BiVO_4/TiO_2$ nanotubes will be synthesized with the electrodeposition method at different condition to study the effect of the deposition on the properties of TiO_2 nanotubes and photocatalytic activity will be investigated for the degradation of Black Amido.

Methodology

Two steps are required for the electro-deposition of $BiVO_4$ on titanium dioxide NTs. Firstly, the Bi thin films were prepared by the electro-deposition method for four periods of time: 25, 50, 150 and 250s.We used an electrolyte bath containing 20 mM$Bi(NO_3)_3.5H_2O$, and 0.1 M $LiClO_4$. A three-electrode Autolab PGSTAT30 potentiostat/galvanostat PGSTAT30 was used for the electro-deposition process: titanium NTs substrate as working electrode, Ag/AgCl (3MNaCl) as reference electrode, and Pt wire as counter electrode. The temperature of the plating solution was fixed at 60 °C and the optimized cathodic potential was -1.6 V. Then, in order to convert Bi to $BiVO_4$ a DMSO solution containing 50 µL of 50mM $VO(acac)_2$ is spread over the entire surface of the Bi film. The film was then heated at 450 °C for 3 h in air (ramping rate = 2 °C min^{-1}).

Result/Discussion

The structure of the as-prepared samples was characterized with X-ray diffraction (XRD). Morphological behavior was investigated using Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) both coupled with EDX. Optical characterizations were performed using photoluminescence and diffuse reflectance spectroscopy. The $BiVO_4/TiO_2$ NTs sample with 50s deposition time gave the highest photocatalytic performance for Amido Black degradation, 99.4% after 150 min under UV light.

Figure 1 depicts the photocatalytic activity of Amido Black AB. The inset image shows how the blue color of AB is gradually decrease in intensity as the irradiation time increases to be completely gone at 180 min.

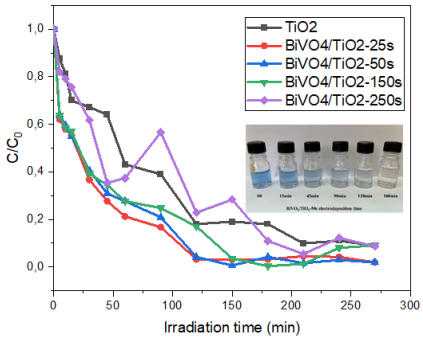

Figure 1. Photodegradation of Amido Black for bare TiO_2 and $BiVO_4/TiO_2$ nanocomposites with different electrodeposition time 25s, 50s, 150s, 250s.

This result has been achieved due to the structure and the optical properties of the sample. The heterojunction of both catalysts showed the synergetic effect on the photocatalytic performance where they remained stable after five cycling runs. Furthermore, quenching tests were conducted and proved that superoxide radicals ($O_2°$) are the main active species during photo-degradation process.

Conclusion

In summary, the deposition of $BiVO_4$ nanosheets on TiO_2 nanotubes showed an efficient and easy approach to enhance the photocatalytic activity of TiO_2. The used method has successfully fabricated $BiVO_4$ nanostructures by electrodeposition of Bi nanoparticles followed by a thermal reaction. The photocatalytic degradation of Amido Black was effected by the deposition time of Bi particles and the 50s $BiVO_4/TiO_2$ sample exhibit the best performance with high degradation efficiency of 99.4% at 150min.

Keywords: TiO_2 nanotubes, $BiVO_4$ nanoparticles, photocatalysis, Amido Black.

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WTR-Or-06

Exploring microplastics in wastewater reuse for irrigation

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Introduction and objectives

Wastewater reuse (WWREUSE) has become a key alternative water resource for irrigation in Tunisia. Since adopting this strategy in 1961, the country has steadily increased its use of recycled wastewater, reaching 21 million cubic meters in 2019 (ONAS, 2019). Although this method holds promise for reducing the amount of water used in agriculture (which accounts for over 80% of total water resources), there is limited knowledge about the impacts of associated pollutants, particularly microplastics. Therefore, it is crucial to investigate the distribution of microplastics in soils and their relationships to WWREUSE in irrigated plots. For this purpose, we developed a comparative analysis based on two plots located in Nabeul (Tunisia) one of which is receiving natural groundwater (GW) while the second is irrigated by treated wastewater (TWW).

Methodology

The method is currently under patent elaboration, at a first stage, the organic adherent material in the water and soil samples were digested. Subsequently, the density separation method was applied followed by microplastic separation based on vacuum filtration. Finally, we observed the microplastic using microscopy and identified the type of polymers using the FTir spectroscopy.

Results and discussions

Microscopic analysis revealed various polymers, including microplastics like fibers, fragments, films, microbeads, and foams, in TWW and GW, as well as in soil irrigated both water types. TWW had a slightly higher microplastic count (950 items/L) compared to GW (800 items/L). Consequently, soil irrigated with TWW had more microplastics (3300 items/kg) than soil irrigated with GW (2800 items/kg).

Fiber polymers dominated the TWW and GW samples, while microbeads were found in TWW (5.5%) but absent in GW. Despite this, soil irrigated with GW had a high percentage of microbeads, indicating other sources. Translucent polymers were most prevalent, in TWW also in soil irrigated with TWW, with blue and black polymers also present, and yellow polymers appearing only in TWW. Microplastic sizes ranged from 0.004 mm to 1.0 mm, with fibers size ranged in GW (100 µm-1mm) and TWW (100 µm- 500 µm). Microbeads were present in TWW (smaller than 10 µm) and soil samples irrigated with the former, witch sizes are between 10 µm and 50 µm.

Preliminary FTIR analysis identified the presence of Polyurethane (PU), Urea-formaldehyde (UF), Expanded Polystyrene (EPS), Polyvinyl chloride acetate (PVCA) and nylon in TWW, GW, and soil samples. Fiber polymers, mainly translucent nylon, were found across all samples, suggesting a textile origin, while black and blue fibers were linked to industrial and domestic sources suggesting a textile origin, while black and blue fibers were linked to industrial and domestic sources. These findings highlight the transport of polymers through both TWW and GW into soils.

Conclusion

This study highlights the pervasive presence of microplastics with shapes and sizes spanning from 4 to 625 μm in the TWW, GW as well as in soils irrigated with the former, with high concentrations. These primary results highlight the urgent need for additional treatment processes for both GW and for TWW prior its use for irrigation for safer environment and public health against risks associated with microplastics.

Keywords: treated wastewater reuse, microplastic monitoring, microfiber, groundwater, irrigated soil

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WTR-Or-07

Electrochemical treatment of the actual waste from the industrial landfills of lindane

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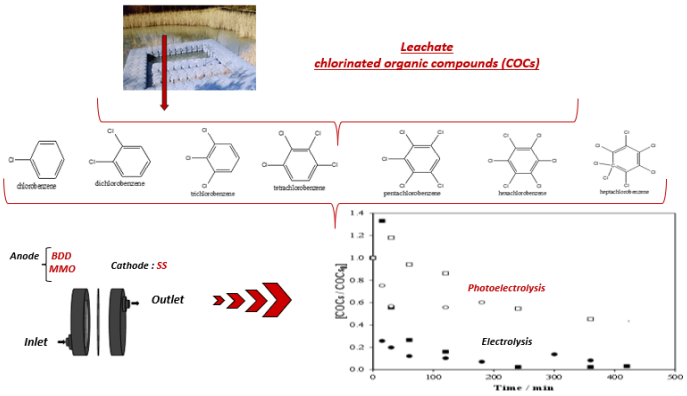
Graphical Abstract



Introduction/Objective:

The main objectives of this study are to assess the technical feasibility of electrochemical technology for treating these wastes and to explore the degradation mechanisms of pollutants in the leachate. The leachate consists of a significant mixture of highly chlorinated cyclic aliphatic and aromatic hydrocarbons.

Methodology:

To achieve this, electrolysis and photo-electrolysis were conducted on real waste samples with varying current densities. A commercial electrochemical cell equipped with boron-doped diamond electrodes and mixed metal oxides was utilized for these experiments.

Results/Discussion:

As a result, electrolysis with boron-doped diamond electrodes induces non-selective oxidation, allowing for the elimination of all measured organic compounds regardless of their chlorine substitutions. In contrast, electrolysis with an MMO anode is gentler and exhibits some selectivity in the oxidation of pollutants, even at high current densities. Electrolysis is affected by UVC irradiation regardless of the type of electrode used, highlighting the superior efficiency of molecular oxidants over radicals in removing these pollutants. Moderate irradiation limits perchlorate formation and promotes the presence of chlorates in chlorine speciation.

Keywords: Lindane; lixiviate; hexachlorocyclohexanes; diamond coating; mixed metal oxides; electrolysis; radical mechanisms.

Water Treatment and Reuse of Non-Conventional Water

Poster

WTR-Po-01

The use of central composite design (CCD) to optimize the coagulation-flocculation process: Application in jar test and industrial scale

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Introduction/Objective

The management of wastewater poses significant environmental and health challenges due to the high organic and microbial loads contained in these effluents. Effective treatment is crucial to mitigate the adverse impacts on water quality and to ensure compliance with environmental regulations. Coagulation and flocculation processes have proven to be efficient in removing diverse contaminants from wastewater. The aim of this study is to optimize the coagulation-flocculation process for treating slaughterhouse effluents in order to improve treatment efficiency, lower costs, and ensure the treated effluent meets regulatory standards [1].

Methodology

10L of wastewater samples were collected from the slaughterhouse effluent after each slaughter activity. The coagulant used was polyaluminium chloride (PAC), and the flocculant was polyacrylamide (PAM) [2]. The initial dosages of these reagents were determined based on preliminary studies and literature recommendations. To optimize the coagulation-flocculation process, a Central Composite Design (CCD) approach was employed [3]. The parameters studied included coagulant dose and flocculant dose. The samples were mixed at high speed initially (100 rpm for 1 minute), followed by slow mixing (40 rpm for 10 minutes). After mixing, the samples were allowed to settle to enable the formation and separation of flocs. Post-treatment, the samples were analyzed for key physico-chemical parameters including pH, conductivity, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_5), Suspended Solids (SS), dry residu (DR) and ammonium (NH_4^+). Filters from SS analysis were also studied under microscope for microparticles detection and identification. Specific pathogens such as Salmonella and Escherichia coli were also analyzed.

Result/Discussion

Preliminary tests with distilled water and tap water highlighted the significant impact of water quality on treatment efficiency. When using distilled water, the treatment with 3 g/L of coagulant and 0.5 g/L of flocculant yielded promising results, reducing the Chemical Oxygen Demand (COD) to 288 mg/L. In contrast, tap water, with its additional impurities, resulted in a higher COD level of up to 576 mg/L, compared to the raw effluent's COD of 3600 mg/L. This suggests that the quality of the influent water plays a crucial role in the effectiveness of the treatment process. Laboratory tests conducted with the optimized parameters (3.6 g/L of coagulant and 0.48 g/L of flocculant) achieved a COD reduction to 768 mg/L, which is lower than the theoretical estimate of 874.5 mg/L. This outcome demonstrates high efficiency of the

coagulation-flocculation process under controlled conditions. The treatment process effectively reduced Suspended Solids (SS) to 310 mg/L, Biochemical Oxygen Demand over 5 days (BOD_5) to 260 mg/L, and ammonium (NH_4^+) concentrations to 20.9 mg/L. Additionally, microbial testing confirmed the absence of pathogens such as E. coli and Salmonella in the treated effluent, meeting the required safety standards. Industrial-scale trials confirmed that the process maintains its effectiveness under real-world operational conditions. However, it was noted that microplastic particles were present in the treated wastewater. These particles were traced back to contamination from water used during cleaning operations. This indicates a need for further investigation and mitigation strategies to address potential sources of contamination and ensure the complete removal of all contaminants in the final effluent.

Conclusion

The study demonstrated that the coagulation-flocculation process, optimized using Central Composite Design (CCD), is highly effective for treating slaughterhouse effluents. By applying 3.6 g/L of polyaluminium chloride (PAC) as the coagulant and 0.48 g/L of polyacrylamide as the flocculant, significant reductions were achieved in key water quality parameters, such as DCO, DBO5, SS, E. coli and Salmonella, meeting the required safety standards. Additionally, the optimization not only enhanced treatment efficiency but also saved $7,122.21 in coagulant costs and $803.03 in flocculant costs annually, reflecting a more cost-effective approach. Despite these successes, the presence of microplastic particles in the treated effluent, linked to contaminated water used during cleaning, highlights the need for further measures to ensure complete removal of these contaminants to prevent potential food chain contamination.

Keywords: Coagulation-flocculation, Central Composite Design (CCD), slaughterhouse effluents, polyaluminium chloride (PAC), Contaminant removal.

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WTR-Po-02

Etiological survey on contaminations of thermal waters and disinfectant tests and purely natural flavorings

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Introduction/Objective:

- Yearly survey of eventual contaminations of thermal water.

-Trials of disinfection using medical and flavouring plants essential extracts and hydrolates.

Methodology:

Water analysis using membrane filter technique that is an effective, accepted technique for testing fluid samples for microbiological contamination which allow the isolation and enumeration of microorganisms.

Screening of antimicrobial activity of some medicinal plant extracts and hydrolates using disc diffusion assay and the minimum inhibitory concentration (MIC) method were used to investigate the antibacterial effects of selected plant extract.

Results/Discussion

Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quality of water available. The result of the survey indicates that the most contaminants found in thermal water are *Enterococcus spp*. and *Pseudomonas aeroginosa*.

There is usually a delay between a pollution incident and detection of the contaminant at the point of water abstraction. The plant extracts that had a better inhibition zone were selected and used for MIC test. Plant extracts exhibited a remarkable activity against bacterial development.

Conclusion

The results obtained in this survey demonstrate that there is a lot of contamination in thermal water which remain a threat for users. Antimicrobial activity of plant extract suggests feasibility to be used in disinfection method.

Keywords (5 keywords): Survey, antimicrobial, plants extract, contaminant, disinfection.

WTR-Po-03

Reduction of total dissolved solids in industrial water storage tanks while maximizing water resource recovery through reverse osmosis

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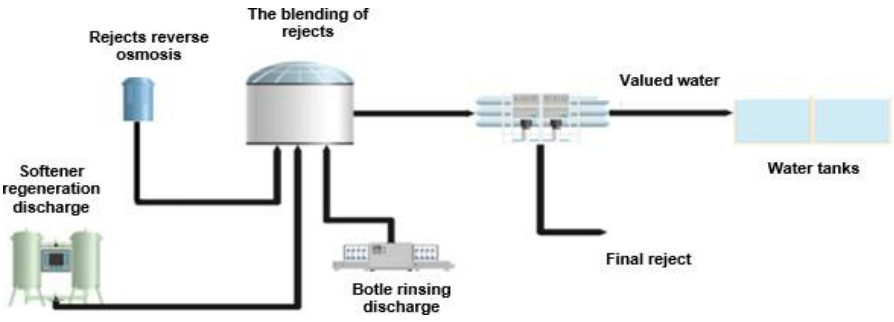
Introduction/Objective

Effective water resource management is increasingly important due to rising freshwater demand from climate change and industrial activities. Our study focuses on reducing dissolved salt concentrations in water tanks while maximizing effluent reuse. We utilized reverse osmosis technology, specifically adapted to reject streams from osmotic systems, softener regeneration units, and bottle rinser discharges. Through design software, we optimized the system, explored different configurations, and improved process efficiency. This approach enhances effluent recycling and supports sustainable water resource management.

Figure 1: *Simplified diagram of the chosen objective.*



Methodology

Our approach focused on applying reverse osmosis technology, specifically adapted to the quality of the discharges, to recycle a substantial portion of the effluents. The project followed a series of steps: first, determining the total discharge volume by quantifying effluents from the softener regeneration, reverse osmosis systems, and bottle rinsers. These three sources were then mixed based on their respective volumetric fractions. Second, identifying the discharge quality through analysis conducted at SEAAL's central laboratory using ion chromatography. Finally, a technical evaluation and sizing of the reverse osmosis unit were performed, covering capacity assessment, module and membrane selection, and system configuration using WinFlows software. The reverse osmosis simulation explored three configurations: parallel, series, and series with a blending system.

Results

Simulations of the various configurations carried out using the WinFlows software allowed for the performance evaluation of each setup. The results, summarized in the table below, show the permeate water recovery rates as well as the quantities of dissolved salts (TDS) in the produced water for each configuration. These findings highlight the differences in performance between the three configurations in terms of water recovery efficiency and the quality of the produced water.

Table 1: *The results of the three configurations of the BW membrane.*

	Parallel reverse osmosis (01)	**Series reverse osmosis (02)**	**Series reverse osmosis with mixing in the feed (03)**
Conversion rate (%)	**62**	**74**	**62**
TDS (ppm)	**132.8**	**87.1**	**37**

Interpretation of Results

The simulations demonstrated that all tested configurations can produce water that meets current regulatory standards. However, Configurations 01 and 02 have higher concentrations of dissolved solids than Configuration 03, which limits their effectiveness in reducing the dissolved solids content of the water tanks. Additionally, the water recovery rate for the parallel configuration (01) is the lowest, justifying its elimination as a viable option. In contrast, Configuration 03 shows a slightly higher conversion rate of 62% and produces better water quality with a TDS of 37 ppm. This result is attributed to the recycling of permeate into the feed water, thereby enhancing the overall efficiency of the process.

Conclusion

Our choice of configuration, with a production of 292.98 m^3/day, optimizes water resource management while reducing the concentration of dissolved salts in the tanks. This solution prevents rapid fouling of equipment, decreases the frequency of cleaning, and minimizes the use of chemicals, thereby enhancing both economic and ecological efficiency. This sustainable approach reduces environmental impact and actively contributes to combating climate change. The adoption of these advanced technological solutions is essential for sustainable water resource management in the face of increasing pressure.

Keywords : Reverse osmosis, Sustainable practices, Valorization, Recovery, Sizing.

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WTR-Po-04

Impact of Wastewater Irrigation on Antioxidant Levels in Tomato Plants (Var. BOBCAT) Grown in Oued Souhil, Nabeul

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Introduction/Objective

In the current context of climate change, dwindling water resources, and rapid poulation growth, water reuse has transitioned from an option to annecessity. Wastewater is increasingly recognized as one of the most stable and sustainable alternative water sources. Consequently, the utilization of wastewater, especially in agriculture – a sector that accounts for nearly 60% of global water consumption- has attracted significant attention.

The aim of this study is to investigate the impact of irrigating tomatoes with treated wastewater on the fruit's composition regarding specific antioxidant molecules of nutritional importance.

Methodology

Tomato seedlings (var. Bobcat), 3 weeks old and measuring 30 cm in length, were arranged in plots and planted in two rows, each 10 meters long and spaced 1 meter apart. The distance between successive plants was set at 60 cm. The first plot was irrigated with well water, following the traditional practices of the farmer, while the second plot received treatedwastewater from the pharmaceutical industry in the Oued Souhail region, processed by the Nabeul wastewater treatment facility. To ensure uniform irrigation, two drip irrigation systems were installed for each row of plants, delivering a flow rate of 1 liter per day per plant." The cultivation took place from April to August. During this growing period, various parameters were monitored. The results presented in this poster focus on the final stages of cultivation and the subsequent harvest. The fruits were harvested and aqueous and ethanolic extracts were prepared. These extracts were subjected to phytochemical screening. Polyphenols and flavonoids were quantified using the protocol established by Dewanto (2002). In contrast, tannins and carotenoids were measured according to the methods of Price et al. (1978) and Lichtenthaler (1987).

Result/Discussion

The results of this study reveal significant differences in the levels of polyphenols, flavonoids, tannins, and carotenoids in tomatoes depending on the type of irrigation used. Tomatoes irrigated with treated wastewater showed higher concentrations of polyphenols and tannins compared to those irrigated with well water. This could indicate that the nutrients or compounds present in treated wastewater stimulate the biosynthesis of these secondary metabolites, which are often associated with health benefits, particularly antioxidant properties.

Moreover, the markedly increased levels of flavonoids and carotenoids in tomatoes grown with treated wastewater suggest a possible synergistic effect from the nutrients or contaminants in these waters. Flavonoids and carotenoids play crucial roles in protecting plants against environmental stress and may also offer health advantages for human consumers. While irrigation with treated wastewater presents advantages in terms of nutritional content, it requires careful management to ensure food safe.

Conclusion

The results of this study demonstrate that using treated wastewater offers a promising alternative for agriculture. Treated wastewater has the potential to supportrobust tomato plant growth, resulting in fruits with high antioxydant contents, surpassing those of conventionally well water-grown tomatoes. these metabolites have ahigh nutritional value and antioxidant potential, which contributes to the pharmacological properties of the tomato fruits.

Keywords: antioxidant molecules, tomato fruit, wastewater, well water.

WTR-Po-05

Impact of Wastewater Irrigation on Tomato Plants (Var. BOBCAT) Productivity, Water Content, and Certain Primary Metabolite Production

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Introduction/Objective

Tomatoes are one of the most important crops in Tunisia, covering approximately 30,000 hectares and ranking among the top horticultural crops in terms of production. This crop holds substantial economic significance as a strategic crop for Tunisia, according to the Group of Food Canning Industries (GICA). However, tomato plants cultivated in open fields require about 5,000 to 6,000 m^3 of water per hectare for optimal growth, primarily sourced from underground water, which constitutes approximately 60% of the total water used for irrigation in the country. This significant reliance on groundwater highlights its vital role in supporting agricultural practices, especially in the face of climate change and other factors contributing to water scarcity, such as increasing water demand and limited surface water resources. Given these challenges, the valorization of treated wastewater has become a necessity. The objective of this work, developed within the framework of the SAFE project, is to explore the potential of using treated wastewater as an alternative irrigation source for tomato cultivation. This study aims to assess the effects of treated wastewater on tomato growth, water content, and certain primary metabolites, ultimately determining whether it could serve as a sustainable substitute for groundwater resources in Nabeul.

Methodology

In Oued Souhil, we established two 10-square-meter parcels, each planted with 20 tomato plants of the variety BOBCAT. A drip irrigation system was used. Parcel 1 was irrigated with treated wastewater and Parcel 2 was irrigated with underground water. The plants were planted on March 25 and completed their cycle on July 31. We followed the growth of the two parcels and started harvesting both parcels simultaneously from June 19 to July 31. On each harvest day, we weighed each tomato fruit to assess productivity. To determine water content, we selected 3 tomatoes from each parcel at the end of the cycle on 31 July and we dried them in a drying oven for 5 days at 80°C. We used the method of Yemm et Willis (1954) to analyze sugar and starch content in tomato fruit at the end of the cycle.

Result/Discussion

The study's results reveal notable differences in the yield and composition of tomatoes based on their irrigation source. Tomatoes from parcel 1, which were irrigated with treated wastewater, produced a remarkable 40% higher yield compared to those from parcel 2, irrigated with underground water. This suggests that treated wastewater may enhance nutrient availability or improve soil conditions, leading to more robust plant growth.

Additionally, tomatoes from parcel 1 exhibited 15.4% increase in sugar content relative to those from parcel 2.

This higher sugar concentration indicates that the nutrient profile of the treated wastewater enhancing fruit sweetness, a quality that is particularly desirable for consumers. Conversely, the tomatoes from parcel 2 showed a 1.7% higher starch content. This difference may reflect the distinct metabolic responses induced by underground water, potentially impacting the fruit's texture or storage properties. Furthermore, tomatoes from parcel 1 contained 1% more water than those from parcel 2, which could contribute to their overall weight and juiciness, making them more appealing to consumers.

Conclusion

These findings suggest that tomato plants irrigated with treated wastewater are more productive than those irrigated with underground water. The water content in tomatoes irrigated with treated wastewater is not significantly higher than in those irrigated with underground water, indicating that their larger size is not due to water accumulation. Additionally, the increased sugar content in tomatoes irrigated with treated wastewater enhances their flavor and makes them more suitable for processing compared to tomatoes irrigated with underground water.

Keywords: primary metabolites, productivity, tomato fruit, wastewater, well water.

WTR-Po-06

Development of eco-friendly biochar from agricultural residues for the removal of Bisphenol A

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Introduction/Objective

Tunisia faces severe groundwater challenges, including overexploitation, salinization, and pollution from agricultural and industrial sources, exacerbated by climate change. Non-Point Source pollution has emerged as a critical environmental challenge, which led to a supply of residual pollutants and organic compounds (such as Bisphenol A) into soils and surface waters. Biochar has been shown to be a promising solution due to its low cost, and high adsorption efficiency. The aim of this study is to develop cost-effective and eco-friendly biomaterials from agricultural waste for the selective removal of BPA.

Methodology

The characterization of surface waters of the irrigated perimeter Oued Souhil, Nabeul showed the presence of several micro-pollutants including Bisphenol A (0.024-0.189 µg/l) [1]. A first set of experiments was performed on several agricultural waste materials, and artichoke leaves were selected as the most effective adsorbent. After pyrolysis for 1,5 h at 500°C, the obtained biochar (AL500) was grounded and sieved. The characterization of biochar was performed by Scanning Electron Microscopy (SEM) coupled with Energy Dispersive Spectrometry (EDS), Fourier Transform Infrared (FTIR) and X-ray diffraction analysis (XRD). Batch adsorption tests were performed using 200 mg/L of BPA solution. The samples were stirred for predetermined time intervals ranging from 15 to 300 min. The supernatant was analyzed by a UV-Visible spectrophotometer. The adsorption parameters were optimized: pH (2–12); temperature (25 - 60 °C) and BPA initial concentrations (10 mg/L - 1 g/L). Isotherm models of Freundlich and Langmuir were fitted on the adsorption experimental data to study adsorption capacity and mechanism.

Results/Discussion

Figure 1 shows the AL500 characterization. SEM indicates the amorphous nature with non-crystalline structure of the adsorbent. We note the presence of pores due to the thermal treatment which induces a consequent development of the porosity by bursting the natural pores existing in raw artichoke leaves. The EDX analysis shows that AL500 was mainly composed of high carbon content (45%), indicating a higher purity of biochar, oxygen (35%) and traces of various other elements such as potassium (8,5 %), calcium (2,6 %), magnesium (1,4 %) and chlorine (2,4). The FTIR analysis shows that the functional groups of biochar samples decrease with pyrolysis temperature. The absence of peaks for aliphatic C–H stretch in AL500 is due to the disappearance of organic molecules by pyrolysis.

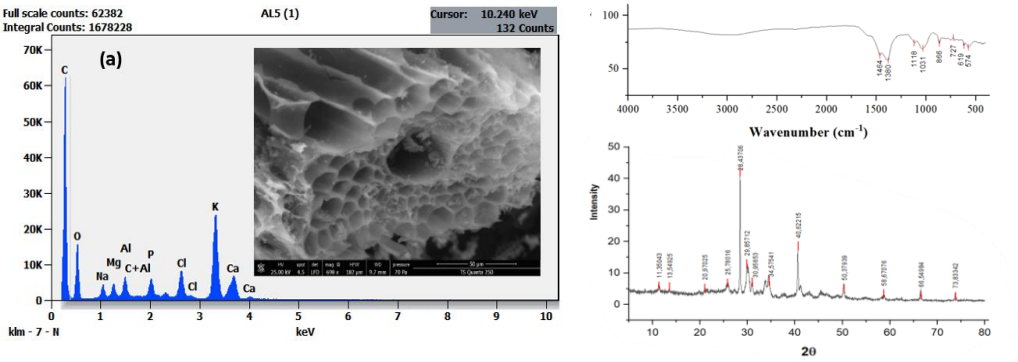

Figure 1: SEM, XRD and FTIR analyses of the AL500 adsorbent

For the adsorption batch tests, the equilibrium was achieved after 120 minutes. The amount of adsorbed BPA per gram of adsorbent is 43 mg/g. **Table 1** summarizes the optimized operating conditions and performances.

Table 1: BPA adsorption optimized operating conditions and performances

Adsorbent	pH	Temperature °C	Micropollutant mg/l	Adsorbent mg/l	Removal %	Equilibrium time (min)
AL500	6	25	10	20	80	120

The application of the Langmuir and Freundlich equations to experimental measurements shows that the Freundlich model is the most suitable for BPA adsorption (**Figure 2**). It assumes the existence of heterogeneous adsorption sites on the surface of the adsorbent.

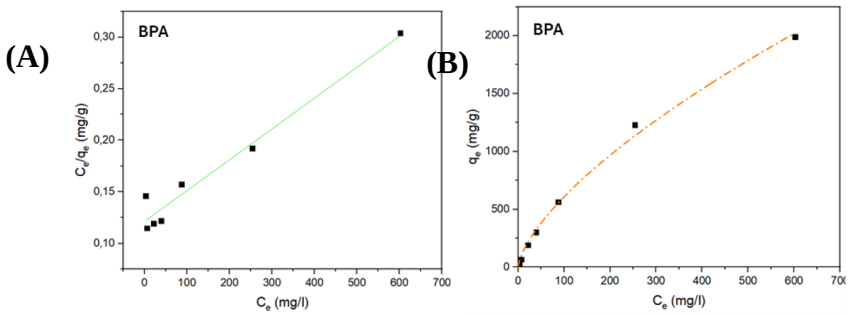

Figure 2: BPA experimental results and best-fitting interpolations obtained with the Langmuir (A) and Freundlich (B) models.

Conclusion

This study demonstrates the effectiveness of biochar derived from artichoke leaves for the selective removal of Bisphenol A. Its characterization and fitting to the models allowed us to better understand its operation. This process offers a sustainable and eco-friendly approach to address water scarcity while protecting groundwater resources from contamination. Future research should focus on cost analysis and the development of scalable systems for widespread implementation.

Keywords: Adsorption, Bisphenol A, Biochar, Artishoke leaves, Freundlich

Acknowledgments: This research was supported by the Horizon Europe project MAR2PROTECT-GA101082048.
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WTR-Po-07

Investigating substrates to enhance constructed wetland performance for wastewater treatment

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Introduction/Objective

Since their inception, constructed wetlands (CW) have demonstrated significant efficiency in wastewater treatment. These engineered ecosystems represent a relevant model of nature-based solutions and provide a sustainable and effective method for water treatment. They can be applied to various types of wastewaters and integrated at multiple stages of the treatment process. This promising approach offers a low-cost, energy-efficient and ecological method alternative to conventional water treatment system [1].

As a key component of constructed wetlands, the substrate plays a crucial role in water purification. Therefore, selecting the most suitable substrate has garnered significant attention in research. Several studies have suggested using a natural, carbon-rich substrate as the filter medium [2].

In this context, as part of the Horizon Europe MAR2PROTECT project (GA 101082048), the main goal of this study is to enhance constructed wetland (CW) efficiency for removing contaminants from wastewater to be valorised and reused for aquifer recharge.

Methodology

A lab-scale system was implemented at the Higher Institute of Applied Biological Sciences of Tunis (ISSBAT). It consists of four parallel lines, each featuring a hybrid CW system (horizontal and vertical CW). The difference between the lines is based on the substrates used as filter media. Two fundamental substrates were examined: gravel and cork. While gravel is a common substrate, the use of cork in wastewater treatment is recently developed. The novelty of this study lies in its varied treatment approaches applied to raw cork, resulting in diverse cork forms.

To assess the efficiency of the lab-scale CW system in removing contaminants, a series of experiments were conducted, adjusting various parameters throughout the process.

Water quality monitoring was conducted after various hydraulic retention times in batch mode. Samples were collected and physico-chemical analysis for the influent and effluent were performed (pH, EC, DO, COD, NH_4-N, PO_4-P, NO_3-N, NO_2-N). Plant performance was assessed by physiological and biochemical parameters/indicators (length, photosynthetic pigmentation, Oxydative stress).

Result/Discussion

The lab-scale CWs system has revealed a significant result in removing contaminants from water (Figure 1). Differences between the substrates used are statistically significant for COD, NH_4-N and NO_3-N removal (ANOVA test: $p<0.05$). Expanded cork provides more stable performance for COD and NH_4-N removal. Raw cork is the most effective for NO_3-N removal.

During the treatment period, comprehensive plant measurements were conducted in each CW unit and in terms of plant numbers and heights. Additionally, analyses were carried out to determine the levels of photosynthetic pigments, including carotenoids, chlorophyll a, and chlorophyll b. Raw cork has the most favorable conditions for plant growth especially in HFCW.

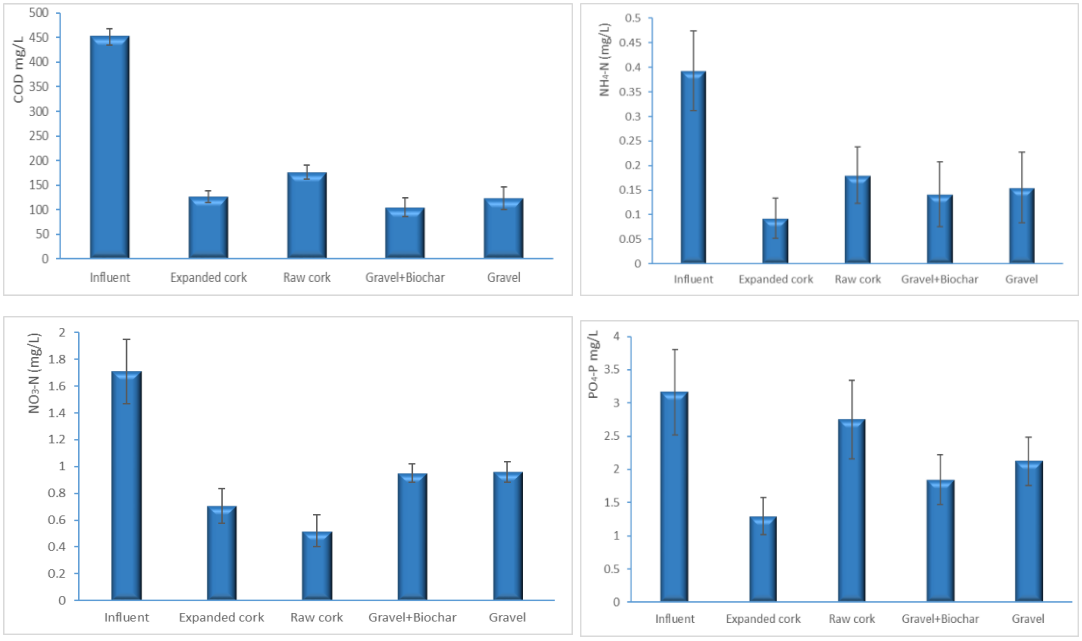

Figure 1. Physico-chemical analysis results: COD, NH_4-N, NO_3-N, PO_4-P

Conclusion

In conclusion, the performance evaluation of the lab-scale CW, using hybrid system combining vertical and horizontal CW, showed promising results for enhancing water quality.

Based on the tested substrates, expanded cork efficiently removed COD and NH_4-N, while raw cork was best for NO_3-N removal and plant growth in HFCWs

On the other hand, research continues to investigate the effect of each substrate on the microbial community involved and to gain a deeper understanding of the interactions among the main actors involved in the removal of contaminants.

Keywords: Constructed wetlands; Substrate; Sustainability; Wastewater treatment

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Acknowledgement

This research was supported by the Horizon Europe MAR2PROTECT project (GA 101082048).

Pollutant Control and Water Quality Assessment

Pollutant Control and Water Quality Assessment

Oral

PC-Or-01

Monitoring, evaluation and improvement of tap water quality

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Introduction and Objective

The scarcity of fresh water is one of the biggest issues that Tunisia urgently needs to address. The per capita share of drinking water is about 104 L/day/person (*Water sector report; Ministry of Agriculture and Water Resources and Fisheries 2022)*. The majority of tap water is characterized by an elevated salinity value (between 1 and 2 g/L). The water qualities often aggravated by the presence of suspended solids, an unpleasant taste, and a chlorine smell. This prompted Tunisians to abandon tap water in favor of bottled water and other types of drinking water. Therefore, the purpose of this work is to evaluate tap water quality in various regions in Tunisia.

Methodology

An observational study was conducted during this work, focusing on physico-chemical analyses, of tap water in different water regions, which include pH, conductivity, TDS, hardness, etc., to assess their conformity to Tunisian standards (NT.09.14) and WHO guidelines. This work was conducted using complexometric and spectroscopic assays Interestedly, Water Quality Index (WQI) and free chloride concentrations (using UV spectroscopy) has been evaluated throughout this work.

Result/Discussion

The obtained results showed that the majority of studied physicochemical characteristics are often within to Tunisian standard, which is not the case for the turbidity (1.3 mg/L). Despite that, the tap water can be considered as hard (TH > 30°F) and slightly brackish (salinity > 1.2 g/L) during the summer. Water Quality Index values showed notable regional difference in values. However, it is anticipated that nearly all of the samples will have high free chloride concentrations (> 2 mg/L), particularly in the Soliman region, which may result in water with a perceptible taste. To address this issue, various technique can be proposed. In Tunisia, Most of people were oriented to bottled mineral water as an alternative for tap water. However, other used domestic desalination to produce fresh water. Hence, this work illustrated the common techniques that can be used for improving tap water.

Conclusion

This study carried out on the evaluation of physicochemical parameters for various tap waters in Tunisia. The results showed high levels of salinity and for free chloride. WQI indexes reveals a variable aspects of selected tap waters.

Keywords: Tap waters; Salinity; Quality; Chloride; Treatment; Membrane

PC-Or-02

Assessment of Microplastics in Tap Water: Insights from the Ben Arous Governorate, Tunisia

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Introduction/Objective

Microplastics, small plastic particles less than 5 mm in size, have become a pervasive environmental contaminant with significant implications for public health and environmental safety. These particles originate from various sources, including the degradation of larger plastic items, industrial processes, and consumer products. The presence of microplastics in tap water, used for drinking, cooking, and washing, raises serious concerns, particularly as they ultimately end up in wastewater treatment plants (WWTPs) and discharged into canals and natural water bodies. This study provides a comprehensive analysis of microplastics found in tap water across various cities in the Ben Arous Governorate, Tunisia. A detailed sampling and analysis was assessed to quantify the presence of microplastics and characterize their types, sizes, shapes and colors.

Methodology

Tap water samples were collected from nine cities within the Ben Arous Governorate, including El Mourouj, Ezzahra, Fouchana, Hammam Lif, Hammam Chatt, Medina Jedida, Radès, and Mhamdia. One liter (1L) of each sample was processed through filtration using a 0.45 µm fiber cellulose filters. Two pairs of unfiltered and filtered tap water samples were collected and tested from the same household in two different cities to evaluate the effeciency of the filtration system. The microplastics were then analyzed using optical microscopy to examine their color, size, number, and shape. FTIR (Fourier-Transform Infrared Spectroscopy) was employed to identify the polymer types of the microplastics, providing insights into the potential sources of contamination.

Result/Discussion

Results indicate notable variations in the concentration of microplastics across different cities. Mhamdia exhibited the highest average concentration of 250 microplastics per sample, while Fouchana had the lowest at 60 microplastics per sample, with an overall average of 135 microplastics per sample in the region. The analysis revealed a predominance of microplastic fragments, with notable presence of fibres /filaments and microbeads in Mhamdia. Color analysis of microplastics revealed a variety of colors, including transparent, white, and black, with additional colors such as yellow, brown, and red observed. Overall, the size range of microplastics spans from as small as 6 µm to as large as 0.68 mm, indicating the presence of both fine and larger particles even in filtered samples. FTIR analysis identified several types of

microplastics including Polyvinyl Acetate (PVAC), Polyvinyl Chloride (PVC), Expanded Polystyrene (EPS), Polypropylene (PP), and Polyvinyl Alcohol (PVA). The most common materials for water supply pipes include PVC, High-Density Polyethylene (HDPE), and other types of polyethylene. PVC is particularly prevalent due to its durability and cost-effectiveness. However, vinyl chloride, the monomer used to produce PVC, has been classified by the International Agency for Research on Cancer (IARC) as a Group 1 carcinogen. It has been linked to various cancers, including liver cancer, brain and lung cancers, lymphoma, and leukemia (Ragusa et al., 2021; WHO, 2022). Aging water distribution systems and construction activities can be direct sources of microplastic contamination. In regions where pipe networks are old or have undergone significant wear and tear, microplastics may be released into the water supply due to degradation processes (Koelmans et al., 2019). Additionally, materials like PVAC, EPS, and PVA are widely utilized in construction applications due to their desirable properties such as adhesive strength, thermal insulation, and moisture resistance. During construction activities, these materials may experience physical stress from handling and installation processes. This stress can lead to the disintegration of larger pieces into smaller fragments that can be released into the water supply, contributing to microplastic pollution (Homin et al., 2023).

Conclusion

The findings highlight a diverse presence of microplastics in tap water across the Ben Arous Governorate, with significant variation in concentration and type among different cities. The presence of particles in the larger size range after filtration might indicate limitations in the filter design, efficiency, or maintenance. Given the detection of microplastics in tap water, including polymers such as PVAC, PVC, EPS, PP, and PVA, several targeted measures can help reduce contamination and mitigate its environmental and health impacts. Regular maintenance and monitoring of water infrastructure are essential to minimize the contamination of tap water with microplastics. One critical action is the phasing out of aging PVC pipes in water distribution networks, which can degrade over time, releasing microplastics into the water. Replacing these pipes with more durable and non-leaching alternatives can significantly reduce this source of contamination.

Keywords: microplastic monitoring, water quality, public health, PVC

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PC-Or-03

Emerging Contaminants in Surface Waters of the Monastir Coast: Implications for Aquatic Ecosystems and Human Health

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Introduction/Objective

Pharmaceuticals, a significant class of micropollutants, have received more attention due to their widespread detection in concentrations ranging from nanograms to micrograms per liter. Their presence in environmental waters, primarily caused by human activities, is a global concern (Raman et al., 2023). Estuaries, receiving discharges from WWTPs, agriculture, and livestock, are key entry points for these pollutants into marine environments (Ngqwala, 2020). Coastal regions, particularly vulnerable, face threats from persistent pollutants like antibiotics and hormones, which pose ecotoxic risk. Few studies have reported pharmaceutical occurrence in African coastal environments, including two from Tunisia (Tahrani et al., 2017), which found high levels of antibiotics, beta-blockers, and psychiatric drugs. This study focuses on pharmaceutical contamination in the Khniss drain along the Monastir coast, southern Mediterranean, and its environmental and health implications.

Methodology

Water samples were collected from the drain of khniss and effluents from urban wastewater treatment plants which flow in coastal areas of Monastir region: Drain of Khniss (35°43'7.25"N, 10°49'14.44"E) using a grab sampling method. The samples were stored at 4°C in 1L amber glass bottles pre-rinsed with methanol and deionized water. After filtration to remove suspended matter, Solid phase extraction (SPE) was used for the extraction and preconcentration of the samples, and liquid chromatography tandem mass spectrometry (LC-MS/MS) was used for the determination of the compounds

Result and Discussion

Occurrence of PPCPs

The twelve pharmaceutical compounds (Pcs) were detected and quantified in surface water samples collected from the drain of Khniss are Acetaminophen, Azithromycin, Levofloxacin, Benzotriazole, Caffeine, Cotinine (MTB), Dimethylxanthine, Carbamazepine, Climbazole, Fluconazole, Metoprolol, Sotalol.

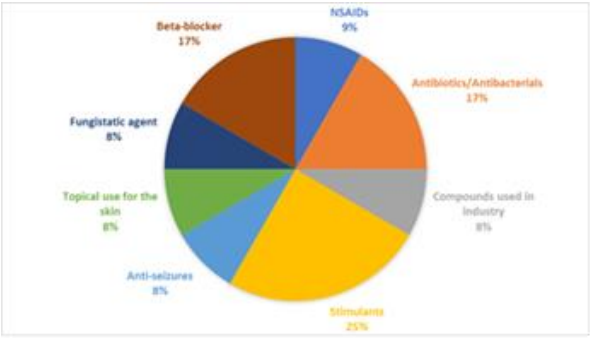

Fig. 1. Class of analyte in the surface water in the drain of khniss

Our study revealed high concentrations of carbamazepine (CBZ), an anti-seizure medication, exceeding 1000 ng/L in the Khniss drain, which flows into the Bay of Monastir. This drain combines industrial effluents and treated wastewater, leading to coastal contamination, raising concerns about CBZ's persistence and ecological impacts noted in Mediterranean research.

Table 1 : Concentrations of pharmaceuticals in different surface water samples of drain of khniss

Compounds list	Class	Tun-N1(ng/l)	Tun-N2	Tun-N3
Acetaminophen	NSAIDs	35.9971	45.70	49.47
Azithromycin	Antibiotics/Antibacterials	15.1498	29.175	22.42
Benzotriazole	Compounds used in industry	>1000	>1000	>1000
Caffeine	Stimulants	>1000	>1000	>1000
Carbamazepine	Anti-seizures	1028.83	1115.74	1087.0
Climbazole	Topical use for the skin	95.02	98.65	91.85
Cotinine (MTB)	Stimulants	39.43	53.16	45.53
Dimethylxanthine	Stimulants	816.0	862.35	757.38
Fluconazole	Fungistatic agent	195.05	213.75	210.42
Levofloxacin	Antibiotics/Antibacterials	24.97	21.97	14.57
Metoprolol	Beta-blocker	15.16	17.55	15.42
Sotalol	Beta-blocker	256.90	294.03	256.95

Caffeine was the most frequently detected compound in the Khniss drain, with levels surpassing 1000 ng/L, likely due to its resistance to biodegradation in wastewater treatment plants. Dimethylxanthine levels ranged from 757.38 to 862.35 ng/L, higher than those in African rivers (Archer et al., 2017), potentially linked to local caffeine consumption.

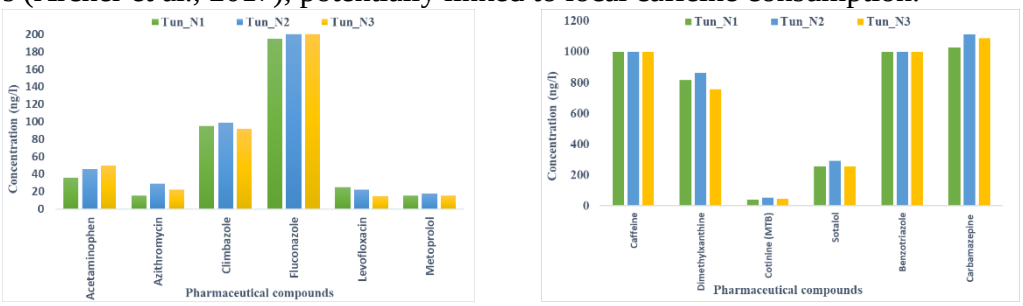

Fig.2. Pharmaceutical compounds (ng/l) in the water sampling of drain of Khniss

Environmental risk assessment

An environmental risk assessment (ERA) was conducted for substances that are ubiquitous in the water samples from the Khniss drain, as well as for compounds included in the watch list. The data indicate that carbamazepine (CBZ), dimethylxanthine, and caffeine present a high environmental risk, while sotalol is assessed at a medium to high risk level.

Conclusion

In conclusion, twelve pharmaceutical compounds were detected in the Khniss drain, with carbamazepine (CBZ), caffeine, and dimethylxanthine presenting the highest environmental risks. CBZ, at levels exceeding 1000 ng/L, highlights persistent contamination, while caffeine's resistance to biodegradation amplifies its impact. The environmental risk assessment confirms the urgent need for monitoring and mitigation to safeguard the Bay of Monastir.

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PC-Or-04

CO_2 Emissions from Soils Fertilized with Arable Crop Wastes Pre-treated by Anaerobic Digestion and Pyrolysis

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Introduction/Objective

The sustainable management of organic waste has gained increasing attention as a means to address soil degradation, particularly in sandy loam soils, which are prone to poor water retention and low nutrient availability. Anaerobic Digestion (AD), a widely utilized process for organic waste treatment, offers multiple benefits, including waste stabilization, methane recovery, and the reduction of greenhouse gas emissions [1, 2]. However, effectively valorizing the by-products of AD, specifically solid digestate, presents challenges that require careful consideration. Solid digestate, commonly used as a soil amendment, has improved soil fertility and physical properties [3]. Despite these benefits, concerns remain regarding the potential presence of contaminants such as heavy metals, pathogens, and organic pollutants, as well as the risk of increased CO_2 emissions due to rapid decomposition. Converting solid digestate into biochar through pyrolysis (in the absence of oxygen) presents a promising solution. Biochar enhances soil structure, increases nutrient retention, reduces contaminant mobility, and promotes carbon sequestration. Recent studies have demonstrated that biochar can improve soil quality while reducing greenhouse gas emissions, including CO_2 [4]. This study evaluates the impact of solid digestate and its derived biochar on soil properties such as pH, organic carbon content, nutrient availability, microbial activity, and CO_2 emissions. The research aims to explore the potential of these amendments to enhance soil quality and water retention, contributing to sustainable agricultural practices in sandy loam soils.

Methodology

A 24-week incubation study at 25°C assessed the effects of solid digestate (SD) and its derived biochar (DB) on sandy loam soils. Soil samples (100 g) were amended with SD and DB at 0, 50, 75, and 100 tons per hectare (T/ha), with each treatment replicated three times in sealed glass bottles.

A non-destructive experiment was conducted in parallel to measure C mineralization. CO_2 released was trapped in 0.5 M NaOH and quantified with measurements taken at multiple intervals from 1 to 180 days.

Soil pH and Electrical Conductivity (EC) were measured in soil/water slurries (1:5 and 1:2.5, respectively). Total organic carbon (TOC) was determined by the Walkley-Black method, total nitrogen (TN) by Bremner (1996) [5], and nitrates (NO_3^-) by distillation [6].

Total heterotrophic bacteria and fungi were enumerated as colony-forming units and protease activity was measured spectrophotometrically by tyrosine release after incubation with casein.

Result/Discussion

The application of both solid digestate (SD) and its derived biochar (DB) increased soil pH in a dose-dependent manner. The most notable increase occurred at the highest rate (100 t/ha), where pH values rose significantly from 7.58 in the control soil to 8.46 for SD100 and 8.53 for DB100. Additionally, the accumulation of SD and DB over six months led to a significant dose-dependent rise in soil electrical conductivity (EC). EC values ranged from 777 μS/cm in the control soil to 980 μS/cm with SD and 864 μS/cm for DB at 100 t/ha.

Soil respiration results revealed that SD applied at the highest dose (100 t/ha), generated five times more CO_2 (5676 mg C/kg) than the control soil (1044 mg C/kg), whereas DB-amended soils only produced 1570 mg C/kg. At 50 t/ha, SD generated three times more CO2 than DB, further indicating SD's rapid decomposition.

These findings align with TOC results, which show that more carbon remained in DB-amended soil than in SD-amended soils, where respiration rates were higher. Specifically, DB at 100 t/ha increased TOC content to 3.27%, compared to 1.76% in SD-amended soil. Both values exceeded the TOC of unamended soil (1%), indicating that both amendments improved soil organic content.

Regarding total nitrogen (TN), SD and DB significantly increased TN levels. At 100 t/ha, SD resulted in TN content of 0.098%, while DB reached 0.042%, reflecting their contributions to soil fertility.

Conclusion

This study demonstrated that both solid digestate (SD) and its derived biochar (DB) improved the physicochemical and biological properties of sandy loamy soils. While SD increased organic carbon and nitrogen content, it also resulted in higher CO_2 emissions due to rapid decomposition. In contrast, DB improved soil properties while reducing CO_2 emissions, highlighting its potential for carbon sequestration. Therefore, DB represents a more sustainable option for enhancing soil quality and minimizing environmental impacts.

Keywords: Solid digestate, biochar, CO_2 emissions, sandy loam soil, Anaerobic Digestion, Pyrolysis

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PC-Or-05

Effect of sewage sludge and municipal solid waste biochars on the physicochemical and biological properties of a sandy soil

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Introduction/Objective

In the last decades, the rapid population growth and high urban development have increased the production of sewage sludge**[1]** and municipal solid waste (MSW)**[2]**.Thus, environmentalists are taking efforts to develop /effective treatment technologies for converting wastes to sustainable value-added products. The pyrolysis of municipal solid waste and sewage sludge is a thermochemical process producing three by-products biochar, gas and biooil. There is an emerging trend of biochar applications in the areas of pollutant removal, soil remediation, agriculture and engineering applications **[3]**due to its large specific surface area, high aromatization, and porous structure**[2]**. Biochar amendment has been a viable method for soil improvement due to its low density, high porosity, pH, cation exchange capacity, surface area, and its capacity to sequester carbon **[3]**.For these aims, we attempted in this work to study the effect of sewage sludge biochar and municipal solid waste biochar on soil physicochemical and biological properties.

Methodology

The biochar used in this work was produced from sewage sludge (BSS) and municipal solid waste (Bmsw). The incubation study was conducted at 25 ◦C in the dark using 100 g of soil sieved through 2-mm mesh and then amended with three doses of BSS and BMSW biochars corresponding to equivalent field applications of 10 t/ha, 20 t/ha and 40 t/ha. The treatments were the following: (1) control soil without amendments (S); (2) soil with BSS (S +BSS); (3) soil with biochar BMSW (S+BMSW). Unamended soil was used as a control, and all treatments were performed in triplicate. Soil parameters were measured periodically up to 12 weeks (W12) of incubation after destructive sampling. Physical and chemical analyses were conducted using air-dried soil samples sieved through 2 mm mesh. Soil pH and EC were determined respectively in (1:2.5) and (1:5) slurry. Ammonium (NH_4^+) and Nitrates (NO_3^-)were determined by colorimetric methods using a ThermoSpectronic UV-VIS spectrophotometer. Microbial biomass C (BC) was determined by the fumigation-extraction method using a Kc factor of 0.45[4].

Result/Discussion

Microbial respiration: Figure 1 shows the variation in cumulative CO_2 released during the mineralization of two biochars for three application rates of 10 t/ha, 20 t/ha and 40 t/ha. The addition of the biochars stimulated microbial activity, resulting in an increase of C-CO_2release during the first few days of incubation as compared to control. Soil amended with municipal solid waste biochar (Bmsw) released more CO_2 than soil amended with sludge biochar (BSS).In fact, the high rates of CO_2 were observed in the soil amended with only 20 t/ha of biochar (Bmsw). After 120 days of incubation, CO_2 levels reached 2142 mg/kg in soil S amended with

20 t/ha, followed by 40 t/ha (2062 mg/kg) and then 10 t/ha (1910 mg/kg). For sludge biochar (BSS), the highest CO_2 releases were observed in the amended soil at 10 t/ha (2150 mg/kg), followed by 20 t/ha (1936 mg/kg) and 40 t/ha (1894 mg/kg).

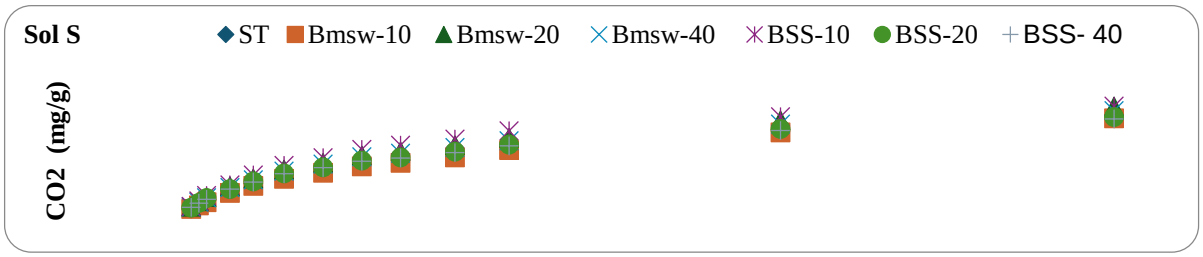

Fig. 1. Cumulative CO_2 variation

Microbial biomass Carbon (BC): The results in Figure 2 show that microbial biomass BC varies with biochar dose. At the start of incubation (first week), the addition of Bmsw at a dose of 10t/ha to soil S produced a notable rise in BC to 320 mg/kg, which was higher than that of soils amended with Bmsw-20 (103.7 mg/Kg) and Bmsw-40 (42.7 mg/Kg).

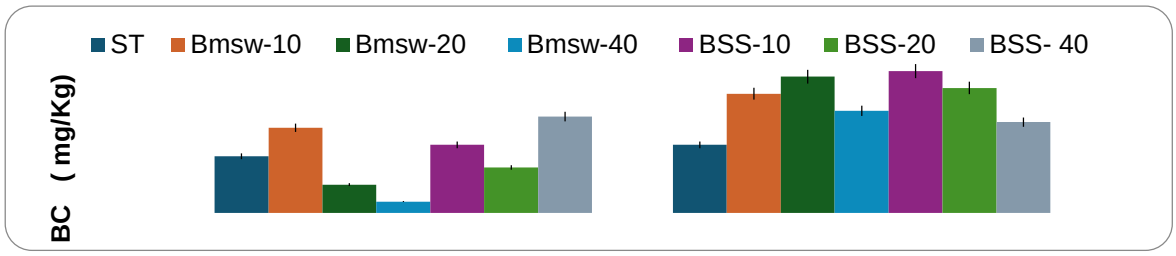

Fig.2. variation of the BC according to the amendment applied

Conclusion

The contribution of amendments such as sewage sludge biochar and municipal solid waste biochar ensures the modification of soil structure and the improvement of its physical and/or chemical and/or biological properties. These amendments increase soil fertility by stimulating soil biological activity and consequently increasing the availability of fertilizing elements. In our context, we are interested in the effectiveness of these amendments in improving the physical, chemical and biological properties of soil.

Keywords: sludge, municipal solid waste, biochar, soil incubation,

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PC-Or-06

Sediment Contamination Patterns in Tabarka's Coastal Ecosystem, Northwestern Tunisia: An Integrative Analysis of Trace Metals and Nutrient Loading Dynamics

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Introduction/Objective

Mediterranean coastal regions are increasingly vulnerable to the combined pressures of climate change and human activities, which accelerate the accumulation of contaminants in marine sediments. The El Kebir River and its tributaries play a significant role in transporting pollutants into the coastal ecosystems of northwestern Tunisia. Recent studies have shown that such inputs can profoundly impact sediment quality, disrupting marine ecosystems (Doe & Smith, 2023). This study aims to assess the impacts of trace metal elements, total organic carbon (TOC), and nutrients from the El Kebir River on the sediment quality of Tabarka's coastal ecosystem. By understanding the sources and distribution of these contaminants, we aim to inform better water management practices to safeguard marine ecosystems in the region.

Methodology

In May 2024, 24 surface sediment samples were collected from both the downstream sections of the El Kebir River and the adjacent coastal waters of Tabarka. The samples were analyzed for trace metals (Zn, Pb, Cu, Fe, Ni) using Atomic Absorption Spectrometry (AAS), following methods similar to those described by Roe and Brown (2021). TOC was determined using the wet oxidation method, and total nitrogen was measured using the Kjeldahl method. The Pollution Load Index (PLI), Enrichment Factors (EF), and other pollution indices were used to assess contamination levels and identify sources of pollution. Sediment quality indices were calculated using local geochemical background trace metal concentrations to evaluate contamination

Results/Discussion

The results reveal substantial contamination in the sediments, with trace metal concentrations as follows: Fe (25,88 mg/kg), Cu (9.45 mg/kg), Zn (81.16 mg/kg), Pb (35.70 mg/kg), and Ni (44.45 mg/kg). The TOC content averaged 0.93%, indicating a moderate level of organic enrichment in the sediments, likely linked to anthropogenic inputs such as wastewater discharge and agricultural runoff. Total nitrogen was absent in the marine stations of the study area but was detected in the El Kebir River stations, oscillating between 0.3% and 0.52%. The highest value was recorded at station S2, located upstream of the wastewater treatment station, suggesting that nitrogen inputs may originate from untreated wastewater and agricultural activities. This pattern reflects the influence of nutrient loading from land-based sources on the riverine stations.

Using pollution indices, we identified two primary components that explain a significant portion of the variance in metal concentrations, reflecting the underlying contamination sources.

The first principal component accounted for approximately 65% of the total variance and was strongly correlated with Fe, Zn, and Cu, indicating these metals share a common origin, likely from wastewater discharge and urban runoff. The high loading for these elements suggests they may be transported through similar mechanisms, such as adsorption onto fine sediment particles and subsequent deposition in coastal zones.

The second component, explaining an additional 20% of the variance, was primarily associated with Pb and Ni, possibly indicating separate anthropogenic sources such as agricultural activities, and untreated wastewater discharge. The distinct association of Pb and Ni suggests that while these metals are influenced by human activities, their transport and accumulation mechanisms may differ slightly, involving complex pathways such as the acceleration of chemical alteration of geological outcrops due to climate change, which has intensified in recent decades, or direct discharge into river tributaries. Notably, the significant correlations among trace metals imply that multiple pollutants often co-occur in the same areas, influenced by overlapping sources such as wastewater discharge and agricultural runoff. The loading patterns also indicate that fine sediments, rich in organic matter, serve as efficient carriers for these metals, facilitating their accumulation in the coastal ecosystem.

Conclusion

This study highlights the significant impact of anthropogenic activities and climate change on the sediment quality of Tabarka's coastal ecosystem. The elevated concentrations of trace metals and total organic carbon in the sediments, along with the presence of total nitrogen in the El Kebir River, underscore the critical role of wastewater discharge and agricultural runoff as sources of contamination. The use of pollution indices has provided valuable insights into the complex relationships among contaminants, revealing that multiple pollutants often share common origins and transport mechanisms.

The findings indicate that the coastal sediments are subject to moderate pollution levels, primarily due to direct inputs from the El Kebir River. This calls for immediate action to enhance wastewater treatment processes and implement effective pollution control measures in the watershed. By addressing these issues, we can mitigate sediment contamination and protect the marine ecosystems that are vital for both biodiversity and local livelihoods. Future research should focus on developing comprehensive management strategies to address multiple contaminants, ensuring the long-term health of coastal environments in the Mediterranean region.

Keywords: Trace Metals, Sediment Quality, Coastal Ecosystems, Wastewater Discharge, Pollution Indices

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PC-Or-07

Anthropogenic effects and contamination of Gabes Gulf coastline: geochemical and numerical approaches

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Introduction/Objective

Coastal environments represent an great capital due to the value of their ecosystems, their cultural heritage, the importance of their social function and their maritime identity. The coastline is also a coveted space where transport infrastructure, tourist urbanization and many industrial installations are concentrated. Population growth, agriculture and the industrial sector are often responsible for coastal degradation and pollution of marine areas. The producing, regenerating and receiving environments are thus heavily solicited and polluted. Interaction between these environments and the imbalance caused by anthropogenic effects deserve to be studied in order to understand how marine environments function and their vulnerability to external disturbances. This study deals with the characterization of the coastline contamination observed in southwest of Tunisia. Particular interest is given to the effect of industrial discharges on the degradation of the coast from Zarat to Skhira. Several potential contaminants were identified. They are differentiated by their compositions, their origins, their vulnerabilities, their degradability as well as by their potential to mutate through reactions with other elements.

Methodology

Sand samples were collected along the coast of the city of Gabès (from Zarat) and up to Skhira North (fig. 1). At each site, two samples were taken in plastic bags designed to be used for this type of sampling. At each point, a sample from the beach and another from the intertidal are taken. A total of 40 samples were taken along the coast of the study area. The various analyses were carried out in the laboratories of the Higher Institute of Water Sciences and Techniques. The concentration of the following elements was measured, by ion chromatography, for the forty samples concerned: Cl, Br, PO4, SO4, Na and Ca. The concentration of heavy metals (Cu, Zn, Pb, Cd) was carried out using atomic absorption. Radioactivity counting was performed using a Geiger counter.

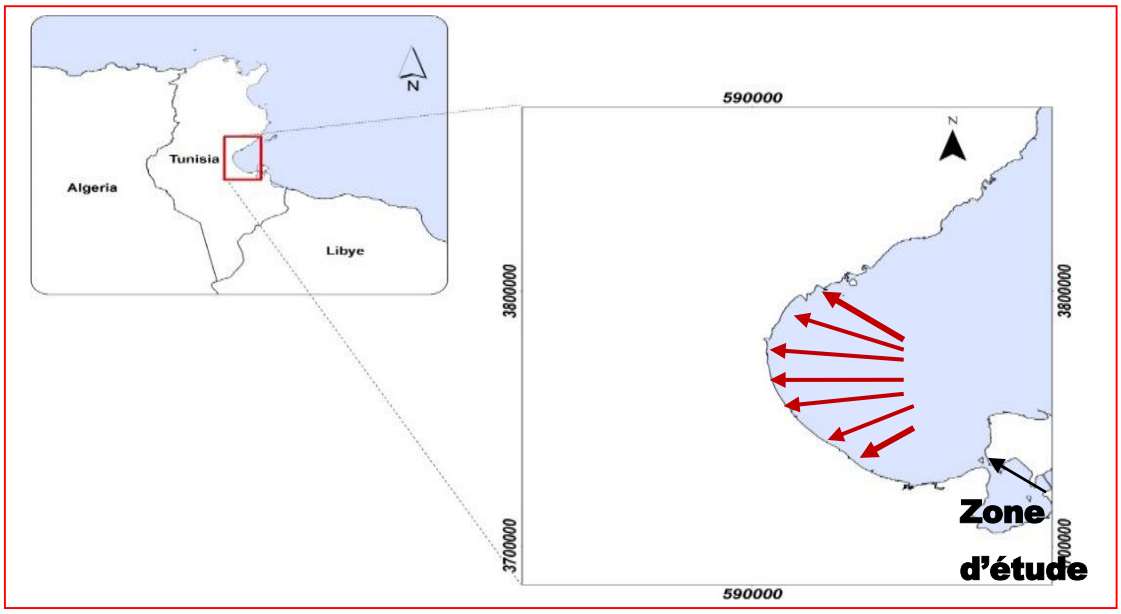

Fig. 1 Studied area

Result/Discussion

The approaches adapted to assess the level of contamination of the coastline from Zarat to Skhira undoubtedly show high levels contamination of surface sediments. In particular, values of Copper, Lead, Cadmium and Phosphorus are high and indicate a severe degradation of the receiving environment. An accumulation of these pollutants is identifiable by concentrations exceeding standards. The spatial variation of pollutants reveals the contribution of coastal drift and wind in the transport and deposition process. It also appears that chemical interactions between certain contaminants have been established and contribute significantly to the enrichment of sediments in heavy metals. he different levels of radioactivity measured at the level of the major part of the study area reveal that half of the values are higher than the limit dose set at 11 SV/h. However, the radioactivity values remain relatively low except in the areas around the phosphate transformation plants into acid.

PC-Or-08

Extent of anthropogenic influence on surface water quality in the wadi Nil watershed (northeastern Algeria): an integrated assessment based on selected characteristic indices.

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Introduction/Objective

The present study assesses the impact of natural and anthropogenic processes on the surface waters of Wadi Nil and its tributaries, located in the Wadi Nil watershed 20 km from the city of Jijel (northeastern Algeria). This systematic assessment of water resources in the Wadi Nil watershed is carried out using the Organic Pollution Index (OPI), the Water Nutrient Pollution Index (WNPI) and the Water Quality Index (WQI). Seventeen water quality parameters were analyzed from ten (10) water samples collected during the month of April. The relationship between hydrological and climatological variables and certain anthropogenic activities with the spatial behavior of water quality parameters is presented to identify sources of water quality alteration due to urbanization.

Methodology

Sampling methods, the choice of sampling points, their conservation and the methods used to carry out the chemical analysis form the basis of the credibility and interpretation of the results. To do this, a sampling plan was drawn up, taking into account the various anthropogenic activities present in the study area, in order to acquire information representative of the spatial evolution of water quality from upstream to downstream.. Samples were taken in the milieu of the wadis in order to obtain a representative sample of wadi water quality (APHA, 2017), in polyethylene bottles after being rinsed 3 to 4 once with the same water sampled and kept in a coolbox at a temperature of 4°C.

Leclercq 2001's Organic Pollution Index (OPI) was used to assess organic pollution in the river. The OPI classifies water quality into five categories, derived from ammonium, nitrite, biochemical oxygen demand (BOD_5) and orthophosphate concentrations (Abahi et al., 2023).

In this study, the nutrient pollution index (WNPI) was used to examine the influence of domestic discharges and the impact of NPK fertilizers on surface waters in the Wadi Nil watershed. Several previous studies have used WNPI (Tokalti, 2021; Isiuku and Enyoh, 2020; Egbueri et al, 2023) using only NO_3^-, PO_4^{-2} and K^+, Whereas in our study other parameters such as NO_2 and NH_4^+ were included in place of NO_3^-, in order to better understand the impact of urban discharges on surface water quality in the Nil wadi watershed according to equation (1).

$$\text{WNPI} = \frac{C(NO_2^-)}{MAC(NO_2^-)} + \frac{C(NH_4^+)}{MAC(NH_4^+)} + \frac{C(PO_4^{2-})}{MAC(PO_4^{2-})} + \frac{C(K^+)}{MAC(K^+)} \quad \ldots\ldots\ldots (1)$$

The WQI can be used to assess the status and trends in the environment's ability to support human and ecological health. In this study, the WQI was calculated on the basis of sixteen water quality parameters (pH, dissolved oxygen, EC, Mg, Na, K, Cl, HCO_3, TH, SO_4, PO_4, NO_3, NO_2, NH_4, Pb, and Cd), using a weighted arithmetic index calculation method (Mgbenu, and Egbueri, 2019). The WQI was calculated using equation (2).

$$WQI = \frac{\sum_{i=1}^{n}(Qi * Wi)}{\sum_{i=1}^{n} Wi} \quad .....(2)$$

Result/Discussion

The organic pollution index (*fig.1*) and the water nutrient pollution index (*tab.1*) reveal a degradation in water quality from upstream to downstream, confirming the impact of anthropogenic discharges on water quality degradation. The WQI calculated for the surface water stations sampled in the study area ranged from 114 to 232, with an average of 160 (*tab.1*). The WQI values made it possible to distinguish a single water quality category, that of non-potable water (WQI>100), observed at all stations due to high lead and cadmium levels resulting from untreated domestic discharges and the intensification of agricultural activities in the downstream part of the watershed.

Tab. 1:WQI and WNPI value for surface waters in the Nil wadi watershed

	WNPI	Water quality	WQI	Water quality
OB1	1,72	Moderately polluted	187.2	Non-potable
OB2	0,6	Not polluted	171.3	Non-potable
OB3	1,5	Moderately polluted	178.5	Non-potable
OS1	0,5	Not polluted	128.24	Non-potable
OS2	0,73	Not polluted	179.7	Non-potable
OS3	2	Moderately polluted	232	Non-potable
ON1	0,3	Not polluted	149	Non-potable
ON2	0,74	Not polluted	208	Non-potable
ON3	0,4	Not polluted	229	Non-potable
ON4	1,004	Moderately polluted	114.5	Non-potable

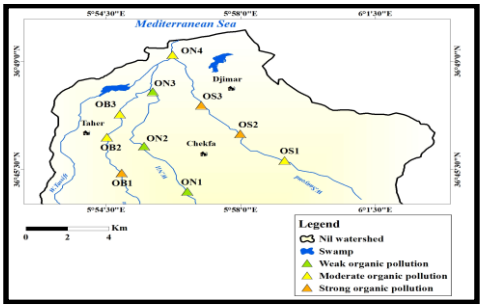

Fig.1:Map of the Organic Pollution Index (OPI) of surface water of Nil wadi watershed

Conclusion

IPO values indicate that 40% of samples show moderate organic pollution, particularly at stations OS3, OB3 and ON4. This increased pollution is associated with high levels of nitrites and phosphates. With regard to nutrient pollution, the WNPI index reveals that 40% of the watershed's surface waters are moderately polluted. Despite the intensity of anthropogenic activities in the study area, the impact of nutrient pollutants on water quality remains relatively limited. Analysis of the water quality index (WQI) indicates that all surface waters are non-potable and severely polluted, requiring appropriate treatment before use. Water quality degradation is linked to major anthropogenic activities.

Keywords, surface waters, watershed, water quality, pollution indices, major elements, Jijel.

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PC-Or-09

Assessment of water quality status using heavy metal pollution indices : A case study from Sidi Driss mine, (North West of Tunisia)

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Introduction/Objective

The Damous wadi drains the Sidi Driss mining deposit and is located approximately 1-3 meters below the Sidi el Barrak dam which holds significant importance on various levels, including economic and environmental aspects, the dam serves to store water for irrigating the surrounding agricultural lands so it plays a crucial role in food security, water resource management, flood prevention, and the overall well-being of the region. The present study aims to (1) investigate the concentration of 22 Heavy Metals (2) evaluate the degree of Heavy Metal contamination in the river by calculating the water quality index.

Methodology

Surface water samples were collected from seven sites, six sites along the Damous wadi and a control site outside the stream in september 2022 in plastic bottles preconditioned with 5% nitric acid and rinsed with distilled de-ionized water. Before sampling, the precleaned sample bottles were immersed about 10 cm below the surface and then the bottles were sealed with gauze and put into a portable refrigerator set at a consistent temperature of 4 °C.

Result/Discussion

The Water quality index **(WQI)** is one of the most successful tools to represent information on the quality of streams, lakes or any water body (Dandge et al., 2021 ; Sethi et al., 2023). The water quality classification based on WQI values revealed that all sites had significant polluted water with respect to metal contamination, except for S1 (Test site) and S2 (the upstream of the Damous wadi), which had WQI values of 0.04 and 0.5 respectively are considred as clean water. The significant water pollution was observed mainly at the sites which corresponds to the downstream (S5, S6, S7) with high values exceeding 2 with value of 4.46, 4.61 and 3.26 respectively. The increase in levels at these sites is due to the leaching of Zinc and Lead mineral deposits and the mine dumps effect. The heavy metal pollution index **(HPI)** of the studied waters were calcluated, the results are presented in Figure 1. The recorded values of HPI showed that the average of HPI were 0.738 to 36.66. The highest HPI values were recorded at the sites S4, S5, S6 and S7. According to (Dheeraj et al., 2023; Sethi et al ., 2023) the water sources were classified as low (< 15 HPI), medium (15–30 HPI), and high pollution (> 30 HPI). So S4, S5, S6 and S7 were classed as sites with high pollution, however the test site S1, S2 and S3 are considered as sites with low pollution. Our results confirmed the previous work of (Salhi et al., 2023), in fact the main sources of the pollution was principally due to the occurrence at surface of sulphides which are oxidised, released and leached. This oxidation process generates acid

mine drainage (AMD), causing the dissolution of carbonates, such as cerussite, from Pb which is released and leached underground (Salhi et al., 2023).

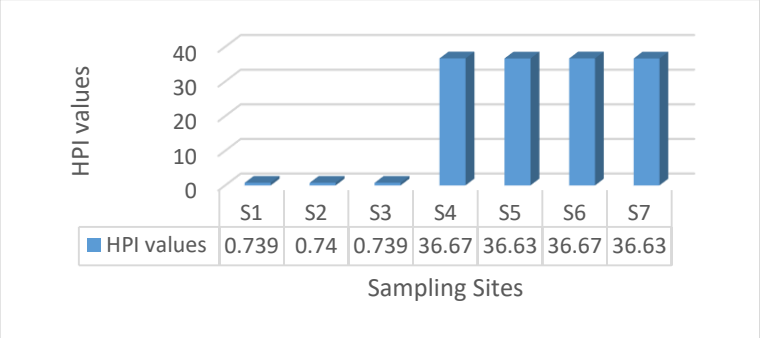

Fig.1. Histogram of HPI values in the study area Degree of contamination (C_d)

PCA (Figure 2) showed highest pollution at the sites of the Damous downstream (S5, S6, S7) influenced strongly by Mn, Cd and Zn emphasizing a common origin and indicated the anthropogenic activity of the mine Pb-Zn.

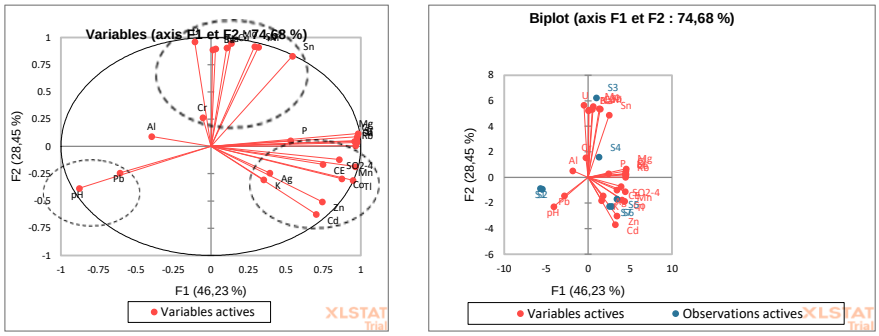

Fig. 2. Results of PCA grouping after Varimax rotation.

Conclusion

The analysis, revealed high concentrations of Sr, Ru, Mn, Zn and Cu exceeding the standards (WHO and Tunisian Standard NT 106.02) resulting from mining activities were found in mine tailings river. By using the four recognisable methods C_d, HPI, and HEI, WQI the heavy metal indices were evaluated in the study area. The water pollution indices show a significant pollution towards the Damous downstream which indicates that the water samples are critically polluted. The Water Quality index (WQI) revealed a significant water pollution mainly at the sites which corresponds to the downstream (S5, S6, S7) with high values exceeding 2 with value of 4.46, 4.61 and 3.26 respectively. The Heavy metal pollution index (HPI) classed the sites S4, S5, S6 and S7 as sites with high pollution. The Heavy metal evaluation index (HEI), considered sites S1, S2, S3, S4 as sites with low pollution (HEI < 15), however S5, S6, S7 are classed as sites with medium pollution (HEI between 15 and 30). We note that the pollution increases significantly from the upstream to the downstream.

Keywords: Assessement, Sidi Driss mine, water, metal pollution index

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PC-Or-10

Conductometric study of struvite prenucleation stage

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Introduction/Objective

Eutrophication can have a number of undesirable effects on aquatic ecosystems. (1)Phosphorus is the limiting factor in reducing eutrophication. It is therefore necessary to limit phosphorus inputs into natural waters.

One of the major problems encountered during effluent treatment is the formation of struvite deposits, which affect treatment efficiency and can endomage plants by clogging pipes.

The study of the struvite germination stage using conductivity was studied for the first time in our laboratory. In this work, we applied a method based on the modeling of electrical conductivity data obtained during the controlled rapid precipitation of struvite. This method was used to highlight the role of the ion pair responsible for pre-nucleation. Good agreement was obtained by considering the Mcclesky model. Taking into account the formation of an intermediate phase, consisting of the MgNH4PO4° triple ion, in the conductivity calculation may explain the decrease of the conductivity observed during the germination stage.

Methodology

In the precipitation test, 0.5 L of solution containing $NH_4H_2PO_4$ and $MgCO_3$ is placed in a glass cell and immersed in a thermostatic bath maintained at different temperatures 20°C and stirred at 800 rpm using a magnetic stirrer to accelerate the CO_2 degassing. Samples of (1 mL) were taken every minute to determine the concentration of PO_4^{3-} ions by vanadomolybdic complexation. Monitoring pH and conductivity made it possible to detect the nucleation time.

Result/Discussion

Measurement of electric conductivity in dilute solution is one of the important methods for studying ion pair formation.

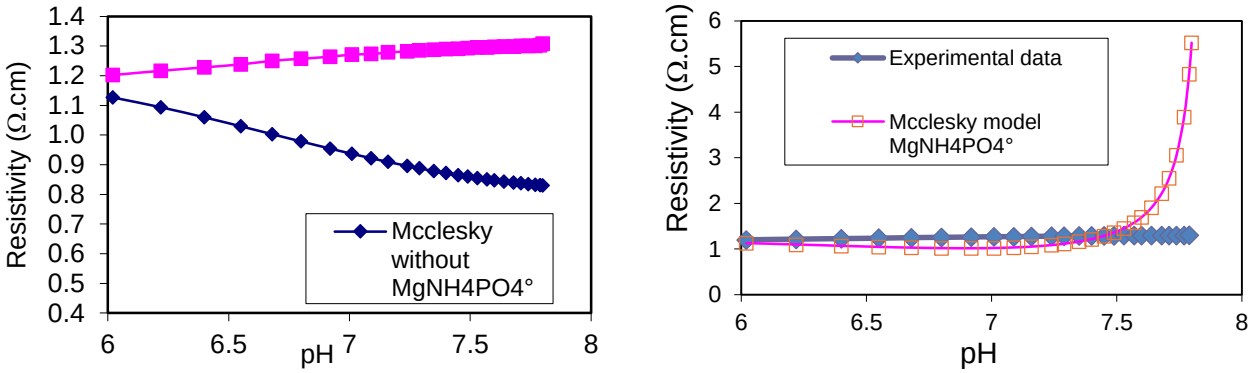
Results show a slight increase of the experimental conductivity, while theoretical conductivity decreases. This deviation can be attributed to the formation of ionic complex. In fact, the ion Mg is susceptible to react with other anions present in solution (phosphate ion PO_4^{3-}, monohydrogen phospohate ion HPO_4^{2-} or dihydrogen phospohate $H_2PO_4^{-}$) leading to three complex : $MgPO_4^{-}$, $MgH_2PO_4^{+}$, $MgHPO_4^{0}$.

A simulation of experimental conductivity considering the formation of $MgPO_4^{-}$ and $MgH_2PO_4^{+}$, seems not having effect. However, the introduction of $MgHPO_4^{0}$ in calculation of conductivity causes a remarkable increase. Because this ion pair is not charged, it can't contribute to the flow of conduction since the conductivity depends on charged species.

In a previous work Gal et al.(2) suggested the formation of the ion pair $CaCO_3^{\circ}$ as a pre-nuclei for the evolution of the calco-carbonic system toward precipitation. Therefore, $MgNH_4PO_4^{\circ}$ can be involved in the nucleation mechanism of struvite according to the following reaction:

$$Mg^{2+} + NH_4^+ + PO_4^{3-} \rightarrow MgNH_4PO_4^\circ$$

For highlighting the role of this triple-ion in the nucleation process, a simulation of experimental conductivity and calculated one with considering the formation of $MgNH_4PO_4^\circ$ is achieved by determination of the equilibrium constant. Conductivity calculation was performed, using Mcclesky equation(3) $K = \sum z_i \lambda_i C_i$ The value of the conductivity K can be calculated from the ionic molar conductivities λ_i of the ions, their concentration C_i and the number of charges z_i of the ion. The ionic molar conductivities λ_i is a function of both ionic strength and temperature $\lambda_i = \lambda_{0,i}(T) - A(T)\frac{I^{\frac{1}{2}}}{1+BI^{\frac{1}{2}}}$ A and B are constants



Conclusion

In the present work, modeled curves of resistivity /pH compared to the experimental one show that, the Kolhrausch model is the most appropriate among four tested models to follow the evolution of $NH_4H_2PO_4$-$MgCO_3$-H_2O system toward struvite precipitation. Taking into consideration all possible reactions between different ions. this modeling has shown and confirmed the formation of $MgNH_4PO_4^\circ$ triple ion in the reaction. So, during the induction period, $MgNH_4PO_4^\circ$ content increases with time and forms aggregates leading to stable struvite nuclei.

Keywords: struvite, prenucleation

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PC-Or-11

Long-term evolution of water quality and interactions with climate change: Case of the Bab Louta (Taza, Morocco)

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Introduction/Objective

The long-term evolution of the physicochemical and hydrobiological quality of the raw waters from the Bab Louta dam reservoir, located in the Sebou watershed about 15 km from the town of Tahla, Morocco, since its filling in 2001 has shown significant interactions with increasingly restrictive climate change.

Methodology

In order to assess the impact of climate change, analytical and climate change databases have been collected and compiled, additional water quality monitoring has been carried out, and physicochemical and hydrobiological analytical databases have been analysed using appropriate technical and regulatory tools for water quality modelling.

Result/Discussion

The results obtained showed that the quality of the water in the Bab Louta reservoir is satisfactory for drinking water production, with a firm thermal stratification running from June to September, the appearance towards the end of the summer of anoxic conditions in the deep waters, and the presence of undesirable elements, particularly manganese, iron and hydrogen sulphide, which give the water a mouldy odour and an unpleasant taste requiring extensive treatment.

The identification and counting of plankton shows a significant algal biomass in the lake, with the presence of phytoplankton species indicative of a deterioration in biological quality, with a very slight presence of algal toxins and a marked tendency for Lake Bab Louta to be eutrophic.

Also, the correlations between the impact of climate change and the evolution of biological and physicochemical water quality have been implemented. To address the issue of eutrophication and its consequences on water treatment, several measures have been taken at this dam reservoir, including the optimization of water intake levels, the introduction of phytoplankton-feeding, the enhancement of water treatment, and the draining of hypolimnetic waters when hydrological conditions allow.

Conclusion

This study presents an assessment of the quality of the water in the Bab Louta reservoir, the correlations between the various physico-chemical and hydrobiological parameters, the effects of climate change and the measures taken to combat the consequences of eutrophication.

Keywords, Taza, Bab Louta, Eutrophication, Sebou, Tahla, Quality; Climate change, Drinking water, Algal toxins. Databases

PC-Or-12

Assessment of Aquifer Pollution Risk Incorporating Characterization of Vadose and Saturated Zones in Mareth, Southern Tunisia

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Introduction/Objective

Located in the coastal plain of Jefara in south-east Tunisia, the mio-plio-quaternary aquifer in Mareth drained by 5 main channels: O. Zigzaou, O. Zerkine, O. Ferd, O. Sourrag and O. Segui Mareth. Segui Mareth, which contribute 11,042,590 m3/year to the replenishment of the mio-plio-quaternary aquifer, divided between direct filtration (5,250,640 m3/year) and filtration after run-off (5,791,950 m3/year), (Chulli et al., 2007). This water table is the oldest to have been exploited in the Gabes governorate serves as a crucial water source. However, it is subject to significant stress due to excessive extraction, this recharge through the soft lithologies of the wadi beds and the and anthropogenic pressures leads to an increased risk of groundwater pollution. This study aims to assess the vulnerability of the Mareth water table to pollution and to identify high-risk areas. In an innovative approach, we have developed and applied a Groundwater Pollution Risk Index (RGPI) framework to classify and map the risk of pollution in the region.

Methodology

In this study, we consider the main parameters that control groundwater sensitivity. For the vadose zone, we examine two parameters: the thickness of each sedimentary layer above the groundwater level and the hydraulic conductivity of each sedimentary unit. For the saturated zone of the aquifer, we assess three parameters: the chemical pollution index, the aquifer productivity index and Groundwater hydrodynamic index. Based on these parameters, a groundwater pollution risk assessment will be carried out to evaluate and monitor the aquifer's susceptibility to contamination.

Result/Discussion

The results reveal a critical situation: more than 40% of the surface area of the zone studied is classified as presenting a very high pollution risk. These results underline the urgent need for immediate and robust measures to protect the aquifer. The methodologies used in this study considerably improve on conventional approaches, providing more accurate assessments of pollution risk through flexible and reliable processing approaches, even with limited data availability.

Conclusion

The advanced methods used make it possible to assess the risks accurately, even with limited data. Immediate action and sustainable management strategies are essential to preserve this vital water resource.

Keywords, Keywords: Groundwater, Groundwater pollution risk index, Mareth, Tunisia

Pollutant Control and Water Quality Assessment

Poster

PC-Po-01

Anthropogenic impacts on a wetland within the Tunis Gulf; wadi Méliane estuary: identification and investigation

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Introduction/Objective

Human activities are causing significant environmental changes in the Gulf of Tunis, particularly at the mouth of the Wadi Méliane. The aim of this study is to exhibit the impact of the inflow of detrital sediments, organic pollutants, heavy metals, and urban runoff on the environmental degradation in this area.

Methodology

The conventional Rock-Eval (RE) method in petroleum geosciences was used to determine the composition of the organic stock in the sediment in the Wadi Méliane estuary. Gas chromatography-mass spectrometry (GC-MS) and high-performance liquid chromatography (HPLC) are employed for biomarker studies, while atomic absorption spectroscopy (AAS) is used for heavy metal research.

Result/Discussion

The sediment composition at the mouth of Wadi Méliane includes sand columns with varying textures and colors, influenced by biological and mineralogical components. These sediments are rich in calcite (20%) and quartz (80%).

Organic matter (TOC: 4.48-7.02%) at the mouth of the Méliane wadi is rich in hydrogenated compounds (HI: 235-376 mgHC/gTOC) and low in oxygenated compounds (IO: 113-152 $mgCO_2$/gTOC). The abundance of free hydrocarbons suggests an oil origin, confirmed by the analysis of aliphatic and aromatic hydrocarbons. The analysis of the analyzed samples shows that there are hopanes and steranes in them, which is a sign of anthropogenic petroligenic pollution. The amount of polycyclic aromatic hydrocarbons (PAHs) in sediment is excessive, as measured by an average of 10183 µg/kg. An abundance of 3-ring PAHs is observed in all profile horizons. POPs are generated from both petroleum and pyrolytic sources, with diesel engine emissions being the main cause. It's common knowledge that these pollutants remain in the environment, bioaccumulate in living organisms, and can have harmful effects on health.

Inorganic inputs like Hg (5-22.26 µg/kg), Cd (<5µg/kg), Cr (307-467 µg/kg), and Pb (589-3069 µg/kg) are also part of this pollution, with a significant presence of Pb. This lead contamination comes in part from mining waste from the Jebel Ressas site, wastewater and atmospheric fallout.

Conclusion

The region's urbanization and industrial activities are the reason behind the pollution load carried by wadis in the Gulf. The marine ecosystem is affected by this runoff, resulting in changes in water quality and sediment composition.

Efforts to mitigate these impacts include monitoring and managing pollution sources, as well as implementing sustainable industrial and urban practices.

Keywords: wetland, hydrocarbons, bioamarkers, POPs, inorganic pollution.

PC-Po-02

Calcined phosphate sludges and metakaolin for alkali-activated geopolymers

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Introduction/Objective

Phosphate mining activities produce significant quantities of phosphate rock, essential for global agricultural and industrial demands. However, these operations also generate waste, including waste rock and phosphatic tailings, leading to serious environmental consequences. Of particular concern are hazardous by-products like phosphate sludge, which contain heavy metals that pose risks of leaching into the environment, potentially contaminating soil and water resources. The extraction of phosphorite by the Gafsa Phosphate Company (CPG) in Tunisia generates million tons of phosphate sludge discharged into hydraulic networks. These discharges present a significant management challenge for sustainable development. This study explores innovative recycling methods using geopolymerization to manage and repurpose this phosphate sludge sustainably.

Methodology

Phosphate sludges were calcined at 700 °C for 3 hours to produce an amorphous phase. The physical and mechanical properties of geopolymers (G1 and G2) formed by gradually substituting alkali-activated metakaolin with two types of calcined phosphate sludge (Cal-PS1 and Cal-PS2) from two phosphate laundries were studied. The microstructure and mechanical properties of the geopolymers were analyzed through various methods, including X-ray diffraction (XRD), X-ray fluorescence (XRF), Fourier-transform infrared spectroscopy (FTIR), compressive strength testing, and specific surface area/porosity measurements. To study the capacity of geopolymers to immobilize heavy metals, leaching test were conducted.

Result/Discussion

XRD and XRF analyses revealed that CaO and SiO_2 were the main oxides in the raw PS1/PS2 samples. Carbonates were present as bearing minerals, while the dominant phases were clinoptilolite in PS1 and heulandite in PS2. The calcined sludges (Cal-PS1 and Cal-PS2) exhibited high SiO_2 and low Al_2O_3 content, necessitating the incorporation of metakaolin. Alkali activation consumed aluminosilicate phases and calcite in geopolymers containing 2.5 wt.%, 5 wt.%, and 10 wt.% of the G1 formulation. In contrast, fluorapatite, quartz, and calcite remained unaltered in geopolymers with 20 wt.% and 40 wt.% G1 and all G2 formulations. Cal-PS1 and Cal-PS2 samples had low densities, and the addition of Cal-PS increased the porosity and apparent density. The sludge density inversely affected the denseness of the samples. Cal-PS1 specimens showed increased strength during curing, with 10 wt.% G1 and 20 wt.% G1 reaching the highest compressive strengths (36 MPa and 37 MPa, respectively) after

30 days. A similar trend was observed in 10 wt.% G2, 20 wt.% G2, and 40 wt.% G2, with 10 wt.% G2 achieving a high compressive strength of 28 MPa after 30 days. However, 2.5 wt.% G2 and 5 wt.% G2 were found to be unstable. Leaching test showed effective heavy metal blocking in geopolymers' network, except for low arsenic levels.

Conclusion

This study introduces a method to repurpose Tunisian phosphate mining sludge by incorporating it into geopolymers with varying proportions of calcined phosphate sludge (2.5 wt.%, 5 wt.%, 10 wt.%, 20 wt.%, and 40 wt.%). The optimal substitution ratio of metakaolin with calcined phosphate sludge was found to be 1.5 (20 wt.%), resulting in compressive strengths of 37 MPa for Cal-PS1 specimens and 28 MPa for Cal-PS2 geopolymers after 30 days. Leaching tests confirmed effective heavy metal containment in the geopolymer matrix, with only minor arsenic release. These results demonstrate the feasibility of recycling Tunisian phosphate sludge through alkali activation to produce sustainable construction materials, offering a viable solution to reduce environmental impact.

Keywords: geopolymers, phosphate sludge, metakaolin, compressive strength, alkali activation.

PC-Po-03

Impact of urbanization on the Tazarka lagoon: sedimentological and geochemical characterization

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Introduction/Objective

Wetlands play a crucial role in maintaining the ecological balance of our planet, serving as critical habitats for a diverse array of flora and fauna The profound significance of wetlands extends far beyond their local ecosystems, as they serve as vital regulators of global climate patterns and biogeochemical cycles. Wetlands are complex and dynamic ecosystems that provide invaluable ecosystem services, such as water purification, flood control, and carbon sequestration, making them integral to the health and resilience of our planet.

The eastern coast of Cap Bon is marked by a series of lagoons stretching from Maâmoura to Kélibia, including the Tazarka lagoon. This area is notable for its rich natural and cultural heritage, recognized as a Ramsar site.

Industrial, agricultural, and urban activities exert significant pressure on the lagoon, impacting environmental parameters like air quality, water quality, and soil health. This influence is evident in foul odors, the discharge of liquid and solid waste, as well as the presence of flies and mosquitoes.

Methodology

Over two days, we conducted a sampling expedition to the lagoon of Tazerka. During this time, we collected a 13 water samples and sediment samples from various locations along the borders of the lagoon. The physical parameters of water and sediments such as: pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) were measured in situ using a multiparameter. In the laboratory, these samples were subject to garanulometric characterization using a Mastersizer 3000 Malvern laser particle size analyzer. Heavy metal analyzes were carried out by Atomic Absorption Spectroscopy.

Result/Discussion

During our fieldwork, we observed a concerning trend: the gradual encroachment of agricultural zones towards the marshy areas of the lagoon (Fig. 19). This expansion has significant implications for its ecosystem. The conversion of marshy zones into agricultural land alters natural hydrological patterns and disrupts the delicate balance of the lagoon's ecosystem. Wetlands and marshes play crucial roles in filtering pollutants, stabilizing shorelines, and providing habitat for diverse flora and fauna. Their transformation into agricultural zones often involves drainage, land reclamation, and the use of fertilizers and pesticides, which can introduce excess nutrients and contaminants into the lagoon. These changes can lead to water quality degradation, increased sedimentation, and loss of biodiversity.

Areas impacted by industrial discharges are marked by the presence of freshwater vegetation and an increase in algae proliferation. This phenomenon suggests potential eutrophication, often resulting from nutrient inflow associated with industrial activities. The abundant freshwater plants indicate that these species have adapted to the altered environmental conditions, thriving

despite pollution. Sediment in these areas is often visibly blackened, indicative of pollutants. The presence of hydrogen sulfide (H_2S) contributes to a foul odor, further highlighting environmental degradation. Moreover, some sections are marred by construction waste, compounding ecological stressors. This situation highlights the ecological changes occurring in the lagoon, driven by human activity, and raises concerns about the long-term health and balance of the ecosystem.

The pH and salinity levels in the lagoon are decreasing due to freshwater input from the sewage treatment plant (STEP) and industrial discharge. This reduction in salinity is leading to algal blooms and potentially causing eutrophication and the invasion of flies and mosquitoes.

The spatial distribution of metallic pollutants such as Copper, Zinc and Chromium in the lagoon shows a clear contamination gradient. The highest levels are observed in the south, in the industrial discharge zone. Whereas, discharges from the STEP present moderate levels of contamination. However, the center of the lagoon is more affected and thus presents a zone of accumulation of pollutants due to the weak water current opposing the propagation of pollutants.

Conclusion

The liquid and solid waste discharges around the Lagoon are causing pollution characterized by high levels of trace elements in sediment such as Copper, Zinc and Chromium.

To ensure effective environmental management of Tazarka Lagoon, the following measures are recommended:

-The wastewater from the STEP is increasing the freshwater input in the Lagoon but might also be impacting water enrichment with nutrients that aid in the proliferation of green algae. An analysis of nutrient elements is necessary as well as control and treatment of wastewater.

-Monitoring all discharges into the lagoon, particularly industrial liquid and solid is necessary.

- Regulate grazing and the exploitation of reed beds.

- Promote ecological agricultural practices to reduce pollution from the excessive use of chemical fertilizers and pesticides.

Keywords: lagoon, Tazarka, sediment, pollution, metal, Tunisia.

PC-Po-04

The effect of some chemical parameters of drinking water in the municipality of Qasr Al-Akhyar- Libya

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Introduction/Objective

Water is one of the natural resources in the world and is a basic source for preserving human, animal and plant life and has a great impact on the country's economy and all human activities. Over the past twenty years, the pressure on water resources has increased due to population and industrial growth and the increasing demand for agricultural and household products, which has become a major concern for the international community.The aim of this study is to analyze drinking water physically and bacteriologically in the city of Nalut.

Methodology

The study included different sites in the city and thirty-six samples were collected from groundwater, wells and various tanks belonging to the state, as well as private wells and the Ain Tala water spring. Other samples were collected from subsurface water tanks filled with rainwater during the rainy season. These samples were subjected to examination of their physical, chemical and biological conditions and the results were compared with the Libyan and World Health Organization specifications for drinking water in order to evaluate the quality of drinking water in the city of Qasr Khiar.

Result/Discussion

The physical and chemical examination of the water samples showed acceptable values of acidity and electrical conductivity. Turbidity was found in the water samples collected from the subsurface reservoirs compared to the Libyan and WHO standards. The acidity was high in the subsurface reservoir water samples and some other groundwater samples that were higher in electrical conductivity. The alkalinity, dissolved solids and water hardness levels in the collected samples were below the maximum acceptable levels for drinking water as recommended by the Libyan and WHO standards. The biological examination results also showed that the water samples were free from coliform bacteria.

Key words: Quality, Agriculture, region, reservoir, Evaluation.

PC-Po-05

Tackling Water Security Challenges through Pollution Control: A Unified Framework for Microplastic Extraction and Analysis

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Introduction and objectives

Water security is a critical concern, particularly in the face of escalating pollution challenges that threaten both ecosystems and human health. Among the most pervasive pollutants are microplastics, whose widespread presence in water systems demands efficient and standardized methods for their extraction and analysis. This study presents a unified framework for the extraction and analysis of microplastics, currently under patent development.

Methodology

The method combines acid digestion, density separation with low-cost, eco-friendly reagents, filtration through 0.45 μm membranes, and FTIR analysis to efficiently identify microplastics.

Results and discussion

This approach efficiently detects microplastics across a size range from 4 um to 2 mm, in various forms such as Microbeads, fibers, fragments, films and foams. Identified polymers include PVC, PVUC, nylon, PET, PP, and PU, with a variety of colors including black, yellow, blue, transparent, brown, red, and pink.

Conclusion

In addition to wastewater samples, the same protocol is being applied to soil and sludge samples, showing promising results for detecting microplastic contamination in these environments. This approach holds great potential for improving microplastic detection and mitigation, supporting policymakers, researchers, and environmental managers in safeguarding both water and soil resources.

Keywords: Emerging contaminants, water quality assessment, patent development, microplastic monitoring.

PC-Po-06

Enhancing Olive Oil composition and Water Conservation: The Impact of Buried Clay Pot Irrigation on the Chétoui Variety in Tunisia

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Introduction/Objective

Tunisia's climate is marked by low rainfall, necessitating the adoption of irrigation systems that prioritize water conservation. Optimizing water usage is essential, particularly in regions suffering from water scarcity. Subsurface irrigation, where water is delivered below the soil surface, helps reduce evaporation losses compared to traditional methods. This technique, including the use of clay pot irrigation, has been utilized since ancient times. It offers a promising solution for conserving water, increasing crop yields, and mitigating the phenomenon of alternate bearing. Moreover, high-quality olive oil cannot be obtained from fruits subjected to severe water stress.

This study aims to evaluate the effects of buried clay pot irrigation on the physicochemical properties of olive oil from the Chétoui variety, with a focus on fruits harvested at different maturity stages.

Methodology

- The experimental site chosen for this study is the Ben Ismail farm, located in the Toukaber region (Béja Governorate) at an elevation of over 400 meters. The Chétoui olive variety, well-suited for this region, was selected for experimentation.
- Characterization of the clay pots involved analyzing their porosity and water infiltration rate.
- Mineral composition of the soil and clay pots was determined via atomic absorption.
- Olive oil quality was assessed after irrigation with buried clay pots, focusing on antioxidant activity and phenolic compound content.

Results/Discussion

Prior to the experiment, the clay pots used were thoroughly characterized. Each pot had a surface area of 2700 cm², a reddish-brown color, an average volume of 11 liters, an average height of 40 cm, and a weight of 4.66 kg. Chemical analysis of the clay pot shards, performed using atomic absorption, revealed a high concentration of iron (Fe) at 905 mg/kg, followed by calcium (Ca) at 105 mg/kg, and magnesium (Mg) at 38 mg/kg. The porosity of the clay pot walls varied significantly from the top to the bottom of the jar. Water infiltration was slow during the first 24 hours, but increased after 168 hours, continuing until the end of the experiment.

After irrigating the olive trees with buried clay pots, analysis of the extracted olive oil was conducted. The concentration of reduced DPPH, antioxidant activity assessed via the β-carotene bleaching test, flavonoid content, fatty acid composition, and phenolic compound levels all varied according to the maturity index, altitude, and irrigation conditions. In all the virgin olive

oils analyzed, oleic acid was the predominant fatty acid, followed by palmitic and linoleic acids. Clay pot irrigation promoted an increase in oleic acid content and a reduction in palmitic acid, particularly in oils from trees grown at different altitudes. Additionally, the total phenol content decreased with increasing altitude, with a slight reduction observed in oils from irrigated trees compared to control trees. The antioxidant capacity of the oils also showed a slight decline in irrigated trees, which could be attributed to the positive correlation between phenol content and antioxidant capacity.

Conclusion

The porous nature of the buried clay pots allows water to seep into the soil at a rate that matches the plant's water requirements, leading to highly efficient water use. This irrigation method outperforms drip irrigation and can be up to ten times more efficient than conventional surface irrigation, making it a promising approach for improving water conservation and crop yields.

PC-Po-07

Electrical properties analysis of $La_{1-x}Sr_xFeO_3(0\leq x\leq 0.5)$ solid solutions

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Introduction/Objective

The revolution in the field of science and technology has made human life easier. Particularly, advancement in the agricultural and industrial sectors has helped the economy boom, which is very essential for every nation's growth. However, on the other side of the coin, the adverse consequences of technological growth have been observed, which is of permanent importance to look into. Various hazardous gases and vapors are being released into the atmosphere Figure 1; thereby generating air pollution. Recent studies have revealed a great interest of $LaFeO_3$ perovskites and its derivatives in the field of gas sensing applications owingtoitseasilytunable electronic property esbyeitherdopingand/ orthepartial substitution of transition metals. Indeed, the operational principle of $LaFeO_3$ gas sensor is based on the change in electrical resistance or conductance once the adsorption and desorption of gas molecules occurred on its surface. Furthermore, the gas-sensing ability of the material can be affected by the synthesis method as captivating morphologies can be generated.

Figure1: Illustration of causes and main resources responsible for the sudden growth in air pollution in urban areas of developing countries.

Methodology

The $La_{1-x}Sr_xFeO_3$ (x = 0, 0.1, 0.2, 0.3, 0.4 and 0.5) polycrystalline samples were subjected to some experimental techniques. The phase purity of the samples was checked by recording X-ray powder diffraction (XRPD) patterns at room.

Morphological analysis was accomplished on pellet ceramic surface, covered with carbon film, using the FEINovaNanoSEM200 within energy-dispersive X-ray spectrometer (EDX) operated at 15 kV.

The Novo control Alpha analyzer impedance has been used in order to determine dielectric properties of the Sr-doped LFO ceramics. Dielectric measurements were carried out at ambient and over the frequency range 0.1 Hz–1 MHz.

Result/Discussion

The present work focuses on the morphology effect of $La_{1-x}Sr_xFeO_3$ ($0 \leq x \leq 0.5$) solid solutions on its electrical properties according to dielectric and complex impedance analyses. The highest ac conductivity happened for the highest Sr-doping effect (x = 0.5) and with the smallest grain morphologies. Similar results are obtained for $La_{1-x}Sr_xFeO_3$ (with x = 0.1, 0.2, 0.3 and 0.4) nano-materials.

Conclusion

The recourse to the complex impedance analysis allows probing the contributions of grains and grain boundaries to the ac conductivities. This analysis shows different electrical equivalent circuits according to the dielectric response represented in Nyquist diagram. As results, grain boundary contributions rely on difference of its impurity concentrations and on structural distortion of the ceramic. The$La_{0.5}Sr_{0.5}FeO_3$ceramicexhibits, the highest increase in charge transferred electron concentration according with the smallest grain morphologies. Theca conductivity is then ensured by the mediation of grain boundary which does not act as barrier for electron transport. These results are in accordance with those of $La_{1-x}Sr_xFeO_3$ (with x = 0.1, 0.2, 0.3 and 0.4) nanomaterials.

Keywords: Structural analysis, Morphological analysis, Dielectric analysis, Complex impedance analysis, $La_{1-x}Sr_xFeO_3$.

GIS, Remote Sensing, and IA applied to water resource

GIS, Remote Sensing, and IA applied to water resource

Oral

GRS-Or-01

Big Data and Deep Learning for Water Loss Detection Using Multiple Sensors

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Introduction/Objective

As a critical resource for human survival and social development, water is also a finite resource. Water loss is a critical issue in water management, leading to significant wastage of a vital resource. Traditional methods of detecting water loss, such as manual inspections and basic monitoring systems, often fail to identify losses in a timely and efficient manner. With the advent of advanced technologies, there is an opportunity to develop more sophisticated systems that can detect and address water loss promptly. This project aims to design a system that leverages deep learning and big data technologies, along with data from multiple devices, to accurately detect water loss. The system is designed to identify two main types of water loss[1]: pipeline leaks and surface area losses, by analyzing patterns in water consumption and utilizing remote sensing data.

Methodology

The proposed system uses two approaches to detect water loss based on the nature of the water loss:

1. Pipeline Water Loss Detection:

- Data Collection: The system gathers extensive data on water consumption patterns from various sensors and smart meters installed throughout the water distribution network.
- Big Data Analysis: This consumption data is processed and analyzed using big data technologies to handle the large volume and variety of data. The system looks for anomalies and deviations from typical consumption patterns, which might indicate potential leaks.
- Deep Learning Models: Advanced deep learning algorithms are applied to identify subtle patterns and trends that human analysis might miss. These models are trained to recognize the difference between normal consumption fluctuations and those that are indicative of a leak. By continuously learning from the data, the system becomes more accurate over time in predicting pipeline leaks. The LSTM [2] model analyzes time series data from these sensors to detect anomalies in water consumption patterns that may indicate leaks. LSTM networks are particularly effective at handling sequential data and can identify deviations from normal consumption patterns over time.

2. Surface Water Loss Detection:

For detecting water loss over larger surface areas, the system uses data from remote sensing technologies and drones equipped with high-resolution cameras and sensors. Specialized algorithms, capable of analyzing satellite and drone imagery, are employed to detect water presence and distribution. The system compares current images with historical data to identify changes that may indicate surface water loss, such as reduced water levels or unexpected water spread due to leaks or inefficient irrigation. The Vision Transformer (ViT) [3] model is used to

analyze the collected imagery. ViT leverages attention mechanisms to process image data and identify patterns indicative of water presence or loss.

Results/Discussion

The evaluation of the system will be conducted in a controlled environment, simulating both pipeline and surface water loss scenarios to ensure comprehensive testing and validation.

1. Pipeline Leak Detection:

The system will be evaluated using simulated pipeline leak scenarios that replicate various types of abnormal water consumption patterns. These scenarios will cover a range of leak sizes and locations to assess the model's robustness and accuracy.

The efficacy of the LSTM model will be measured based on its ability to accurately detect abnormal consumption patterns. The system's responsiveness will be evaluated by its capability to process and analyze vast amounts of consumption data in real-time, demonstrating its scalability for large networks. The deep learning model is anticipated to show a high degree of accuracy in detecting leaks, significantly reducing identification time compared to conventional techniques. The integration of big data technologies will ensure that the system can handle large datasets efficiently, providing timely and accurate leak detection.

2. Surface Water Loss Detection:

For surface water loss, the system will be tested with real-world data captured using remote sensing technologies and drones. Various scenarios will be simulated to evaluate the model's performance in detecting and analyzing surface water changes.

The effectiveness of the water detection algorithms will be assessed by their ability to identify even minor changes in water distribution. Metrics such as detection accuracy, false positives, and response time will be used to gauge the system's performance. The precision and timeliness of the detection will be crucial in evaluating the system's ability to quickly address potential surface water losses. The combined use of remote sensing and drone data is expected to provide highly accurate and timely detection of water level changes. The system should effectively identify and map areas of water loss, enabling prompt responses to mitigate surface water issues.

Conclusion

The integration of deep learning and big data technologies, combined with multi-device data collection is an effective approach for detecting water loss in both pipelines and surface areas. The system's ability to analyze large datasets and identify patterns in real-time offers a significant improvement over traditional water loss detection method. This approach not only allows to enhances the accuracy of detection but also allows for faster intervention, ultimately contributing to more efficient water management. Future work could focus on evaluating our system in real condition and expanding the system's capabilities to other types of water-related issues.

Keywords: water loss, pipeline leak, Deep Learning, Big Data, Multiple sensors.

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GRS-Or-02

Enhancing Satellite and Aerial Images: Advances in Spatial and Spectral Super Resolution Techniques

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Introduction

In recent years, the demand for high-resolution satellite and aerial imagery has surged due to applications in environmental monitoring, urban planning, and disaster management [1]. However, conventional imaging systems face a trade-off between spatial and spectral resolutions due to hardware limitations. Increasing both simultaneously weakens the signal and lowers image quality. Consequently, hyperspectral images (HSIs) with high spectral resolution often suffer from lower spatial resolution, reducing visual clarity and spectral interpretation accuracy, and posing challenges for image processing [2].

Over the past decade, deep learning has significantly advanced spectral and spatial super-resolution (SR) for remote sensing imagery [3]. This review explores deep learning methods, such as convolutional neural networks (CNNs) and generative adversarial networks (GANs), in enhancing hyperspectral and multispectral images. These models capture intricate spatial and spectral patterns, improving image resolution. The review also covers various remote sensing datasets from satellites, aerial platforms, and ground-based systems, showing how deep learning optimizes performance across data types. Integrating deep learning in SR reconstruction addresses traditional trade-offs between spatial and spectral resolutions, enabling more accurate remote sensing applications.

Methodology

To gather relevant studies for this review on spectral and spatial super-resolution using deep learning techniques, we conducted targeted searches across reputable databases such as Google Scholar, IEEE Xplore, and ScienceDirect. Our search employed various combinations of keywords related to deep learning, super-resolution, hyperspectral imaging, and remote sensing. Various HSI reconstruction methods have been developed over the past few decades, encompassing both non-learning methods, categorized into wavelet transform-based, maximum a posteriori estimation-based, and spectral-mixing-analysis-based approaches, and learning-based approaches gained traction for their ability to handle large datasets and complex patterns efficiently. Convolutional neural networks (CNNs), and generative adversarial networks (GANs) are among the leading DL models applied to HSI SR [4, 5]. These models excel at learning hierarchical features and leveraging spatial and spectral correlations, resulting in faster and more accurate super-resolution. Their capability to integrate end-to-end learning and

adaptation to various noise levels and imaging conditions makes DL-based SR approaches a promising advancement over traditional techniques.

Results and Discussion

The results underscore the effectiveness of integrating deep learning techniques for spectral and spatial super-resolution. Commonly utilized are satellite-based hyperspectral and multispectral datasets, tailored to enhance image resolution and spectral detail. Among the deep learning algorithms, Convolutional Neural Networks (CNNs) and Generative Adversarial Networks (GANs) stand out for their capability to achieve superior results in super-resolution tasks.

Each of these approaches aims to tackle the challenges of hyperspectral image super-resolution by leveraging the strengths of different computational and mathematical techniques, from probabilistic models to advanced deep learning frameworks. Future directions for SR techniques should focus on:

1. Developing advanced SR algorithms that enhance both spatial and spectral information and designing their accuracy evaluation metrics.
2. Creating benchmark datasets that accurately represent the diversity of remote sensing (RS) imagery.
3. Exploring the integration of SR with other image processing techniques, such as fusion and denoising, to further enhance the quality of remote sensing data.

Conclusion

Integrating spatial and spectral super-resolution frameworks with advanced deep learning techniques significantly advances high-resolution imaging applications. This approach provides critical insights and detailed information for scientific research and operational decision-making. This research addresses the trade-offs between spectral and spatial resolutions, overcoming the limitations of conventional imaging systems. The enhanced imagery produced through these methods meets the growing demands of various applications, including environmental monitoring, urban planning, and carbon footprint. This work underscores the potential of technological innovation in transforming remote sensing and imaging practices, paving the way for more accurate and detailed analysis across diverse fields.

Keywords: Hyperspectral images, Spectral super-resolution, Spatial super-resolution, Generative adversarial networks

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GRS-Or-03

Digital Twins for Africa: Exploring Foundational Concepts, Modern Technologies Integration, Application Landscape, Development Challenges, and Strategies

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Introduction/Objective

The rapid advancement of digital technologies has led to the emergence of Digital Twins (DT) as a critical innovation integrating AI, IoT, Big Data, and cloud services. DTs can create real-time, dynamic digital replicas of physical systems, enhancing decision-making and optimization across various industries. We systematically reviewed the core concepts of Digital Twins, assessed their integration with advanced technologies, and explored their applications within the African context. The main objective is to address current challenges and propose strategies for future development in key sectors.

Methodology

The employed methodology follows a systematic review process [1] on Digital Twins (DT), particularly focusing on integrating emerging technologies like AI and IoT. This process involves four key stages. At the first level, the research objectives were clearly defined, centering on the role of new technologies in DT applications. Second, the PRISMA guidelines were utilized for the paper selection process, documenting each step of identification, screening, and selection through a PRISMA flowchart [2, 3]. In the third stage, both descriptive and content analyses were conducted, with quantitative analysis tracking publication trends. This quantitative approach used Scopus and Google Scholar databases to track keyword combinations and visually represent publication trends, offering insights into DT research growth globally, particularly in Africa. A qualitative approach complemented this by examining the geographical distribution of DT research, revealing a significant underrepresentation of African countries, and highlighting specific regional challenges that need to be addressed for wider adoption.

Result/Discussion

Despite the substantial growth of Digital Twin (DT) research and development across various domains worldwide, our analysis reveals a stark underrepresentation of African countries, contributing less than 3% of the worldwide studies in this field (Figure 1). This disparity highlights African nations' challenges in adopting and advancing DT technologies. Major obstacles include inadequate digital infrastructure, limited access to computing resources, and a shortage of technical expertise across the continent. Additionally, issues related

to data quality, availability, and funding further complicate the integration of DT technologies in sectors such as resource management and energy. To address these challenges, we recommend several strategies, including improving infrastructure, fostering partnerships, and tailoring DT technologies to local contexts. These steps are essential for promoting sustainable development and ensuring that Africa's progress aligns with global advancements in DT applications.

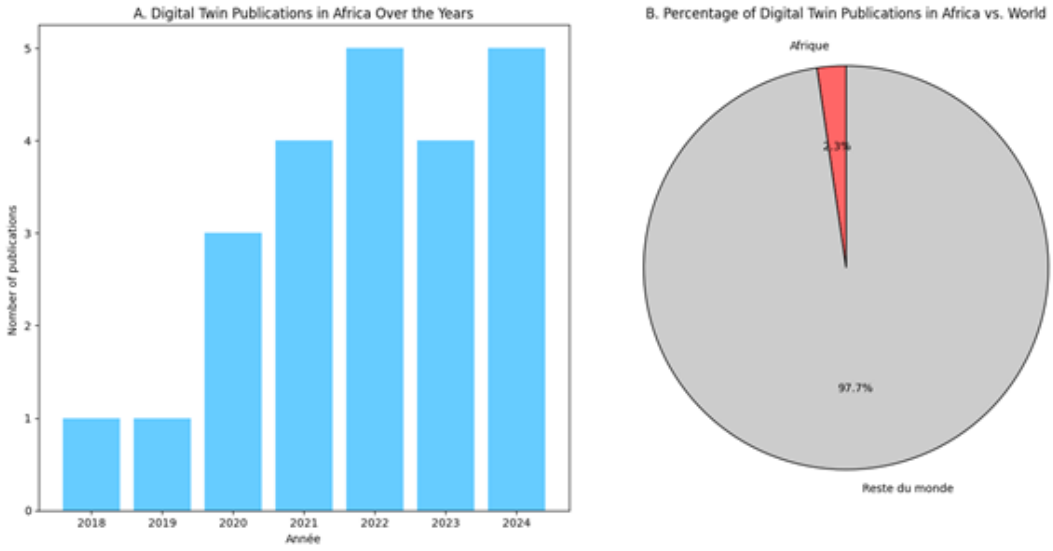

Figure 1: Number of DT's papers in Africa

Conclusion

In summary, this study systematically explores the core principles and the incorporation of advanced technologies in Digital Twins (DT), with a particular focus on their applications across various sectors and a specific emphasis on Africa. While DTs are making significant strides globally, Africa's contribution to DT research remains under 3%, highlighting a substantial gap. Despite this, the potential for DTs to drive innovation in resource management, energy, and urbanization on the continent is immense. Addressing challenges such as inadequate infrastructure, limited technical expertise, and data availability will be essential. By implementing targeted strategies, Africa can bridge the gap and fully harness the transformative power of Digital Twins for sustainable development.

Keywords: Digital Twins (DT), Artificial Intelligence (AI), Internet of Things (IoT), Sustainable Development.

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GRS-Or-04

Mapping of storage sites for olive mill wastewaters: A combined approach using AHP and machine learning

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Introduction/Objectives

In 2024, Tunisia, with over 95 million olive trees, produced approximately 220,000 tons of olive oil, generating about 200,000 cubic meters of olive mill wastewater (OMW). Managing these effluents remains a critical unresolved challenge, requiring an appropriate approach to minimize their environmental impact. Our study focuses on proposing a solution by identifying the most suitable locations for OMW storage sites in the Bizerte governorate, Tunisia. We adopted a spatial multicriteria analysis approach using the Analytic Hierarchy Process (AHP), complemented by a machine learning model to predict optimal zones for establishing OMW storage facilities.

Methodology

In our study, we developed a methodology integrating multicriteria spatial analysis and spatial trend prediction. This approach begins with creating a suitability map from established and weighted criteria using the Analytic Hierarchy Process (AHP). Spatial trend prediction relies directly on the results from this suitability map.

Firstly, we rigorously delimited the study area, excluding incompatible zones for OMW storage based on predefined exclusion criteria. These criteria include constraints such as watercourses, aquifers, wetlands, road networks, forests, protected areas, and residential zones.

Next, the remaining area was evaluated by applying standardized appreciation criteria calculated through the AHP method to create classified maps. The chosen appreciation factors for assessing potential OMW storage sites include soil science to analyze soil capacity for safely receiving OMW, topography with restrictions on terrain slope to ensure adequate stability, hydrology to assess impacts on local water resources, social aspects such as proximity to residential areas and impacts on local communities, economic considerations to evaluate costs and benefits associated with site development, climate considering local weather conditions, and finally, forests to assess impacts on forest ecosystems and biodiversity. By integrating advanced machine learning techniques, our approach accurately predicted the suitability of different zones and generated an optimal final map for OMW storage sites. Three machine learning algorithms (SVM, RF, XGBoost) were employed for this purpose, and their performances were compared to select the most suitable model.

Results and Discussion

The data is divided into training and test sets according to an 80% training and 20% test split (80/20). The metrics used to evaluate model validation include Accuracy, Precision, and Recall:

Table 1: Results for the 80/20 split

	Accuracy	Precision	Recall
SVM	0.9712	0.9738	0.9761
RF	0.9766	0.9779	0.9804
XGBoost	0.9266	0.9337	0.9228

The results from Table 1 show the performance of models for the 80/20 split. Machine learning techniques such as SVM (Support Vector Machines) and RF (Random Forest) prove more effective than XGBoost in predicting locations for OMW storage. SVMs are particularly effective at classifying data into distinct classes, whether linear or non-linear, which is crucial for accurate prediction of storage sites. RF utilizes a combination of multiple decision trees, enhancing its robustness against noise and data variability. This capability is critical for handling complex relationships among storage site features, minimizing errors from outliers. Although effective, XGBoost carries a risk of overfitting, especially with large datasets, necessitating rigorous regularization to mitigate this issue. However, its computationally intensive training process can slow down processing times and increase resource requirements, which is a significant consideration for large databases

Conclusion

The study aims to locate the best sites for storing olive mill wastewater (OMW) in the Bizerte governorate using a multi-criteria spatial analysis approach and spatial trend prediction algorithms. We utilized the Analytic Hierarchy Process (AHP) to evaluate relevant criteria and create a map of the most suitable sites for OMW storage. To refine our results, we integrated spatial trend prediction based on this suitability map. Three machine learning algorithms (SVM, RF, XGBoost) were employed to train models using the data, and their performances were compared to select the optimal model. Finally, a detailed analysis of the results was conducted to guide future decisions regarding territorial planning and sustainable resource management in the region.

Keywords: Olive mill wstewaters, Bizerte Governorate Tunisia, Multi-criteria spatial analysis, Spatial trend prediction

GRS-Or-05

Advancements in Lithological Mapping: A Review of Machine Learning Algorithms and Remote Sensing Data

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Introduction/Objectives

In recent years, the scarcity of natural resources with increasing demand has driven geologists to seek innovative methods for processing diverse data types across all exploration stages. Mapping geological is considered as an essential step to inform decision-making for targeting water and mineral resources. Various remote sensing datasets, including satellite, airborne, and ground-based data, have emerged as solutions to common challenges in lithological mapping, such as accessibility and environmental conditions. The growing volume of remote sensing data has driven geological data analysts to develop advanced methodologies, particularly machine learning methods, which can effectively manage large volumes of data, extract meaningful information from noisy data, and provide faster and more efficient processing.

Over the past decade, the combination of remote sensing datasets and advanced data analysis techniques, including machine learning algorithms, has significantly enhanced lithological mapping. This review explores the application of popular machine learning methods in processing remote sensing data for lithological mapping. It delves into different types of remote sensing datasets, such as data from satellites, airplanes, and ground-based systems, and evaluates the advantages and disadvantages of commonly used machine learning approaches.

Methodology

To gather relevant documents for this review, we used targeted keywords across reputable databases like Google Scholar, IEEE Xplore, and ScienceDirect with different combinations of keywords. This approach aligns with established methodologies in the field [1, 2]. We applied strict inclusion criteria, selecting peer-reviewed articles focused on lithological mapping using machine learning and remote sensing, published from 2010 onwards. We excluded non-English publications and studies not using classification algorithms. Our search initially yielded 319 publications, which were screened down to 238 after removing duplicates and irrelevant studies.

Results and Discussion

A review of research papers published since 2010 has revealed key trends in machine learning (ML) and remote sensing (RS) techniques for geological mapping. The findings show that integrating modern machine learning algorithms (MLAs) and deep learning techniques with remote sensing data can significantly enhance the accuracy, efficiency, and comprehensiveness of geological mapping [4-6]. Both altimetric and radiometric data play significant roles in geological mapping, with radiometric multispectral data predominantly employed for lithological mapping and altimetric data favored for lineament detection.

Spaceborne multispectral datasets are frequently used for this purpose. Among the machine learning algorithms, Support Vector Machine (SVM) and Random Forest (RF) have been identified as the most accurate for lithological mapping. However, selecting the most suitable data and classifier depends on the geological context, specific objectives, and the application. Future research will likely focus on identifying the most effective algorithms for various geological settings to achieve higher accuracy and produce more reliable, high-quality maps. Additionally, it will emphasize developing the best methods for quantifying algorithm accuracy.

Conclusion

The combined use of remote sensing data with machine learning methods offers a powerful approach to lithological mapping, addressing many of the traditional challenges faced by geologists. The effectiveness of spaceborne multispectral datasets and machine learning algorithms highlights the potential for significant advancements in geological exploration. This comprehensive review underscores the evolving landscape of geoscience, where technological innovation continues to drive progress in resource exploration and management.

Keywords: Lithological mapping, Machine learning, Remote sensing

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GRS-Or-06

Big geospatial data in favour of smart and sustainable cities : Use case: Real-Time Road Monitoring and Accident Detection Platform for Smart Cities

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Introduction/Objective

The concept of a Smart City has emerged as a pivotal response to the growing challenges of urbanization, aiming to enhance the quality of life for citizens through the integration of advanced technologies and sustainable practices such as internet of things, Artificial Intelligence and Big Data particularly big geospatial Data.

In the context of smarty city, the importance of smart transportation and road monitoring cannot be overstated. These systems not only contribute to the smooth operation of urban mobility but also play a key role in ensuring public safety, reducing life risking incidents and enhancing the overall quality of life for city residents.

With all that in mind, the objectives of this work where clear and focused. Our goal is to develop a system that enhances public transportation safety by leveraging modern technologies to monitor road accidents and optimize emergency response times. By achieving immediate accident detection, we aim to prevent delays in intervention and ultimately save lives.

Methodology

This project focuses on the development of a real-time road monitoring and accident detection platform aimed at improving urban safety and traffic management for smart cities called “SafeWatch”. As part of the "Smart City" initiative, which leverages big geospatial data to provide sustainable city services, the platform was designed to monitor road conditions and detect accidents using advanced technologies. A network of cameras connected to Raspberry Pi 4 devices is deployed at key road intersections. These cameras detect accidents and count vehicles in real-time using the YOLOv8 deep learning model. The data collected is transmitted to a central server via Wi-Fi and stored in a ScyllaDB big data database.

Additionally, the platform integrates weather data from the OpenWeather API to calculate a "driving factor" based on conditions such as temperature, visibility, and precipitation. This factor is updated regularly to assess driving conditions on monitored roads. A web-based dashboard alerts authorities in case of an accident and displays live video streams, traffic statistics, and historical data. The system also calculates the shortest emergency response path using factors such as traffic flow, weather conditions, and road status, dynamically updating as conditions change.

Key technologies used include ScyllaDB for real-time data storage, Apache Sedona for spatial data processing, NSGA-II for multi-objective optimization, Flask for RESTful APIs, WebSocket for real-time updates, and React for a responsive web dashboard. This platform demonstrates the transformative potential of integrating big geolocated data, IoT, and machine learning to enhance road safety and traffic management in smart cities. The next phase of the

project will involve implementing the solution in the city of Bizerte as part of the Smart City initiative.

Results/Discussion

This project aims to lower accidents casualties and prevent delays in intervention and ultimately save lives. Finally, we took the region of Bizerte and we managed to build a robust platform and detect in real time accidents. An open discussion is how to scale the project to cover larger geographic regions, incorporating more data sources, and expanding to additional use cases beyond accident detection and make it an emergency response platform that takes in consideration all hazardous events.

Conclusion

We demonstrated successful integration of advanced technologies, including IoT, AI and big data particularly big spatial data, within the smart city framework to address traffic and road safety challenges. The proposed system “SafeWatch” combines real-time accident detection, vehicle flow monitoring, and geospatial data processing to offer a comprehensive platform for authorities to improve road safety and optimize emergency response times.

While this research has made significant strides, the are several areas for future exploration and enhancement such as scalability and wider deployment, more advanced machine learning models and integration of more data sources.

Keywords : Smart City, Internet of things, Big Data, Artificial Intelligence, Geospatial Big Data, Road Monitoring, Accident Detection, Real-Time data Processing.

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GRS-Or-07

A Machine Learning-Enhanced SWAT Model for Dynamic Assessment of Natural Groundwater Recharge

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Introduction/Objective

A significant problem facing the scientific community and water experts is their limited understanding of the natural response of aquifers to climate change and human activity. Although various techniques have been developed to assess flow trends in the context of global transitions, our knowledge of soil dynamics remains inadequate. This poor understanding hampers the application of effective management policies.

In this context, the present study focuses on the response of natural groundwater recharge to land use and land cover change (LULC) and climatic conditions in the semi-arid Tunisian context, particularly in the Oued Chiba watershed.

Methodology

The Chiba watershed was selected as a case study (Figure 1), because of its generally semi-arid climate and the impact of human activity on its subsurface drainage systems.

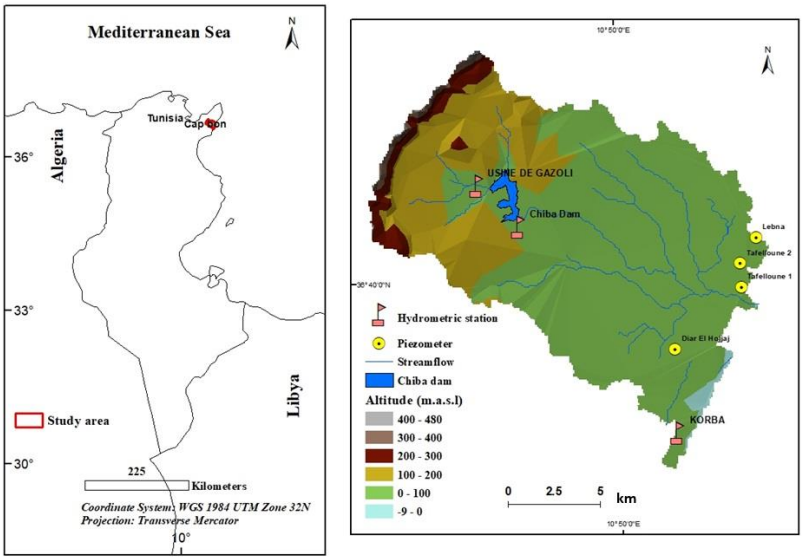

Figure 1:Topography of Chiba watershed

The methodology integrates Machine Learning (ML) techniques with hydrological modeling. The natural groundwater recharge model was created using the Soil and Water Assessment Tool

(SWAT) model. The random forest (RF) classification method was created for LULC assessment. The field data used in this study were collected from 1985 to 2021.

Result/Discussion

Findings show that arable land (12%) and bare soil (2,5%) have significantly increased, whereas market gardening (-2,6%) and arboriculture (-9,3%) have decreased simultaneously. According to the simulations, there will be a 33% decrease in natural recharge rates due to a 16% increase in annual evaporation rates and a 2% increase in average annual precipitation. At the watershed scale, these important hydrological indicators are especially susceptible to variations in precipitation and LULC. The majority of the natural recharge has occurred in the central and southern zones of the watershed because irrigated crops promote infiltration. However, because the average yearly recharge per sub-basin cannot exceed 3 mm/year, groundwater recharge levels in the basin remain relatively low.

Conclusion

The investigation's conclusions suggest that efficient groundwater resource management requires an understanding of aquifer dynamics. The research findings provide policymakers with crucial information for creating water management policies, especially considering Tunisia's semi-arid climate.

Keywords: Groundwater, Natural recharge, Climate Change, Human activities, Random Forest, SWAT, Modelling.

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GRS-Or-08

Applying Machine Learning Techniques with Earth Observation Data to Forecast Groundwater Levels: A Case Study of the Lower Medjerda Valley (Tunisia)

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Introduction/Objective

Groundwater is vital for ecosystems and human use, particularly in semi-arid and arid regions. Increasing demand, climate change, and limited data availability pressure freshwater resources. Effective management requires accurate groundwater level (GWL) monitoring and forecasting. This study focuses on Tunisia, especially in the water-scarce Lower Valley of the Medjerda Basin. It explores the potential of combining Earth observation (EO) data with machine learning techniques to enhance groundwater forecasting in regions with limited data availability. The research utilized a comprehensive dataset that integrates EO data from GRACE, GLEAM, GLDAS, and CRU, along with in-situ measurements. Four machine learning models—Random Forest, XGBoost, Support Vector Regression, and Long Short-Term Memory networks—were assessed for their predictive performance.

Methodology

The methodology used to estimate groundwater levels (GWL) in the Lower Valley of Medjerda (LVM) involved several key steps. First, a spatial database was constructed by integrating remote sensing data from GRACE, GLEAM, and GLDAS, along with historical GWL data. Next, monthly time series data were generated by converting raster data into point-based data for each well location. The time series data cover the period from April 2002 to December 2019. The data were collected from eight piezometric wells located within the phreatic aquifers of the Lower Valley of Medjerda (LVM). These wells were carefully selected to ensure that the groundwater level (GWL) measurements accurately represented the characteristics of the shallow aquifers in the region.

During the pre-processing phase, missing data were treated, and the dataset was normalized for consistency. The models were then built using Random Forest (RF), XGradiant Boosting (XGBoost), Support Vector Regression (SVR), and Long Short-Term Memory (LSTM) algorithms, with 80% of the data used for training and 20% for testing. Model performance was evaluated using metrics of performance that are MAE, EVS, NS, RMSE, and R^2, followed by an uncertainty analysis using the Monte Carlo Method to assess the reliability of the predictions.

A Generalization ability is also calculated to show the model's effectiveness in accurately predicting outcomes. For the sensitivity analysis, a suitable function is used for each model to clarify the relative impact of various input data on each model's performance.

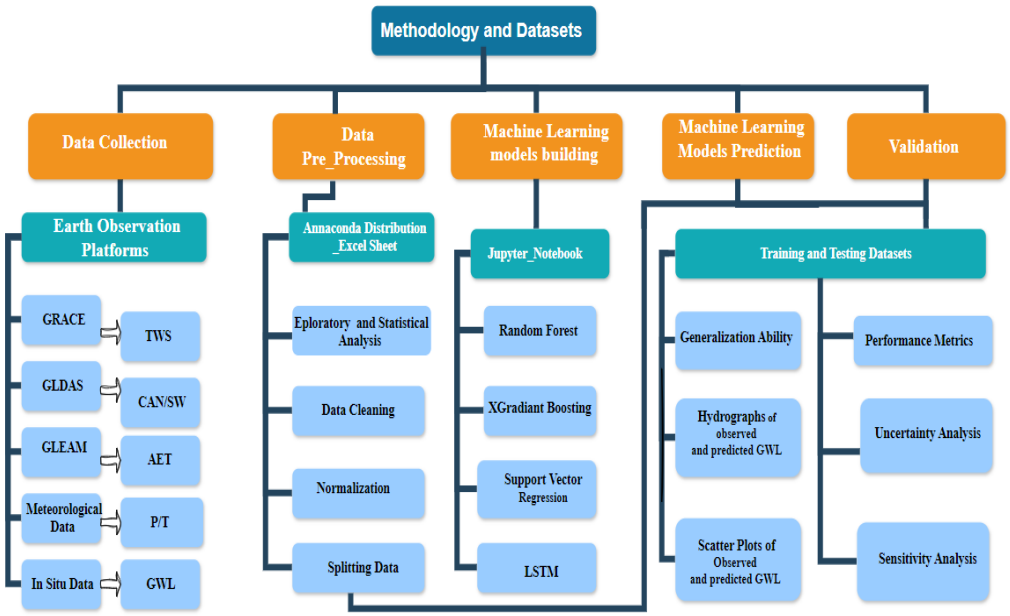

Figure 1: Flowchart of the methodology

Result/Discussion

The results indicate a steady decline in groundwater levels, emphasizing the urgent need for better water management strategies. For the models tested, the RF and the XGBoost showed superior accuracy and robustness compared to SVR and LSTM. An Uncertainty analysis proves the reliability of all models in GWL predictions with RF and SVR performing the best. The sensitivity analysis identified Total Water Storage (TWS) extracted from the GRACE as a key factor influencing groundwater levels, highlighting its importance for future predictions. The study also demonstrated that integrating Earth observation data with machine learning significantly enhances the accuracy and reliability of groundwater forecasts and solves data gaps.

Conclusion

These findings offer a valuable framework that can be applied to other regions in Tunisia and areas with similar hydrological conditions. They provide important insights for improving groundwater management and tackling water scarcity challenges.

Keywords: Machine learning, Prediction, Groundwater, Tunisia, EO Data

GRS-Or-09

Geospatial Technologies for Monitoring Water Resources in Supporting life

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Introduction/Objective

Tanzania is considered to be water abundant, however, heterogeneous climate and geology contribute to significant seasonal, interannual, and geographic variability in water availability and water quality challenges. Water stress is moderate as the total annual renewable water per person is approximately 1,680 m3 and only 13 percent of its total water resources are abstracted by major economic sectors, which is less than the SDG 6.4.2 water stress benchmark. Key sectors fuelling demand for surface and groundwater include agriculture, animal husbandry, hydropower, and mining. In addition, the environmental flow requirements are also generally high due to the significant coverage of key nature reserves. Precipitation is projected to increase due to climate change, although the probability of extreme drought and increasing inter-annual rainfall variability will also grow. Heavy rainfall events will constitute a greater portion of received precipitation, compounding vulnerability to heavy flooding. There is still a gap between the tremendous potential of these technologies and the world of environmental decisions and policy-makers. So it is very important to monitor the available water sources and predict the water variations for better water use and management.

Methodology

Geospatial technologies and remote sensing are valuable resources for monitoring the United Nations' Sustainable Development Goals (SDGs) and their corresponding targets and indicators. They enable unbiased observation and analysis across borders, administrative boundaries, and nations. Furthermore, geospatial information and technologies are particularly critical for strengthening urban and rural resilience, where economic, agricultural, and various social sectors intersect. Google Earth Engine (GEE) is a game-changing technology, a free cloud-based platform providing access to multiple repositories of worldwide satellite imagery and geospatial data as well as powerful computation for quick analysis and visualization of large datasets. The GEE platform is used as an agile tool for data collection, catalog, storage and analysis as well as results visualization and interpretation.

Result/Discussion

Tanzania currently undergoing significant climate change effects such as water stress and drought, but monitoring of water resources is limited, in part due to a lack of remote sensing knowledge, tools and methods. This study provides a comprehensive approach to creating a national-scale water resources monitoring system using remote sensing data to inform decision making, policy formulation, and combat water stress and drought challenges.

Conclusion

A comprehensive water resource monitoring system is presented in this study. This system will enhance water conservation programmes and support efforts in sustainable water utilization and conservation not only Tanzania but to the whole world.

Keywords: Water resources, water stress, environmental flows, geospatial technologies and remote sensing

GRS-Or-10

Spatialization and mapping of water erosion hazard based on multi-decisional AHP approach: case of Medjerda watershed in the North of Tunisia

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Introduction/Objective

Water erosion is becoming currently as one of most dramatic problems worldwide, affecting agricultural lands, ecological and environmental systems Wuepper et al., 2019; Djoukbala et al., 2024). Indeed understanding, mapping and modelling of water erosion process become a serious concern for water and soil conservation practitioners, as well as decision-makers concerned with natural resource management, agricultural policies and the sustainable development of nations (Borrelli et al., 2017). Plenty of models are available for studying soil erosion, which strongly differ in terms of required data availability, application scales, research area conditions and complexity (Atoma, 2018; Raza et al., 2021). The current study intends to prove how the multi-criteria analytical hierarchy process (AHP) can be adopted in environmental studies, especially for water erosion hazard mapping in Medjerda watershed in Northern Tunisia (Figure.1).

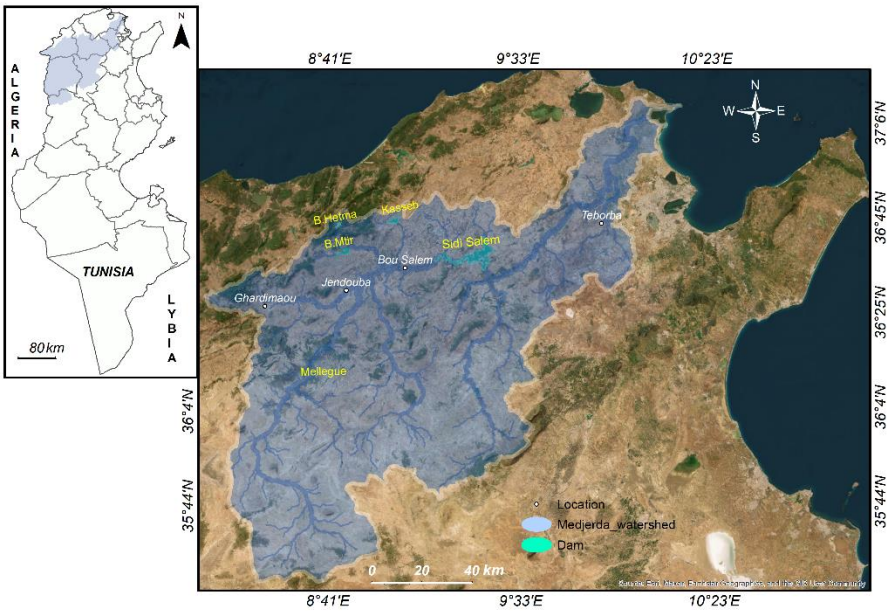

Figure 1: Geographic location of the study area

Methodology

This adopted methodology was performed by integration of different geospatial data, geographic information system (GIS) and remote sensing techniques. The middle-valley part of Medjerda watershed is the subject of mapping of water erosion hazard in the present study. Ten factors were used as evaluation criteria including: rainfall erosivity (R), land cover resistance (C), topographic roughness index (TRI), Topographic wetness index (TWI), soil erodibility (K), river drainage density (D_d), stream power index (SPI), soil moisture (S_m), land surface temperature (LST) and lineament density (L_d). The weights of the factors were determined based on the AHP technique.

Results/Discussion

Key outcome of this research is the spatial distribution map of erosion vulnerability in the middle-valley of Medjerda Watershed corresponding to the hydrologic year (2022-2023). This map shows that 31% of the basin is characterized by a moderate vulnerability to erosion, where 22% represents high susceptibility and 10% very high susceptibility. Indeed, a larger part of the basin (63%) presents high water erosion risks. Factors consistency was verified by the consistency ratio (CR) having an acceptable result of 7.8%. Main results showed that rainfall erosivity is the most important factor, followed by the topographic indices, soil moisture, LST, drainage density and SPI.

Conclusion

This work aimed to map water erosion in Medjerda watershed based on a coupling between the AHP multicriteria method, EO-data and geospatial techniques (GIS and remote sensing). Key findings may be helpful for developing of decision-making programs of resources management and mitigation in the considered watershed.

Keywords: water erosion hazard, AHP, GIS and RS, mapping, Medjerda watershed, Tunisia.

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GRS-Or-11

Flood susceptibility mapping using machine learning models: case of the Wadi El Bey Watershed, North-eastern Tunisia

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Introduction/Objective

Flood risk mapping plays a critical role in the development of effective flood control strategies, aimed at mitigating the devastating effects of flash floods. This study aims to evaluate three machine learning models : XGBoost, Gradient Boosting Machine (GBM), and a hybrid stacking model to predict flash flood susceptibility in the Wadi El Bey Watershed, located in the Cap Bon Peninsula, northeastern Tunisia.

Methodology

This study employed three predictive models : XGBoost, Gradient Boosting Machine (GBM), and their hybrid stacking model to assess flood susceptibility. The models were trained using a dataset of 600 points, split equally between flood and non-flood locations. This dataset, derived from a post-flood satellite image dated September 23, 2018, and supplemented with topographic data, was divided into 70% for training and 30% for testing. The analysis incorporated 17 causative factors related to topography, hydrology, and land use to develop and validate the prediction models.

Result/Discussion

The hybrid stacking model demonstrated the highest performance, achieving an accuracy of 99.2% and a Kappa coefficient of 0.984, surpassing the individual models. XGBoost performed well with an accuracy of 95.2% and a Kappa of 0.904, illustrating its effectiveness in identifying flood-prone areas. GBM, while slightly less accurate, achieved 91.3% accuracy and a Kappa coefficient of 0.825, providing reliable predictions but with lower performance compared to XGBoost. These findings underscore the enhanced predictive capabilities of hybrid models, making them a valuable tool for flood risk mapping.

Conclusion

The results indicate that the hybrid stacking model significantly outperforms individual models, offering superior accuracy in flood susceptibility mapping. This highlights the potential of integrating advanced machine learning techniques for improved disaster risk management.

Keywords: flood risk mapping, machine learning, XGBoost, GBM, hybrid model

GRS-Or-12

Groundwater & LCLU monitoring of the Aousja-Ghar El Melh Coastal Aquifer, Gulf of Tunis, Tunisia, Mediterranean

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Introduction/Objective

The quality of groundwater in semi-arid coastal regions is increasingly impacted by both human activities and climate-related factors. Extended droughts combined with over-exploitation of groundwater resources are placing significant stress on these systems, leading to degradation. This study aims to assess the impact of land use and land cover (LULC) changes on groundwater in the Aousja-Ghar El Melh region, located downstream of the Medjerda River in Tunisia. By analyzing these changes, we seek to understand the relationship between land occupation, climate variability, and groundwater quality degradation over time.

Methodology

The study utilized remote sensing data from Landsat 5 and Landsat 8 satellites to analyze LULC changes between 1997 and 2023. The datasets included Landsat 5 MSS (MultiSpectral Scanner) data from 1997 and Landsat 8 OLI (Operational Land Image) from 2023, both with a spatial resolution of 30 meters. Remote sensing data was complemented by fieldwork and historical groundwater quality records. LULC changes were classified based on urban areas, vegetation, bare soil, and water bodies, while groundwater salinity data from 1997 and 2023 were compared to assess changes in water quality.

Result/Discussion

Preliminary results revealed significant LULC changes between 1997 and 2023, including a 7% increase in urban area coverage and a 10% decrease in vegetation cover, along with an expansion of bare soil areas. Despite these shifts, the surface water bodies, including the Ghar El Melh Lagoon (GEM) and Sebkhet Sidi Ali El Mekki (SSAM), remained relatively stable. Groundwater salinity, however, showed a substantial increase, rising from 0.77 g/L (770 ppm) in 1997 to 4 g/L (4000 ppm) in 2023. The increasing salinity is associated with the expansion of agricultural lands, over-exploitation of groundwater, and reduced vegetation, all of which have exacerbated water quality degradation in the region.

Conclusion

The study underscores the need for adaptive groundwater management strategies that address the impacts of land use and land cover changes, particularly in the context of climate variability and increased agricultural demand. The alarming rise in groundwater salinity and the loss of vegetation highlight the critical challenges facing water resource management in semi-arid coastal regions. Effective management must account for these factors to ensure sustainable groundwater use in the future.

Keywords: Land Use, Water Resources, Climate Changes, Groundwater, Coastal.

GIS, Remote Sensing, and IA applied to water resource

Poster

GRS-Po-01

Soil salinization investigation in the Mejerda lower valley by remote sensing (El Habibia -Mansoura land) Tunisia

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Introduction

Intensive agriculture often leads to an increased risk of agricultural soil degradation and a decrease in crop yields (Eswar et al., 2021). As a result of mediocre to high salinity water resources use, especially in arid to semi-arid climates countries; This inevitably leads to the appearance of varying degrees of soil salinization processes (Mukhamediev et al., 2023).
Climatic factors are very important and essential for agricultural production, but in arid regions, irrigation is resorted to by water of uncertain quality in order to respond to the problems of insufficient rainfall, which leads to an amplification of the salinization process (Hachicha, 2007; Samaali, 2011; 2021). In recent decades, satellite remote sensing has proven to be an important tool for Earth observation and the study of environmental and climate change (Wuyun et al., 2022). It provides data at a large scale and at regular intervals, which is particularly relevant for assessing changes in soil salinization over a long period.

Methodology

In this context, the soil salinization of the lower Mejerda valley was assessed according to a diachronic study using satellite images in three steps : (i) Characterisation of the soils for 23 years according to satellite images; (ii) Calculation of soil salinity indices; (iii) Use the Google Earth Engine platform to determine natural and/or anthropogenic factors influencing agricultural soils salinity ; (iv) Determination of the land degradation evolution via Machine Learning.

Results and discussion

The processing of (Landsat 5, 7, and 8) satellite images of the lower Mejerda valley for 23 years (2000-2023) discloses three periods (fig.1): From 2000-2005: reveals exceptional peaks that sometimes affect very high index values of 0.65. During this period, there is an increase in water salinity in the region, although the variations are less pronounced in the Manouba area;

From 2005-2010: In the Mansoura area, the values were initially around 0.2 but reached the threshold of 0.3 in 2010. Similarly, in the El Habibia area, there is an increase in salinity of about 0.3, especially in the eastern and south-eastern regions.

From 2010-2023: an initial value of 0.27 for the Mansoura zone in 2010, and 0.251 for the El Habibia zone. This value then exceeds 0.326 for the year 2023 in the El Habibia region.

The results highlight the importance of taking into account the geographical and hydrological characteristics of the region when inferring salinity variations. Aspects such as land slopes, evaporation rates, precipitation, and drainage all play a crucial role in understanding salinity patterns and more specifically irrigation water quality.

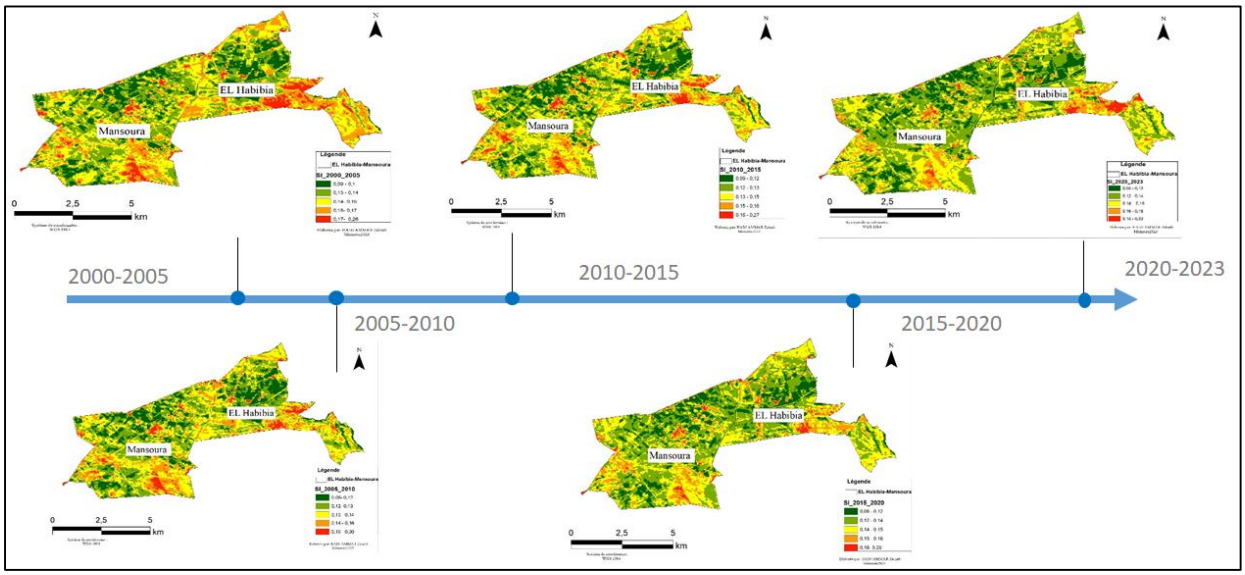

Figure 1: Soil salinity maps (2000-2023)

Conclusion

The results of this study confirmed the interest of multitemporal reflectance data measured on soils to characterize their properties. The method presented establishes a mapping approach supporting the soil maps updating in northern Tunisia. It is inexpensive and can use a free multi-temporal image series covering a large zone. It allows for fine characterization of soil properties using multispectral bands freely shared and most commercial sensors. The maps produced from this method will be able to support farmers and their agricultural consultants in the management of soils and crops.

Keywords: Soil salinity, Salinity indices, Google Earth Engine, Mejerda low valley, Tunisia

GRS-Po-02

Groundwater human health risks assessment using GIS technique: A case study of Mornag aquifer

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Introduction/Objective

The Mornag aquifer, located in north-eastern Tunisia, is under overexploitation, which can pose serious implications for the region's water supply (Gasmi et al., 2022). The Mornag watershed, including the groundwater aquifer, constitutes a pivotal water source for the regional water supply. Since 1960, the Mornag basin in northeastern Tunisia has witnessed substantial growth in both agriculture and industry (Gasmi et al., 2022; Yousfi et al., 2019). The intensive use of pesticides and fertilizers in cultivated areas has resulted in a quality decline in the Mornag aquifer, which is unsuitable for consumption purposes (Gasmi et al., 2022). In this context, this work aims to investigate organic and inorganic pollution in groundwater and assess the potential environmental and human health risks in the Mornag region.

Methodology

An evaluation of heavy metals, pesticides, polycyclic aromatic hydrocarbons (PAHs), and nitrate contents was carried out in order to ascertain the health risks associated with the residents of the Mornag region. Both geochemical and hydrochemical methodologies, as well as geographic information system techniques, were employed to provide information on the origin of the Mornag groundwater pollution. The Nitrate Pollution Index (NPI) was calculated to assess the extent of pollution arising from increased nitrate concentrations in the Mornag groundwater and The hazard quotient (HQ) index has been used to evaluate the impacts of the Mornag groundwater quality on human health (Belhouchette et al., 2021).

Result/Discussion

The Nitrate Pollution Index (NPI) distribution map reveals prevalent and considerable nitrate contamination in the groundwater of the Mornag region, predominantly characterized by a very significant type. The heightened concentrations of nitrate pose a substantial health risk, as they can undergo conversion into nitrite within the human body.

The spatial distribution maps of the HQ index indicate that the majority of the aquifer's total surface area is designated as highly contaminated, posing significant risks to human health. Furthermore, the hydrochemical results show that the groundwater of Mornag suffers from diffuse pollution of anthropogenic origin, namely from agriculture since the samples enriched in nitrates, pesticides, and certain heavy metals are located in agricultural areas. As agriculture seems to be the main pollution source, this also explains why several other organic compounds, such as pesticides (e.g., fungicides, bactericides, and insecticides) were also found in the groundwaters of this region. However, this scenario can be even more serious since some pesticides are hydrophobes and cannot be in water but can be present in soil.

Conclusion

The present study was conducted to assess the water quality of the Mornag aquifer and to investigate the health risks associated with the use of GIS information to obtain spatial distribution maps of potential contaminants in groundwater. The results indicate that the Mornag aquifer is subject to diffuse pollution of agricultural origin due to the intensive use of fertilizers and pesticide treatments. Consequently, protective measures must be implemented for the Mornag aquifer through the development of a monitoring strategy to resist water degradation and ensure restoration to its natural state. Overall, the findings of this study highlight the significant impact of anthropogenic activities on the sustainable use of groundwater in the Mornag plain. These results should draw the attention of decision-makers and prompt their response to halt any further contamination.

Keywords: Groundwater quality, GIS technique, Human health risk, heavy metals, Nitrate pollution index, Mornag aquifer.

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GRS-Po-03

Analysis of Land Cover Changes and Stream Network Evolution in Chaffar Region (Eastern Tunisia) Using High-Resolution Remote Sensing Data

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Introduction/Objective

Hydrological responses of watersheds are in perpetual change through the combined effect of climate change, the evolution of land cover and land use conditions, and anthropogenic activities. The Chaffar Watershed, South-eastern Tunisia, has been affected by devastating flash floods and soil erosion. Mapping and monitoring the occurrence of Hydrological hazards is considered an important component of successful land management. In this context, this work aims to develop a method to assess Land use/cover changes, and the possible drivers of change of the basin morphology and characteristics.

Methodology

Remote Sensing (RS) and Geographic Information Systems (GIS) tools were adopted for data assessment. Regional trend analysis was made possible via the use of spatial resolution time series obtained from Landsat and Sentinel missions. The processes involve several steps: image acquisition and selection, preprocessing, land cover legend designation, supervised classification with maximum likelihood method, transition matrix, statistical analysis of factors, and choice of suitable algorithms for change detection.

Result/Discussion

The Chaffar Watershed has witnessed noticeable changes over the 45-year study period. The results showed that the spatio-temporal dynamics of land use are characterized by the ever-increasing anthropogenic pressure of agriculture and urbanization on natural formations. From a statistical perspective, the mean annual progression rates for the buildup class are 0.035, 0.051 to 0.062 for 1975, 2000, and 2020. while cultivated land changed from a rate of 0.24 to -0.11 and by 0.14 from 1975 to 1985 and in 2020. Monitoring of the evolution of the intermittent watercourse network showed a reduction in its ramifications in some areas and an increase in others. The decrease in ramifications may be explained by the effect of water and soil conservation works and anthropogenic activities. the analysis of the impact of land use dynamics on runoff showed a slight correlation.

Conclusion

Finally, this study has shown that anthropogenic action and rainfall conditions cause profound modifications of the land use patterns in the study area.

Keywords: Hydrographic Network, Land Cover/Land Use, Satellites Images, GIS, Chaffar Watershed.

GRS-Po-04

Hydrology modeling of El Bey Wadi: A Case Study in Tunisia

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Introduction/Objective

Advances in software and hardware now enable the simulation of pollutant transport within the soil-water system through sophisticated mathematical and numerical models. These models are frequently employed to predict solute concentrations before management strategies are implemented. By adopting the SWAT model, one can simulate a time series of daily streamflow in basins with limited data availability and temporary river networks. This adaptation serves as a guide for addressing the challenges of modeling streamflow in such basins. Additionally, the results are highly valuable for river ecologists in assessing ecological status and can aid water resource managers in effective watershed management.

Methodology

To build the SWAT geodatabase for the El Bey Wadi watershed, available data were integrated with data from international databases as necessary for model execution. The watershed drainage area was defined by the SWAT model based on the Digital Elevation Model (DEM) with a 1-meter pixel provided by CRDA Nabeul, along with the land use map. The soil properties database was constructed by combining derived data from the soil map provided by CRDA Nabeul and the international soil reference maps and African soil property databases provided by the International Soil Reference and Information Centre (ISRIC), (Hengl et al., 2015). For the calibration, SWAT-Cup was used.

Result/Discussion

The watershed delineation phase is crucial for accurately representing the local variation in land use, soil, and slope when setting up the SWAT model. Using Arc-SWAT, the surface area of the Oued El Bey watershed was determined to be 493 km2 and was subdivided into 29 sub-basins. To define Hydrologic Response Units (HRUs) unique combinations of land use, soil, and slope with threshold values of 4%, 12%, and 20% were assumed respectively. The calibration results for discharge showed a satisfactory PBIAS value of 24%, indicating an underestimation of discharge (Moriasi et al., 2007), however, R2 and NSE values were 0.70 and 0.70. For Mediterranean river basins, forecasting hydrological processes is challenging due to extremely low flow and flow intermittency (Sachse et al., 2017), for these reasons, several authors have considered NSE > 0.35 as a satisfactory values (Zema et al., 2016).

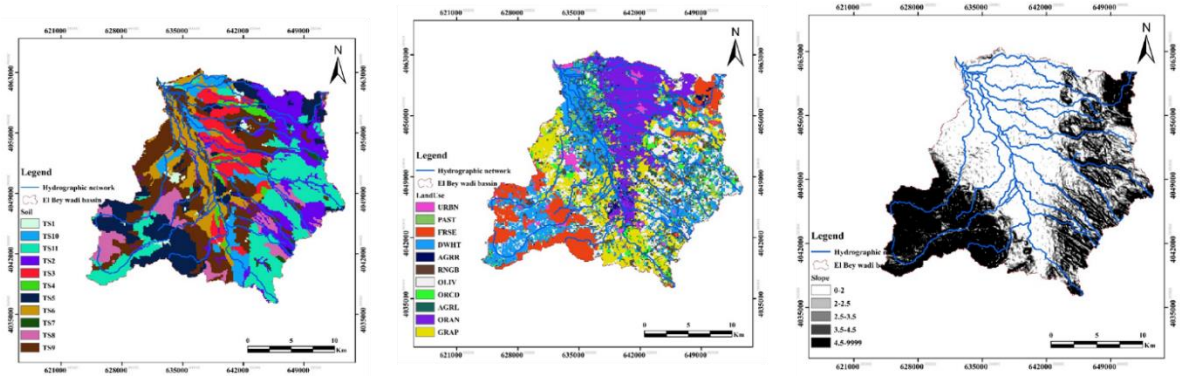

Figure 1: Implementation of land use, soil, and slope

Conclusion

Since measured data were not continuous during the calibration period, it was difficult to identify and compare all components of the hydrograph. However, the comparison between measured and simulated data showed that the model was able to predict the highest peak discharge but with an underestimation. The reasons that could have determined the low performance could be related to the lack of daily stream flow data for the wadi and the merging of real and simulated information such as climatic data.

Keywords: El Bey wadi, hydrology modeling, SWAT, Grombalia

Acknowledgments This research was supported by the INWAT project, PRIMA section 2.

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GRS-Po-05

Extraction of geological lineaments using convolutional neural networks in the Hairech Massif

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Introduction/Objective

This work focuses on the use of convolutional neural networks (CNN) for the mapping of geological lineaments in the Hairech massif region, utilizing multispectral images from Landsat-8 OLI and radar data from Sentinel-1. Geological lineaments, as surface fractures, are key indicators of the presence of groundwater, which is essential for irrigation and drinking water supply. The main objectives of this research include detecting new potential areas for water resources and experimenting with deep learning techniques for rapid and accurate mapping.

Methodology

The images used in this study come from two main sources: Landsat-8 OLI and Sentinel-1. Landsat-8 OLI was chosen for its multispectral capabilities, allowing for precise identification of surface features, which are essential for detecting geological lineaments. In contrast, the radar data from Sentinel-1 provides additional information on topography and terrain structure, thus complementing the optical data.

The methodological process began with image processing using ENVI and SNAP software. These tools allowed for the preparation and preprocessing of the necessary data for analysis. For the programming phase and the creation of the CNN model, Google Colab was used, facilitating the development of the training dataset with the PyTorch deep learning library. Additionally, ArcGIS was employed to establish a geographic database, integrating various elements of geospatial processing, while PCI Geomatica was used for trend analysis through rose diagrams. Finally, the obtained results were validated by comparing them to the faults on the geological map of the region.

Result/Discussion

The final analysis results revealed an effective extraction of geological lineaments, highlighting notable differences between the data from the two sources. The images from Landsat-8 OLI showed a dominant east-west (E-W) direction of the lineaments, accompanied by a secondary northeast-southwest (NE-SW) direction. This configuration underscores the importance of these fractures in the local hydrogeological dynamics, as they can influence groundwater movement and aquifer recharge zones, while illustrating the geological complexity of the region.

Conversely, the interpretation of the Sentinel-1 data highlighted a predominance of northwest-southeast (NW-SE) oriented lineaments. These geological structures play an essential role in the drainage and flow of surface waters, thus impacting the available water resources for irrigation and consumption. This divergence in the orientations of the lineaments emphasizes the complementarity of the two types of data: while Landsat-8 provides information on surface characteristics and their relationship with hydrology, Sentinel-1 offers a more detailed understanding of the underlying geological structures that affect water behavior. Together, these data enable a more comprehensive and precise assessment of water resources in the Hairech massif region.

Conclusion

This research has demonstrated the importance of integrating remote sensing, geographic information systems (GIS), and artificial intelligence (AI) in water resource management, focusing on the mapping of geological lineaments in the Hairech massif. Advanced remote sensing image processing techniques have allowed for precise and large-scale evaluation of water resources, identifying areas potentially rich in groundwater. The use of convolutional neural networks (CNN) has facilitated the rapid analysis of vast geospatial datasets, offering effective classification of lineaments. Moreover, the validation of the results against the faults on the geological map has strengthened the credibility of the analyses conducted. These findings underscore the need to adopt integrated technological approaches to address growing environmental challenges.

Keywords: Geological Lineaments, Water Resources , Remote Sensing, Landsat-8 OLI ,Sentinel-1, Deep Learning and Convolutional Neural Networks (CNN)

GRS-Po-06

Advanced machine learning techniques for modelling reservoir management with irregular data

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Introduction/Objective

Algeria has 80 dams with a total capacity of 7.6 billion cubic meters (MRE, 2022). Managing these dams is challenging due to the need to balance reliable water supply and economic viability. Current management relies on human judgment rather than established models, influenced by water storage levels. While various models have been developed to assess hydrological factors (Babaei et al., 2019; Mohamadi et al., 2020), the focus on water volumes for drinking and irrigation has been insufficient. This research aims to improve dam management in Algeria using an AI-driven model. By analyzing historical operational data from the Zit Emba and Guentira dams (2009-2017), we will create predictive models for drinking water supply (DWS) and agricultural water supply (AWS) using random forest regression (RFR) and multilayer perceptron neural network (MLPNN) techniques. The goal is to identify the most effective model to aid managers in optimizing water management strategies.

Methodology

The development and validation of models for estimating total water volume allocated (VTAL) occurred in three stages. First, data from the Zit Emba and Guentira dams were collected and updated, comprising eight variables: three hydrological (inflow, rainfall, evaporation) and five operational (water levels, stored water volumes, discharged water volumes, and total allocated volumes), recorded daily over eight years. The second stage involved identifying the optimal input variable combinations through correlation analysis to inform an artificial intelligence model. The final stage focused on constructing machine learning models, specifically a forward propagating MLPNN and RFR, using the identified vectors. The best model was selected based on performance metrics, including Pearson's correlation coefficient, root mean square error, mean absolute error, and Nash-Sutcliffe efficiency coefficient.

Result/Discussion

The results of five input variables confirms the effectiveness of the evaluated models, with the MLPNN showing promise for forecasting total volumes. During validation, the RFR model achieved the highest correlation (R) and efficiency (NSE) coefficients, along with the lowest RMSE and MAE values, while the MLPNN closely followed. These results differ from Qie et al. (2022), who found that the SVM algorithm outperformed both RFR and MLPNN in predictive ability.

Tableau 1 : Comparaison des performances des modèles

Barrage	Modèles	R	NSE	RMSE	MAE
Zit EMBA	**RFR**	**0.920**	**0.847**	**0.006**	**0.003**
	MLPNN	0.863	0.746	0.008	0.006
Guenitra	**RFR**	**0.886**	**0.784**	**0.020**	**0,013**
	MLPNN	0.876	0,750	0.022	0.014

The scatter plot (Fig. 1) findings align with Table 1, showing estimated values clustering around the 45° regression line, indicating high precision in model estimation.

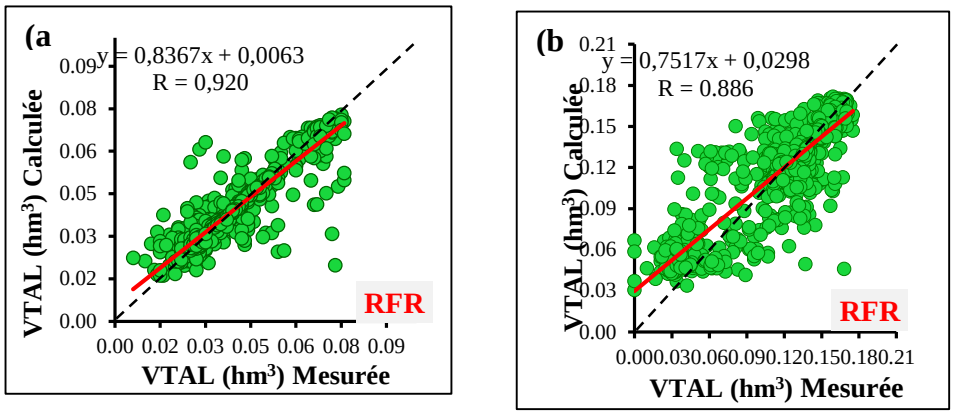

Figure 1: Relationship between observed and estimated TVA by the model RFR in the validation phase: (a) Zit Emba dam, (b) Guenitra dam

Conclusion

In conclusion, this research successfully achieved its aims by examining two machine learning algorithms RFR and MLPNN to model the Total Volume of Water Available (TVA) for the Zit Emba and Guentira dams in Algeria, using eight years of daily data (2009-2017). Seven combinations of input variables were assessed, with those including five variables yielding the best results. The analysis showed that all models improved TVA estimation, with RFR outperforming MLPNN. While MLPNN demonstrated good predictive accuracy, it struggled with extreme TVA values. This study presents a quick and cost-effective method for estimating TVA from reservoirs, relying on historical and projected data for model fitting and validation.

Keywords: Water resources, Irrigation, RFR, MLPNN.

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GRS-Po-07

Geospatial Insights into Carthage's Defensive Strategies: Unveiling Visibility Patterns in Northeastern Tunisia

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Introduction/Objective

The city of Carthage, originally named "*Carthago"*, was founded by the Phoenicians in the 9th century BC. Located on the northern African coast, near present-day Tunis, this city-state is renowned for its maritime empire, commercial advancements, and notorious conflicts with Rome, particularly during the Punic Wars (Ennabli A. 2020). Despite being razed by the Romans in 146 BC, Carthage has left a rich archaeological and historical legacy behind. The historical significance of the Carthaginian Empire and its terrestrial and coastal expansion along the Mediterranean shoreline highlight the crucial role of geospatial analysis in formulating military strategies against adversaries. Spatial analysis of archaeological sites unveils spatial and defensive dynamics of ancient societies (Siart et *al*., 2016). Within this context, our study analyzes the visibility of the "*Carthago*" site and its surroundings using a spatial approach.Our objective is to investigate how analyzing the visibility of Carthage's archaeological site can elucidate this ancient city-state's defensive and commercial strategies, along with the geospatial implications for deepening our understanding of Carthaginian geopolitics.

Methodology

To achieve this, we first adapted data from digital elevation models (DEMs) to reflect the paleo-landscape of that era, reconstructing past viewing conditions. Next, we utilized ArcGIS Desktop GIS software to conduct a geospatial analysis based on predefined lines of sight (LOS). The goal was to create a map of the visible zones from observation points (guard fortresses) in Carthage, considering the region's topographical parameters and natural obstacles.

Result/Discussion

The results reveal that the Romans strategically placed fortified guard posts at the base of mountains and along major roadways to assert their supremacy and control trade routes. Furthermore, lighter guard posts, likely made of wood, were positioned on prominent mountain peaks and hills, allowing comprehensive regional surveillance and rapid alert in case of attack.

Conclusion

In this study, we delved into the geospatial dynamics of Carthage, an ancient city-state with a storied history. We gained valuable insights into its defensive and commercial strategies by analyzing the visibility patterns of historical sites. The visibility map and lines of sight offer a clearer perspective of this strategy. The spatial analysis of the distribution of Roman fortresses may be considered as a valuable tool for comprehending the military and economic strategy of ancient civilizations. The outcomes of this study can be leveraged to a deeper understanding of its geopolitical significance and enrich our historical knowledge of the major battles chronicled by historians.

Keywords: "*Carthago*," archaeological sites, paleo-landscape, visibility map, DEM, GIS

Hydro-Hazards and Early Warning System

HH-Po-01

Development of the white plan of the district hospital of Bousalem; governorate of Jendouba - Tunisia; year 2022

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Background: In the face of escalating health threats posed by epidemics, technological incidents, climate-related disasters, and deliberate acts, the imperative to fortify our healthcare infrastructure becomes paramount. The absence of a white plan at BouSalem Hospital, mandated by legislative circular (50-200), underscores a critical gap in emergency preparedness. This study aimed to develop the white plan for BouSalem Hospital, Jendouba, for the year 2022.

Methods: Comprehensive demographic and social data were collected, alongside detailed information on human resources, material assets, and service capabilities. This included mapping the health district, categorizing human resources, assessing hospital capacity and equipment, and analyzing hospital and outpatient activity metrics. "Version 0" of the plan was drafted on January 21, 2022, and subsequently presented to the hospital management committee for approval in a meeting held on January 26, 2022. Final revisions culminated in the distribution of "Version 1" in both paper and digital formats on January 28, 2022.

Results: The developed white plan comprised 51 pages, featuring structured content with references, page numbers, sheets, tables, reflex cards, and flowcharts. Objectives of the plan focused on enabling the hospital to effectively manage exceptional health crises. Key components included activating the white plan under the direction of the Hospital Director, monitoring stress indicators with emergency and in-house managers, implementing emergency support activities, convening the crisis team, and conducting crisis cell meetings. The crisis cell encompassed 18 distinct functions, each managed by designated personnel or their deputies, ensuring comprehensive emergency response coverage.

Conclusion and Recommendations: The white plan represents a critical emergency response framework tailored to BouSalem Hospital's specific needs. Its structured approach not only enhances preparedness for crisis scenarios but also underscores the importance of systematic planning, coordination, and leadership in safeguarding public health and hospital operations during emergencies.

Keywords: crisis, plan, public health, climate change

Geological Modeling and Resources Exploration

Geological Modeling and Resources Exploration

Oral

Geo-Or-01

3D Geological modeling of multilayered Aquifer Systems

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Introduction/Objective

Geomodeling is essential for accurate characterizations of multilayered aquifer systems and developing efficient representations of both surface and subsurface geological units. This study focuses on the geological modeling of the Gabes Aquifer System in Southern Tunisia, aiming to establish a robust geometrical framework for hydrodynamic simulations. The main objective is to create a detailed architectural model of the aquifer system that reliably predicts its hydrodynamic behavior, taking into account the structural complexity and interplays within horst and graben structures, as well as the connectivity between these geological compartments.

Methodology

The methodology integrates a multi-source database comprising well data, geophysical records, and auxiliary information sampled from outcrops to address areas with insufficient geological data. A geostatistical investigation using 3D ordinary kriging was applied to replicate the elevation and thickness of aquifer components (Chihi et al., 2023). For the subsequent 3D geological modeling, the potential field co-kriging method was employed, incorporating well data, synthetic cross-sections, and the elevation maps from the geostatistical study (Calcagno et al., 2008, Chilès et al., 2004). The computed models adhere to a set of topological rules that govern the relationship between faults, reservoir interfaces, and geological structures, offering a cohesive and realistic framework for further analysis (Mezni et al., 2022).

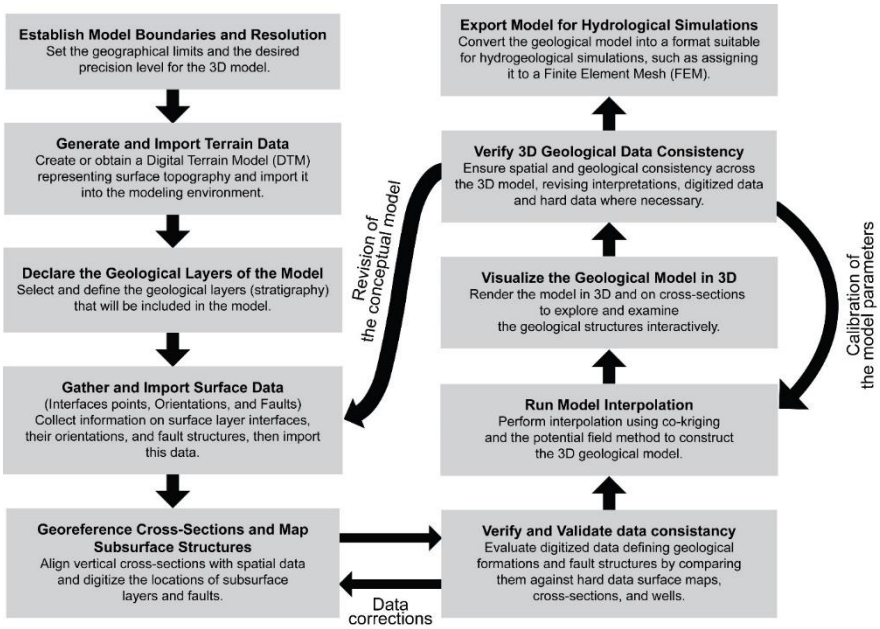

Figure 1 : Modeling workflow

Result/Discussion

The resulting 3D geological model synthesizes current knowledge of the Gabes Aquifer System. It provides detailed visualizations, such as 3D blocks and Venn diagrams, which enhance the understanding of the system's structural complexity. The model also supports hydrodynamic simulations by offering improved representations of groundwater level within the studied compared to previous hydrodynamic models, which primarily depicted the aquifer architecture as a simple gradient dipping towards the Mediterranean. This refined model emphasizes the impact of accurate structural delineation on predicting aquifer behavior between and within its different compartments.

Conclusion

This study successfully integrates geomodeling into the analysis of the Gabes Aquifer System by combining well data, geophysical records, and outcrop observations through potential field co-kriging. The resulting 3D geological model offers a detailed representation of the aquifer's structural framework, providing key insights into its hydrodynamic behavior. The comparison with previous models underscores the importance of geomodeling in enhancing the accuracy of hydrodynamic predictions, thereby improving resource management and decision-making for groundwater systems.

Keywords: 3D geological modeling, Potential field co-kriging, Geostatistics, Groundwater modeling, Multilayered aquifer systems, Horst and Graben.

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Geo-Or-02

Comparative Hydrogeological Assessment of Late Cretaceous and Early Eocene Carbonate Aquifers in the Mateur-Hedil region

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Introduction/Objective

The Mateur-Hedil region, located in northern Tunisia, is a tectonically deformed area with two primary geological zones: the imbricated thrust system and the Eastern Bejaoua Senonian anticlines (Booth-Rea et al. 2023; Elgattoussi et al., 2023). While the surface geology and structural features have been extensively studied (Melki, 1997 ; Melki et al., 2011), there is still a lack of detailed knowledge about the subsurface hydrogeology, particularly the Late Cretaceous and Early Eocene carbonate aquifers. This research aims to address this gap by using geophysical methods to image the subsurface and evaluate aquifer characteristics, ultimately improving groundwater exploitation in the Mateur-Hedil region.

Methodology

A combined geophysical approach, using 2D Electrical Resistivity Tomography (ERT) and Time-Domain Electromagnetic (TDEM), was employed to image subsurface resistivity distributions. These geophysical data were integrated with existing geological maps, borehole data, and surface observations to obtain a comprehensive understanding of the aquifer systems.

Results/Discussion

The integration of geophysical and geological data has revealed significant variations in lithology and structure within both aquifers. The Late Cretaceous aquifer comprises a fractured Campanian bar and a karstified Maastrichtian bar, separated by alternating layers of marl and limestone. While the Campanian bar exhibits fracturing, it also contains thin marl interbeds that can impede fluid flow (Fig.1b). Conversely, the Maastrichtian bar consists of massive, thick-bedded limestones, offering extensive and interconnected cavities spaces that are highly susceptible to karstification (Fig.1a). This lithological contrast explains the greater development of karstification in the Maastrichtian bar compared to the Campanian bar. The complex structure of the Late Cretaceous aquifer enhances its hydrogeological potential by facilitating groundwater flow and storage. In contrast, the Early Eocene aquifer, despite being karstified, has reduced thickness and increased structural complexity, limiting its exploitation potential. The presence of cavities and sinkholes (Fig.1c), often filled with clay, within the Lower Eocene formation significantly disrupts aquifer recharge. These clay fillings substantially reduce the effective porosity and permeability of the carbonate formations, thereby limiting groundwater flow and storage.

Conclusion

This study provides valuable insights into the spatial variability of groundwater resources in the Late Cretaceous and Early Eocene carbonate aquifers. The Upper Cretaceous aquifer's dual structure, with fractured Campanian and karstified Maastrichtian bars, enhances its hydrogeological potential. In contrast, the Early Eocene aquifer's reduced thickness and clay-filled cavities limit its groundwater exploitation. Understanding these differences is crucial for effective groundwater management in the region.

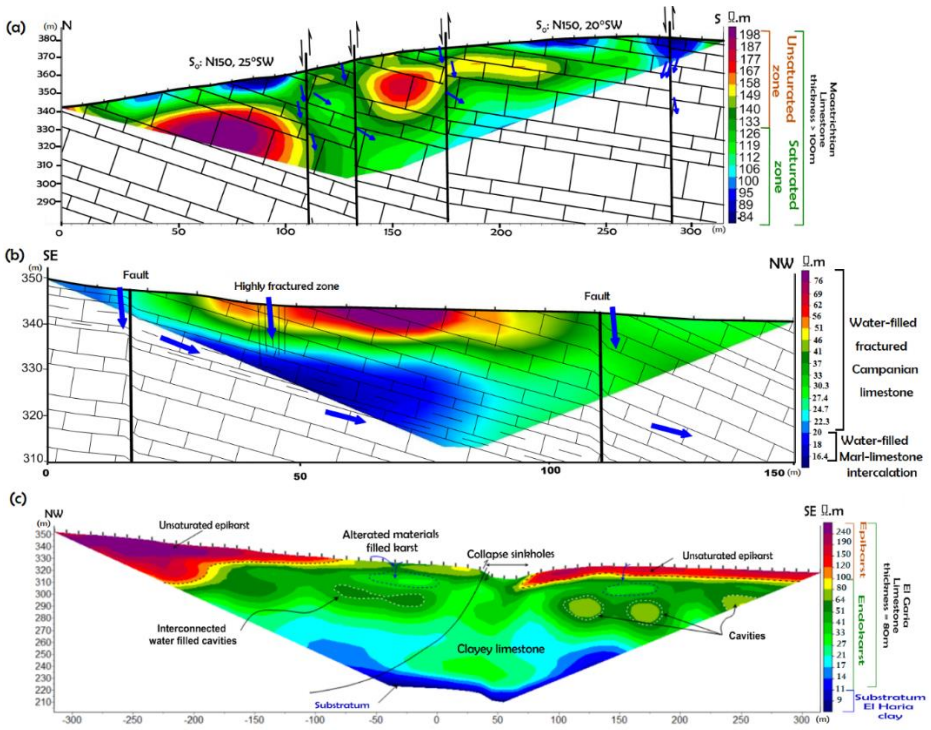

Figure 1: ERT inversed models showing (a) Maastrichtian karst aquifer, (b) Campanian fractured aquifer, and (c) Ypresian karst aquifer.

Keywords: Faults, Karstification, Carbonate aquifers, Late Cretaceous, Early Eocene, ERT, TDEM, Hydrogeology.

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Geo-Or-03

Geodynamic Study and Petroleum Interest of the Lower Cretaceous in the EL Kef Region (NW Tunisia)

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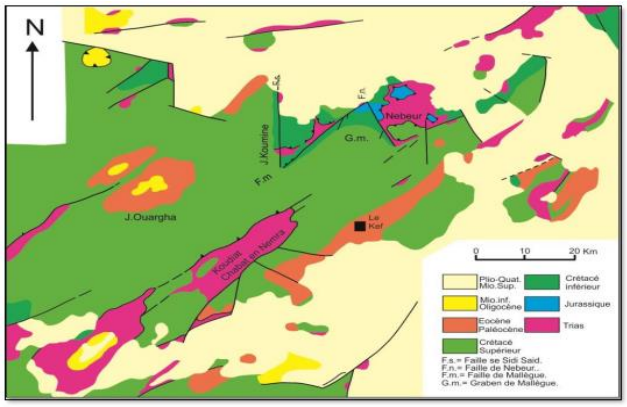
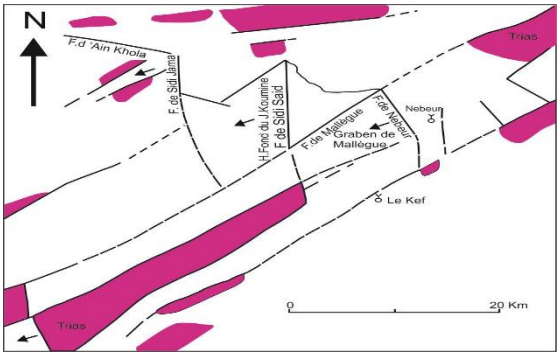
Introduction/Objective

During the Early Cretaceous, the southern Tethys margin was marked by extensional tectonic activity that resulted in a reactivation of earlier rift faults that had developed during the opening of the Tethys.



Picture1: Schematic geological map of the Kef-Nebeur region (from Martinez et al., 2008; modified)

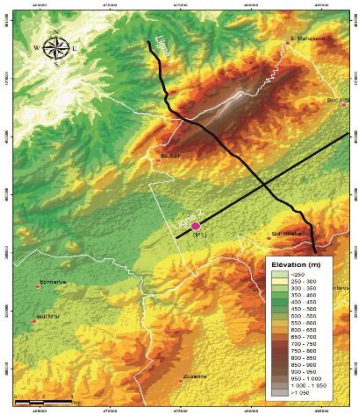
This tectonic instability acted on the salt by triggering halokinesis that was at the origin of tilting processes resulting in blocks tilted in various directions.



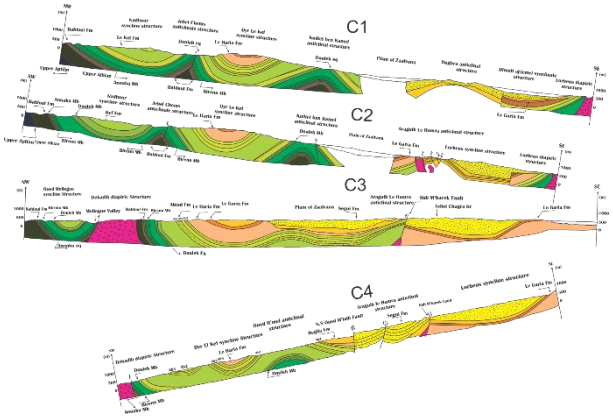
Picture 2: Organizational diagram of the major accidents in the Kef-Nebeur region. Their relations with the Triassic extrusions and their extensions (dashed lines) under the Upper Cretaceous cover (from Martinez et al., 2008; modified)

Methodology

The present work aims to highlight remarkable and rapid variations in thickness and facies of the Early Cretaceous deposits in northwestern Tunisia. Our approach based on comparative surface and subsurface geological investigations shows rapid lateral variations of the Cretaceous reservoir and source rocks.



Picture 3: Position plan of the 2 seismic lines interpreted on DEM model map



Picture 4: Serial Geological Cross-Sections

Result/Discussion

The importance and style of these variations change abruptly from the Aptian–Early Albian deposits of M'Cherga to the Fahdene black shales and the more recent Upper Albian series. A regional unconformity identified for the first time in the study area, marked by the non-deposition of the Middle-Lower Albian series, allows a direct contact between the Aptian reservoir rocks and the Upper Albian "black shales", considered as excellent source rocks in Tunisia. Subsidence inversions are found immediately above this regional unconformity. Indeed, the subsiding zones that received thick Aptian deposits have been transformed, since the Upper Albian, into relatively paleohighs. Conversely, the latter have been covered, since the Upper Albian, by thick sedimentary packages, often based on black shales.

Conclusion

Overall, the use of a multidisciplinary approach, integrating both subsurface and outcrop data, provides better interpretations of the subsurface and hydrocarbon exploration modeling.

Keywords: Geodynamic, Lower Cretaceous, EL Kef Region, Petroleum System, black shales.

Geo-Or-04

Advancing Mineral Resource Characterization through Geomodeling and Gravimetry

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Introduction

Geomodeling concepts are becoming essential for mineral resource assessment, offering improved accuracy in the modeling and characterization of ore deposits, particularly in complex geological environments [1].

This study focuses on the fluoro-baryte deposits of the Zriba - Jebel Guebli mine, hosted within the Jurassic Dorsal. The objectives are twofold: first, to consolidate fragmented data into a georeferenced digital database, and second, to conduct a comprehensive geological and structural investigation. The methodology integrates gravity data, borehole logs, and geological outcrop observations into a unified geomodel, enhancing the understanding of the region's structural complexity and improving predictions of mineral resource distribution and quality.

Methodology

The gravimetric survey plays a fundamental role in this study, involving a micro-gravimetry campaign across a network of 419 stations spread over 16 profiles to detect subsurface density variations. These measurements were subjected to various corrections for external influences, such as instrumental drift, tidal effects, latitude, and altitude, to isolate significant Bouguer anomalies that indicate variations in subsurface geology.

The corrected gravimetric data were then integrated with geological information, including borehole and surface observations. Geomodeling-based geostatistical methods [2] were employed to synthesize these diverse datasets into an architectural model, allowing for a more accurate interpretation of subsurface structures. The resulting model offers a detailed visualization of the faulted and folded structures, enhancing the understanding of mineralization patterns in the region.

Results and Discussion

By integrating these gravimetric findings with borehole and geological data, the study has identified significant subsurface anomalies corresponding to mineralized zones. The application of Geomodeling-based geostatistical methods allowed for a more refined correlation between surface observations and subsurface features, providing a clearer images of the region’s geological complexity. The geostatistical model developed in this study significantly improves the ability to predict the location and quality of mineral resources, supporting more targeted and efficient exploration strategies.

Conclusion

Geomodeling-based geostatistical methods has proven to be an effective tool in this context, offering significant potential for broader applications in fields such as mining exploration, petroleum prospecting, and land-use planning. Through the combination of gravimetric analysis and geomodeling, this study sets a precedent for the future of mineral resource characterization in Tunisia and beyond.

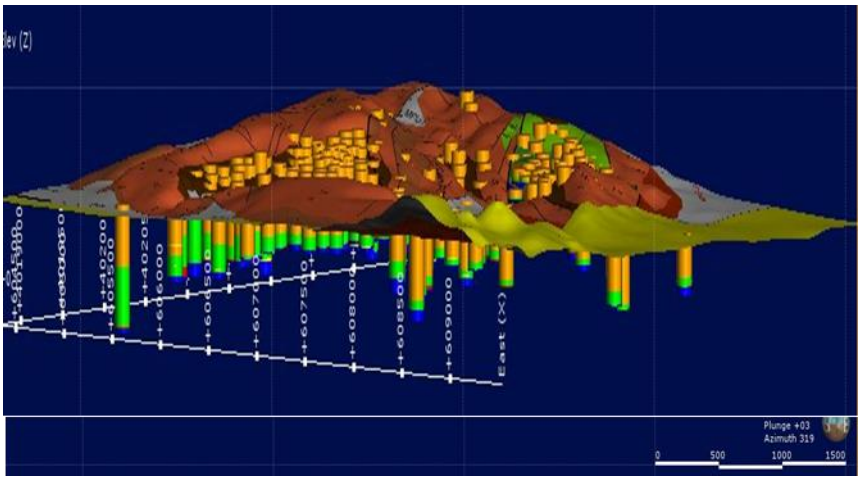

Figure 1: 3D representation of borehole distribution across the different compartments of the mining district.

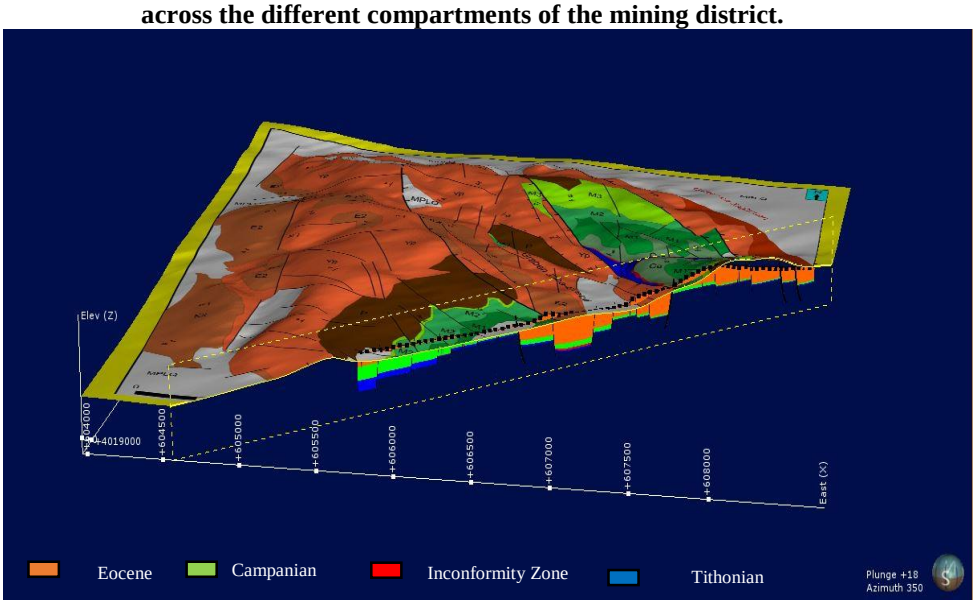

Figure 2: 3D visualization of the geomapped structural model and a computed geological cross section

Keywords: Geomodeling, Mineral resource assessment, Structural complexity, Digital georeferenced database, Gravity data, Borehole logs, Geological outcrops.

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Geo-Or-05

Gravity analysis of the Northeastern Atlas of Tunisia

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Introduction/Objective

The north eastern atlas study region in northern Tunisia shows several geological structures associated with intense tectonic deformations that induced genesis of over thrusts and tectonic imbrications. This region exhibits multi-scale tectonic deformations related to the basins structure and the regional geodynamic of the Northern African margin. Several geological studies have focused on the northeastern Atlas of Tunisia. However, many geological structures are still poorly understood, and the geodynamic evolution of the area remains, to this day, a subject of ongoing controversy among researchers. The aim of this study is (1) To determinate the deep inherited fault system network ,(2) to identify the tectono-sedimentary evolution of the study area, and (3) to provide a structural map for the north eastern atlas study area using outcrop and gravity data.

Methodology

In order to aid in determining how these structures were formed, a detailed gravity analysis was conducted in the north eastern Atlas of Tunisia. This analysis utilized publicly available Bouguer gravity anomaly data along with newly acquired data at 1-kilometer spacing from the National Office of Mines. A power spectral analysis reveals information regarding the depth of significant density contrasts in the crust as well as the structural features of the crust. A third-degree polynomial regression enabled us to produce the regional gravimetric map of the study area. After we generated the residual gravimetric map which corresponding to the gravity effect of superficial structures by subtracting this regional response from the Bouguer map. Upward continuations at increasing elevations, combined with the maxima of magnitude horizontal gradients (MHG), allowed for the identification of lineaments and their dips, potentially highlighting various contacts such as faults, flexures, and wrinkle structures. Geologically, Euler depths detect the fractures or fault patterns as well as the edges of lithostratigraphic formations.

Result/Discussion

The lineaments identified through the horizontal gradient method were interpreted as deep faults with predominant orientations in NE–SW and NW–SE directions, corresponding to major tectonic corridors. These interpretations were validated by automatic depth estimations using the Euler deconvolution technique. The separation of gravity anomaly bodies at different depths indicates that nearly all the lineaments align with NE–SW and NW–SE directions. Specifically, the NW–SE trending lineaments are associated with deep faults, while the NE–SW oriented lineaments define the global direction of the surface and are related to shallow structures.

Conclusion

This study not only confirms some faults previously identified or inferred by traditional geological research but also reveals a new deep fault that was obscured at the surface. Additionally, it provides valuable insights into the depths of major faults and the relationships between various geological structures.

Key word: gravity data, deep faults, the north eastern Atlas, Tunisia.

Geo-Or-06

Decoding the Soliman Coastal subsurface geometry structure (Tunisia, Mediterranean area): Gravity VS Seismic Data Analysis

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Introduction/Objectives

Understanding the coastal subsurface structure is crucial for assessing the vulnerability of coastal areas to various environmental threats, including erosion, sea-level rise, and flooding (Douglas and Robert, 2011; Ayari et al., 2024). The subsurface geology structure influences how water interacts with the land, affecting groundwater flow (Ayari et al., 2024) and sediment stability. The main objective of this work is to exhaustively map and analyze those structures to identify structural lineament patterns and rose diagrams. The integrated methodology demonstrates its ability to extract lineaments and highlights the relationship with the Soliman coastal zone vulnerability.

Methodology

The gravity data used in this research work was obtained from the National Office of Mine Tunisia (ONM). A free air correction was made using the 1967 International Gravity Formula (Morelli 1976), with a reduction density of 2.4 g/cm3. They used a homogeneous gravity network measurement of one point per kilometer over the whole research region, with a sensitivity range of 0.1 mGal. A bouguer map and data processing were made by analyzing the signal. After that, a residual map, Tilt map, and Euler deconvolution map were generated.To better understand the gravity analysis, two seismic lines, provided by the Enterprise Tunisienne d'Activités Pétrolières (ETAP), located along the Soliman plain were analyzed. Seismic sections were calibrated by a petroleum borehole log.

Result/Discussion

After the subtraction of the regional anomaly, the produced residual anomaly map reveals three positive and negative anomalies linked to the Grombalia basin, as well as one negative anomaly associated with the Soliman Plain. The latter displays wavy curves, suggesting the potential presence of hidden structures. So, we choose a tilt angle analysis, and the findings (Fig.1) demonstrate that the anomalies are highly personalized, with less noise and a lower amplitude. Individualization of the negative anomaly into three anomalies is the result of a hidden structure between two negative anomalies and near shore. The other anomalies are clearly visible, likely due to the lineament effect. To better undercover those lineaments we opted for Euler deconvolution analysis. The Euler map shows the western faulting Graben system presented as 3 Faults with NE-SW direction and the eastern faulting Graben as faults with N-S and NW-SE directions. The Euler map shows also that in plain of Soliman lays several faults also under the main river and the lagoon, with varying depth.
The interpretation of the seismic profile sections confirms the location of the Pop-up structure which is bordered by two major faults that may have occurred in the Miocene also clearly

detected by the Euler deconvolution analysis (Fig.1). A different minor fault fracture was detected in a different direction.

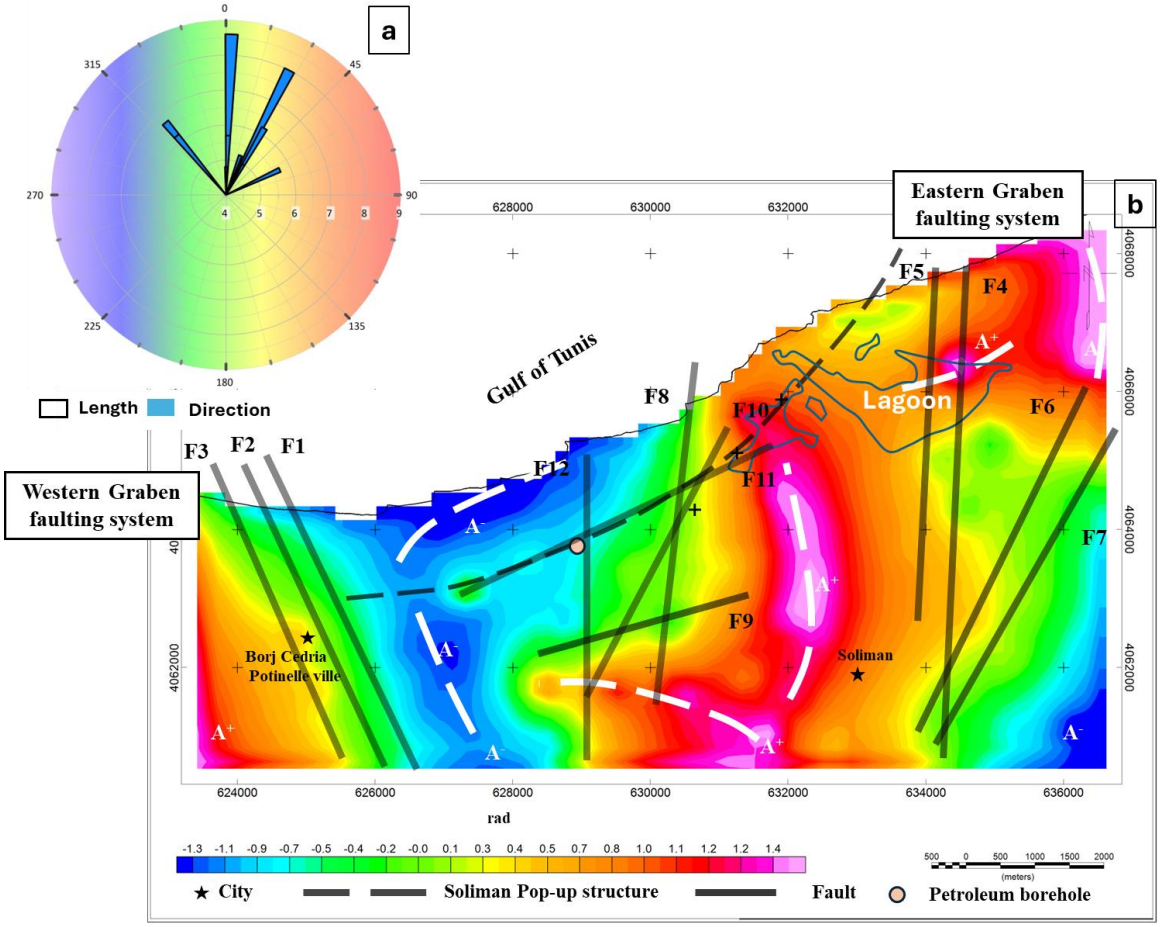

Figure 1: Soliman interpreted Gravity map a) Rose diagram b) Joint of Tilt lineament map

Conclusion

The current preliminary work demonstrates that beneath the ground structure of Soliman coastal zone is primarily governed by a fault network system with varying depths. The faulting system at Soliman is chaotic, as evidenced by its placement in the Graben Soliman-Grombalia-Hamammet influences the form and thickness of the aquifer. The findings also reveal the fault under Wadis and the lagoon, demonstrating that this type of structure explains how the lagoon and Wadi formed, as well as how sedimentation lays.

Keywords: Coastal zone, Structure, Euler, Mediterranean basin, Hidden Pop-up.

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Geo-Or-07

Mathematical modeling of Upper Tithonian Calpionellids (Protozoa, *incertae sedis*): the genus *Crassicollaria* as a key marker for updated stratigraphy and phyletic reconstructions

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Introduction

Calpionellids are widespread protozoan microfossils of a Late Jurassic-Early Cretaceous age, typically found in Tethyan pelagic domains and related paleobiogeographic provinces. Their abundance and rapid evolution make them excellent biochronological markers as they are considered by the Berriasian Working Group of the ICS's International Subcommission on Cretaceous Stratigraphy as primary tools for fixing a GSSP to the base of the Berriasian stage (Jurassic-Cretaceous boundary). Available 3-D morphologies of these precious microfossils are very limited and they are mostly studied in thin sections where they are randomly cut, leading to apparent variations among representatives of an individual taxon. Therefore, their taxonomy, phylogeny and related biozonations are still subject to divergent interpretations. Our presentation aims at a mathematical modeling of calpionellid microfossil morphology using polynomial approximations, where characteristic n-order polynomial coefficients can be assigned to a given species.

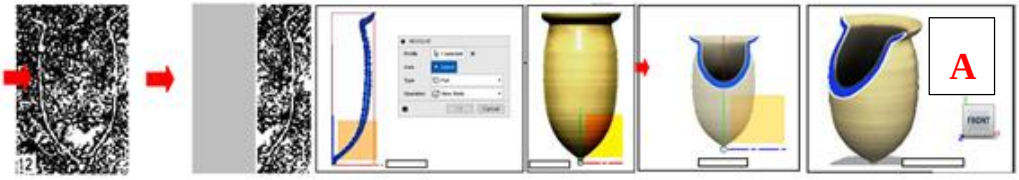
Methodology

After a first restoration of 3-D tests from sagittal sections of known species, generated sub-sections depending on the cut angle and its distance from the symmetry axis are digitalized using the «Web-Plot Digitizer» sofware. A set of cartesian (X-Y) coordinates are then attributed to every generated sub-section of a calpionellid species. This first set of data served for a polynomial approximation of their numerical graph by means of the « Origin 2022 » sofware. The obtained graph is considered as the representative of an n-order polynomial function characterized by an equation including (n+1) coefficients. All gathered coefficient data sets of the corresponding studied sub-sections are finally assumed to be a (p*n) matrix where the «p» columns constitute the studied sub-sections and the « n » rows refer to the polynomial coefficients. The correlation matrix generated by the « Excel » software allow to evaluate the distance between all the compared subsections as expressed by the corresponding Pierson coefficients : a more objective and rapid way of identifying similarities and differences between microfossil tests.

Result/Discussion

Sixty three calpionellid sections of five Tithonian species are studied. These belong mainly to the genus Crassicollaria spanning three reference subzones around the Jurassic-Cretaceous

boundary. Following the above-mentioned methodology steps, data compilations of the (63*63)-correlation matrix allow to easily identify morphological similarities betwween



	I.0.90	I.0.75	I.1.45	I.1.60	I.1.75	I.1.85	I.2.45	I.2.60	I.2.75	I.2.80	I.-1.90
I.0.90	1										
I.0.75	-0,361953	1									
I.1.45	-0,345377	0,8990405	1								
I.1.60	-0,323533	0,9861511	0,955458	1							
I.1.75	-0,010576	0,8618048	0,6332512	0,8191156	1						
I.1.85	0,5404073	-0,956708	-0,785482	-0,907758	-0,822781	1					
I.2.45	-0,356382	0,9439987	0,9926015	0,9820508	0,7012205	-0,84493	1				
I.2.60	-0,35836	0,9980726	0,9202679	0,9926405	0,8423039	-0,941685	0,9600718	1			
I.2.75	0,2922444	0,5608445	0,2791147	0,5053272	0,9027563	-0,533941	0,3499025	0,5301363	1		
I.2.80	0,6860023	-0,923142	-0,81732	-0,887765	-0,677423	0,9711678	-0,862531	-0,917227	-0,323434	1	
I.-1.90	0,5233521	0,3144569	0,0660486	0,274381	0,7468738	-0,258279	0,1229909	0,2876256	0,9529959	-0,03205	1
B. 0.60	-0,3475	0,888615	0,9991395	0,9482659	0,6211293	-0,77581	0,988275	0,9100794	0,2690324	-0,809123	0,0578819
B.0.75	-0,370796	0,9799774	0,967094	0,9963749	0,7736545	-0,906406	0,9900593	0,987975	0,4371476	-0,903277	0,195666
B.0.90	-0,39128	0,9979089	0,8844157	0,976662	0,8485305	-0,966288	0,9333362	0,9943637	0,5402858	-0,937314	0,284885
B. 1.60	-0,352601	0,9337867	0,9958886	0,976799	0,6858958	-0,830701	0,9994681	0,9511405	0,3342451	-0,85137	0,1109476
B.1.75	-0,341967	0,97386	0,971169	0,9947752	0,7645398	-0,885047	0,99278	0,9850487	0,4257743	-0,885156	0,1929837
B. - 1.75	-0,342734	0,8912403	0,9997484	0,9502124	0,6205428	-0,774067	0,9906239	0,9137031	0,2647784	-0,809233	0,0545957
B.1.85	-0,374192	0,996944	0,8663085	0,9709334	0,8722994	-0,971085	0,9185764	0,9906227	0,5803439	-0,930652	0,3276091
B.-1.90	-0,342035	0,9883996	0,9520423	0,9977777	0,8041252	-0,913397	0,9817633	0,9949035	0,4780132	-0,900181	0,2396005
B.2.45	-0,335218	0,853256	0,99543	0,9233092	0,5658647	-0,727689	0,9768718	0,87908	0,2087448	-0,773645	0,0084076
B.2.60	-0,376978	0,9791104	0,9671616	0,9951808	0,7657062	-0,903879	0,9906621	0,9881507	0,4237973	-0,90506	0,1821469
B.2.75	-0,375368	0,9984224	0,88034	0,9769065	0,863442	-0,967394	0,9296217	0,993592	0,5651436	-0,93108	0,312331
B.2.80	-0,379598	0,9961891	0,8630358	0,9689481	0,8716509	-0,973303	0,9158339	0,9893197	0,5800632	-0,932733	0,3259713

Figure 1: **Methodology of mathematical modeling of a calpionellid section and the generated correlation matrix. A**: Computer assisted steps from a calpionellid section observed under a light microscope to its 3-D reconstruction and subsection restoration. **B**: An extract of the generated correlation matrix and similarity degree between the subsections of two calpionellid species (for subsections titles in columns and rows: **I.0.75**= a subsection of *Crassicollaria intermedia* (**I**); passing by the symmetry axis(**0**) following a cut angle of **75°** ; **B. 1.60**= the subsection of *Crassicollaria brevis* (**B**); passing at one unit (**1**) from the symmetry axis following a cut angle of **60°**).

subsections previsiously attributed to different species. However, «virtual» dissimilarities among different sections of the same species are also detected. These first numerical identifications among calpionellid taxa may bring a new light towards a major taxonomic revision and its phyletic implications: a new numerical paleontology has to rise considering the example of an updated phyletic scheme of calpionellids through the upper Tithonian proposed here.

Conclusion

This new numerical approach of calpionellid section morphology leads to a more objective systematic paleontology of calpionellids : a preliminary guide towards updating calpionellid phyletic relationships and biozonation schemes. Beyond calpionellids, our methodology may generate further ideas and alternative digital tools for micro paleontologists and paleontologists working on thin sections, leading to improvements in fossil determinations, taxonomical studies and stratigraphic implications. These first numerical proxies may serve as a base for AI applications in the rising disciplines of numerical paleontology and logician stratigraphy.

Keywords: Calpionellids, Mathematic modeling, Taxonomy, Phylogeny

Geo-Or-08

Updated biozonation and correlations of Upper Barremian-Middle Albian successions from NE Tunisia (Zaghouan area): regional geodynamic implications

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Introduction

As part of the Lower Cretaceous of the South-West Tethyan margin, the Upper Barremian to Middle Albian sequences of NE Tunisia have been the subject of preliminary biozonations established by pioneering researchers, primarily based on planktonic foraminifera and ammonites. The limited and stratigraphically constrained sections present challenges in biostratigraphic interpretations due to inadequate sampling and varying taxonomic classifications. To our knowledge, no prior studies have addressed the well-exposed outcrop of the Sidi Medien section in the Zaghouan region. This study aims to provide a high-resolution biozonation chart for foraminifera within the Upper Barremian to Middle Albian interval. We discuss long-distance correlations of the identified biozones within the Tethyan realm. Additionally, correlations between the study section and three well-dated coeval sections from northern Tunisia allowto a tectonostratigraphic model for the onset of these successions within their broader regional geodynamic context.

Methodology

The Sidi Medien section, located in the Tunisian Dorsale (NE Tunisia, Zaghouan area), was systematically sampled over 180 meters. A total of 80 samples were collected and treated with hydrogen peroxide (H_2O_2). The samples were subsequently washed through a series of four superimposed sieves (from bottom to top: 63 µm, 125 µm, 250 µm, and 400 µm) and then dried. All foraminiferal specimens were examined using a binocular magnifier equipped with a Nikon camera, while photographic documentation was conducted using a scanning electron microscope. Systematic interpretations of both benthic and planktonic foraminifera were based on the most recent available reference works.

Result/Discussion

Planktonic foraminiferal assemblages (25 species) and benthic foraminiferal assemblages (53 species) spanning the Upper Barremian to Middle Albian interval, allowed the establishment of a precise biozonal framework. The identified biozones include: the Primare Zone (Upper Barremian to lowermost Aptian), the Blowi and Cabri Zones (Lower Aptian), the Luterbacheri and Ferreolensis Zones (Upper Aptian), the Planispira Zone (Lower Albian), and the Primula Zone (Middle Albian). These zones have been correlated with coeval units from other regions within the Tethyan realm. Notably, a significant sedimentary hiatus is observed, encompassing the Algerianus, Trocoïdea, Cheniourensis, and Eubejaouaensis Zones of the Upper Aptian.

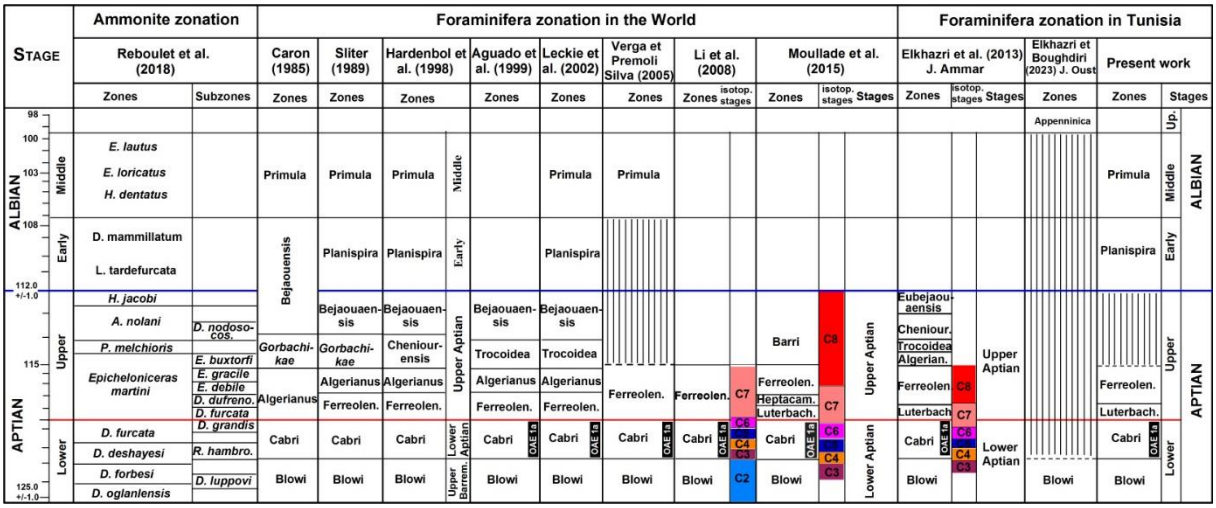

Figure 1: Biozonal correlations of NE Tunisia successions with their lateral equivalents from the Mediterranean area.

Within the study section, the early Aptian anoxic event OAE1a significantly influences the distribution of foraminifera. This analysis has been reinforced by total organic carbon (TOC) weight measurements and spatio-temporal assessments of all foraminiferal taxa to evaluate oxygen deficiency and elucidate the adaptive strategies of planktonic species. The quantitative analysis of both planktonic and benthic foraminifera yields a three-phased model: (1) prior to the OAE1a event; (2) during the OAE1a event; and (3) following the OAE1a event. Ultimately, based on regional correlations, a tectonostratigraphic framework is proposed. This model interprets the Aptian-Albian unconformity as the lower boundary of an Albian post-rifting package that overlies Aptian pre- and syn-rift units, following a regressive phase identified as Uppermost Aptian.

Conclusion

In NE Tunisia, the high-resolution biozonation of planktonic and benthic foraminifera from the well-exposed Sidi Medien section enables the proposal of a regional chart correlated with coeval schemes in the Tethyan realm. The OAE1a event is dated as Lower Aptian (Cabri Zone), which aligns with dates proposed in other Mediterranean sections. The absence of the Algerianus, Trocoïdea, Cheniourensis, and Eubejaouaensis zones of the Upper Aptian is attributed to a significant sedimentary hiatus occurring around the Aptian-Albian transition. This phenomenon is evident along a southeast-northwest transect, where correlations of thickness and facies variations support the hypothesis of syn-sedimentary tectonic control, delineating half-graben mini-basins bordered by the major faults of Zaghouan, Tunis-Ellès, and El Alia-Teboursouk. Future research should focus on employing additional biozonation tools. Notably, previous attempts at ammonite biozonation in Tunisia have emphasized ammonite assemblages rather than defining biozones based on index species.

Keywords. Aptian-Albian transition, Anoxic Event OAE1a, Planktonic foraminifers, Zaghouan region, Sedimentary hiatus, Regional correlations, Northeastern Tunisia.

Geo-Or-09

Sedimentological assessment of the Water Table Vulnerability to Pollution by Olive Oil Mill Wastewater, Oued Laya, Sousse area, Eastern Tunisia

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Introduction/Objective

The region of Sousse is known by its vast olive groves as it is one of the leading producers of olive oil, and, consequently, of significant quantities of Olive Oil Mill Wastewater (OMW). These latters are considered as harmful for the environment; their management being mainly based on storage tanks to be naturally eliminated by evaporation. This method has shown that in Sousse region, the distribution of OMW tanks is unbalanced due to the presence of 4 storage tanks (one at Sidi Bou Ali and three at Kalaa Kebira). Furthermore, this distribution is anarchic due the storage tanks installation in unsuitable areas. This needs to focus on the the sedimentological evaluation of the storage tank locations as an important factor to minimize their impact on the groundwater.

Methodology

For a suitable choice of storage tank locations, our approach is based first on a sedimentologic analysis of the outcropping deposits which are correlated to to petroleum well drilled in the studied area and refined by mapping. For this aim, the methodology adopted consists of acquiring a database of hydrological, hydrogeological, topographical and geological data of the study area. These are integrated and analyzed using the Geographic Information System (GIS) for restitution and mapping. From the obtained thematic and superimposed maps, we aim to determine the susceptible zones for potential infiltration of OMW pollutants leading to minimize and/or stop their contamination for the Oued Laya aquifer.

Result/Discussion

The sedimentological study of the Sidi Bou Ali ?site shows that Miocene deposits are silty sands with clayey-silty intercalations, marking the prevalence of upper foreshore environment, evolving into lower foreshore to upper shoreface. In addition, the mapping of watersheds and hydrographic networks, the determination of both of geomorphological characteristics and the water flow direction as well as the the relationship between permeability and granulometry of the deposits, show that Kalaa Kebira sites are considered as favorable for infiltration but unsuitable for the installation of OMW tanks.

Conclusion

Sedimentological investigations integrating the Geographic Information System for restitution and mapping allow to refute the location of two OMW tanks as not suitable for the Oued Laya aquifer. This is related to the high to medium infiltration potential of the sedimentary deposits in the study area. Further analyses would associate in-course multidisciplinary studies where more data and parameters are involved.

Keywords: Sedimentology, OMW, Mapping, Infiltration zones, phreatic groundwater contamination, Sousse.

Geo-Or-10

Modeling Soil Water Retention in Plastic Clays under Cyclic Wetting and Drying

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Introduction/Objective

This study deals with the modelling of unsaturated water flow in deformable porous media, focusing on highly plastic clay soils. Experimental drying and wetting tests were carried out in a climatic chamber on clay samples in order to identify the soil's water retention curve. These curves were determined following the methodology developed in Rafraf et al. (2017), which incorporates the hysteresis effects observed in cyclic drying and wetting processes. The final objective is to model both the drying and infiltration phases using a coupled hydro-mechanical approach.

Methodology

We have developed a numerical model using COMSOL Multiphysics to solve Richards' equation for flows in unsaturated porous media, taking into account soil deformation. The model incorporates the concept of effective stress, where the degree of saturation directly influences the mechanical behaviour of the soil. The soil water retention curves used are based on experimental data and were fitted using a dynamic contact angle model as described by Rafraf et al. (2017).

The simulations were performed on a 2D geometry representing a soil column. Boundary conditions included controlled water inflow at the top surface (for infiltration) and free drainage at the base. The lateral boundaries were assumed to be impermeable (Fig.1). The simulation was run over several days to account for both short-term infiltration and long-term dewatering processes. The numerical methods used included finite element discretization with an adaptive time step to handle the transient nature of the processes and the complex non-linearities involved.

Results/Discussion

The results of the numerical simulation were compared with the experimental data from the laboratory tests. They show a strong correlation, particularly in detecting hysteresis effects during wetting and drying cycles. The model proved to be an accurate predictor of water transfer in unsaturated and deformable soils, particularly during the transition between saturation and desaturation. It also demonstrated that hysteresis plays an essential role in determining the trajectory of the soil water retention curve, affecting both infiltration rates and drying patterns.

Table 1: Physical parameters of the soil sample.

Soil Type	Particle Size Distribution Curve Form	Distribution of Granular Fractions (NF EN ISO 14688-1)	γs (KN/m3)	Atterberg Limits	CaCO3 (%)
	Cu (µm)	Cc (µm)	Csi (%)	MSi (%)	FSi (%)
	>20 à 63	>6.3 à 20	>2 à 6.3	<2	
Soil	55	1.14	1	3	6

Csi: Coarse silty, MSi: Mean silty, FSi: Fine silty, Cl: Clay

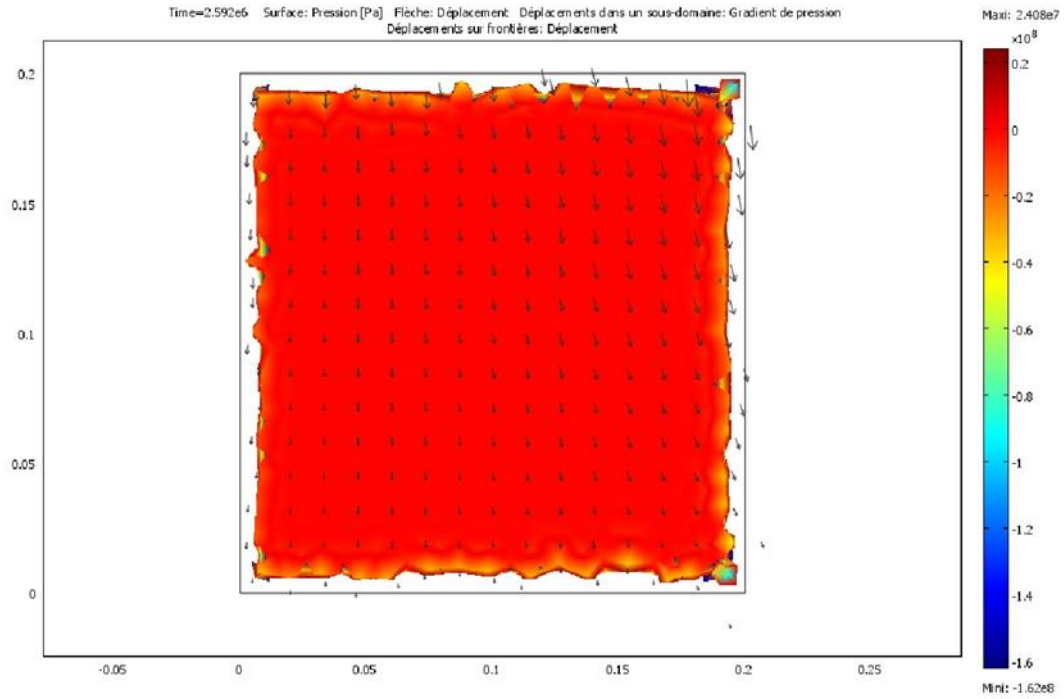

Figure 1:Pressure distributions for a drainage path after 30 days and displacement according to the preferred flow direction (z)

Conclusion

This study has enabled us to understand the hydromechanical behaviour of clay soils, particularly under cyclic drying and wetting conditions. The modelling results suggest that the coupled simulation approach improves our understanding of soil moisture dynamics and its influence on structural stability, such as in strip footings and embankment dams. The model could be used to assess the impact of seasonal cycles of soil moisture variation on construction pathology.

Keywords: Soil water retention curve, Unsaturated clay, Hydro-mechanical coupling, Richards equation, COMSOL, Soil hysteresis.

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Geo-Or-11

Storage of phosphogypsum in clayey soils: geotechnical and mechanical impact

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Introduction/Objective

The large stockpiles of phosphogypsum waste, a by-product of the phosphate industry, present significant challenges for Tunisia, due to its high production volume and its environmental implications. Managing this solid waste has become a critical issue, particularly considering the environmental damage observed in several regions, such as Sfax and Gabes, where improper handling of these by-products is noted. This study examines the potential of using two soils from southern Tunisia as a natural impermeable barrier in phosphogypsum (PG) disposal sites.

Methodology

The impact of phosphogypsum wastewater on the samples was evaluated in the laboratory across several parameters. A series of tests, including X-ray diffraction (XRD), grain size analysis, Atterberg limits, permeability, consolidation and shear strength (conducted with both tap water and phosphate solution), were carried out.

Result/Discussion

Laboratory analyses data showed a notable decrease in shear strength cohesion in the presence of acidic water, with values dropping from 77 kPa with tap water to 49 kPa with acidic solution for Soil-1. In contrast, Soil-2 exhibited an increase in cohesion, rising from 83 kPa to 148 kPa. The results showed that soil-2 exhibits the highest values of cohesion (c') and friction angle (ϕ') which can be explained by the presence of a larger quantity of smectite beared by Soil-1 compared to that of Soil-2. Despite these variations in shear strength, the compressibility of the soils remained relatively unaffected.

Conclusion

Our results suggest that the soils structures are sensitive to the phosphate solution, which could both enhance or impair its potential use as a natural layer in phosphogypsum storage sites, depending on the soil type and specific conditions.

Keywords: Solid waste, storage sites, shear strength, clay, southern Tunisia

Geo-Or-12

Characterization and assessment of stone deterioration on Antonin's baths ruins in CARTHAGE

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Introduction/Objective

Considering that by 2050 the effects of global climate change will subject buildings to extreme conditions, there is particular cause for concern for historic masonry buildings, where many cases of damage are currently being observed threatening our cultural heritage. Climate change is also expected to lead to increased moisture loading, which in the case of buildings near the sea will lead to deeper penetration of moisture and salt ions into buildings (Fahmy et al., 2022), increasing the risk of damage.

Antonin's baths on the archaeological site of Carthage are a valuable cultural heritage that requires special attention and conservation efforts. The presence of salt-related issues in these ruins constitutes a major risk, threatening their structural stability and historical significance. Our study aims to address this challenge by providing a detailed characterization of the deterioration mechanisms caused by salt, combined with an assessment of the petrographic and petrophysical characteristics of the building materials. These results will help decision-makers to establish effective strategies for the long-term preservation of these ruins.

Methodology

In-situ visual inspection and series of analytical techniques were carried out on samples taken from the site, including:

X-ray diffraction (XRD), ion chromatography (IC), inductively coupled plasma-emission spectroscopy (ICP-OES), and digital and scanning electron microscopy with EDS (SEM-EDS) analysis. Furthermore, measurements of porosity and density with a helium porosimeter (HP) and analyses with an optical microscope (OM) on thin rock sections were conducted to better understand the physical behavior of the rocks.

Result/Discussion

Visual inspection of the studied area revealed three prevalent anomalies affecting building blocks: honeycombing, efflorescence and black crusting.

The laboratory tests indicate that the building material is calcarenite, with a high total porosity (43% on average) and a predominance of calcite and quartz. The main soluble exogenous salts detected in the XRD analysis are halite, gypsum, and anhydrite.

In addition, an overview of the spatial distribution of soluble salts was provided.

Conclusion

Halite, gypsum, and anhydrite appear to result from contamination by sea spray and atmospheric pollutants, notably sulfur dioxide. Capillary rise and infiltration were pointed out as the main means by which soluble salts penetrate porous stone materials.

Numerical modelling of the processes of water flow, salt transfer, evaporation, etc. taking place in the construction stone forms the continuation of this work.

The model thus developed will be a powerful tool for testing different remediation scenarios.

Keywords: historical site of Carthage, limestone decay, X-ray diffraction, Chromatography, SEM-EDS, petrophysical characterization.

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Geo-Or-13

Use of Tunisian clay and spent bleaching earth in the manufacture of lightweight aggregates

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Introduction/Objective

Lightweight aggregates (LWA) are granular materials characterised by a porous core and low density. In accordance with the European standard UNE-EN-13055-1 (2003) [1], they are defined as having a loose bulk density of less than 1200 kg/m³. These materials are distinguished by a high strength-to-weight ratio, which is attributed to their internal porosity. Additionally, they exhibit effective thermal and acoustic insulation properties, a consequence of their porous inner core and dense outer shell. LWA can be produced from natural clays as well as industrial waste materials, including spent bleaching earth (SBE) and sewage sludge. This manufacturing process optimises the utilisation of these challenging wastes, thereby reducing their environmental accumulation while assigning them novel functions. This process contributes to the sustainable management of industrial waste and facilitates the production of high-performance materials. This dual benefit – reduction of pollutants and production of quality products – makes of LWA an innovative solution for the circular economy and environmental protection. Additionally, the LWA can be employed in water treatment due to their high porosity, which allows them to effectively absorb and filter contaminants. Consequently, they constitute a sustainable solution for the purification and management of water resources. In this context, the aim of this work is to use a Tunisian clay combined with an industrial waste (spent bleaching earth SBE) to produce lightweight aggregates. The study also examines the effect of the addition of SBE and the firing temperature on the properties of LWA.

Methodology

In order to achieve this objective, (ACBL) clay was collected in North-Eastern Tunisia, while SBE was obtained from an oil refining industry. The samples were subjected to a series of analyses, including X-ray diffraction and chemical characterisation. Subsequently, the raw materials were pulverised and finely ground. The impact of SBE incorporation on the characteristics of LWA was examined at varying firing temperatures, with added SBE to Clay ACBL in concentrations of 1%, 2.5%, and 4%. The prepared mixtures were then extruded, shaped manually, and subjected to a sintering process in a Nannetti® TO-R 120-14 rotary kiln at temperatures between 1140°C and 1160°C for a duration of five minutes. A total of six

samples were prepared and subjected to characterisation in order to ascertain a number of parameters, including percentage of expansion, loose bulk density, apparent particle density, dry particle density, loss on ignition, water absorption, compressive strength and porosity.

Results/Discussions

For the raw materials, the ACBL clay is primarily composed of illite and kaolinite proportions, while the spent bleaching earth (SBE) is predominantly composed of organic matter. The firing experiments demonstrated the suitability of both the clay and spent bleaching earth for producing lightweight aggregates that conform to the UNE-EN-13055-1, 2003 standard [1] (Figure 1). In fact, the loose bulk density values of these products range from 0.19 to 0.35 g/cm³. These indicate that both the SBE content and the firing temperature exert a significant influence on the properties of the lightweight aggregates (LWA). In this line, an increase in SBE content and firing temperature implies a higher expansion percentages and increased porosity (up to 91%) with a simultaneous reducing of densities and compressive strength. Moreover, the incorporation of elevated proportions of SBE can reduce the requisite firing temperature by up to 20°C, thereby contributing to diminished energy consumption.

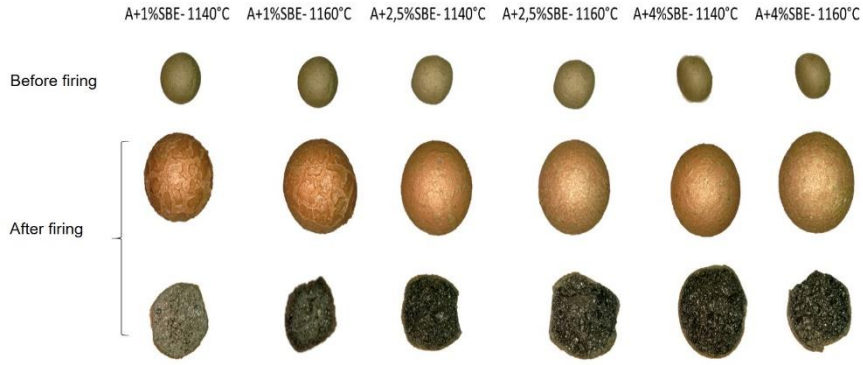

Figure 1: Photo of the lightweight aggregates (LWA) produced from ACBL mixed with spent bleaching earth (SBE) at 1140°C and 1160°C

Conclusions

This study highlights the advantages of integrating substantial quantities of organic carbon from SBE throughout the manufacturing process, illustrating the potential of lightweight aggregates to facilitate the recycling of pollutants. The LWA play a pivotal role in the recycling of waste materials, particularly in the transformation of spent bleaching earth (SBE) into inert products. Furthermore, they offer an environmentally adequate solution for water treatment. Their high porosity facilitates the adsorption of organic and inorganic pollutants, as well as suspended solids, thereby contributing to the purification of water systems. This upcycling process has the potential to significantly mitigate the environmental impact of industrial waste, serving a crucial function in both pollution reduction and water purification, as well as reducing the necessity for landfilling.

Keywords: Lightweight aggregates, spent bleaching earth, Tunisian clay, water treatment

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Geological Modeling and Resources Exploration

Poster

Geo-Po-01

"ED" method to detect the edges of the subsurface structures in the Enfidha plain (Tunisian Sahel) Hydrogeological implications

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Introduction/Objective

Due to population growth, climate change, and agricultural activities increase, the Enfidha region (Tunisian Sahel) suffers from severe water scarcity. To ensure sustainable management of groundwater resources, the reconstitution of aquifers geometry is crucial. In this context, the present study is realized. It aims to delineate accurately the subsurface features that may influence the arrangement of the water reservoirs using full tensor gravity gradient data.

Methodology

Nine signal components have been computed from full tensor gravity gradient data to extract the small-scale of the geological features. Directional Theta angle and Edge Detector (ED) techniques have been applied. The maximum values express the boundaries of the subsurface structures. Using horizontal directional analytic signal and directional total horizontal derivatives, the directional Theta are deduced: Tetha X, Tetha Y and Tetha Z. The new filter "ED" combines the horizontal directional Theta (Tetha X and Tetha Y). To validate the results obtained from this filter and elucidate the impact of the identified gravity lineaments on the aquifer system, we have interpreted seismic profiles calibrated by petroleum wells.

Result/Discussion

The "ED" map exposes several lineaments having different directions. The eastern part shows major lineaments mainly oriented E-W. NW-SE lineaments are encountered in some localities. In the southern part of the plain, the detected lineaments have NE-SW and N-S trends. The E-W lineaments are infrequent. The seismic interpretation proves that many of the lineaments identified from "ED" filter correspond to tectonic faults influencing the depth and thickness of the Mio-Plio-Quaternary deposits, which include the main aquifers of the Enfidha region.

Conclusion

"ED" is an effective tool for detecting the edges of geological structures that may control the geometry of an aquifer as well as water circulation. However, the identified features must be validated by another prospecting approach such as seismic and electrical methods.

Keywords: Enfidha plain, "ED" tool, aquifer geometry

Geo-Po-02

Late Cretaceous-Paleocene Ostracods and foraminifera assemblages from the Fguira Salah section (Fahs Region, Northern Tunisia): Biostratigraphy and Palaeogeography

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Introduction/Objective

The aim of the biostratigraphic study of the Fguira Salah section (Fahs area, Zaghouan region, Tunisia) is to provide details on the age of the series studied at this level using planktic foraminifera, which are more abundant in the washing residues and studied previously and the ostracods studied for the first time in this section. The Fguira Salah section has been the subject of several biostratigraphic and micropalaeontological studies based on planktic foraminifera and ammonites but never on ostracods. Thanks to the importance of these micro-crustaceans in understanding the depositional environment, a detailed lithostratigraphic cross-section was taken.

Methodology

Based on 43 samples, the biostratigraphic revision of this section made it possible to identify 47 species of planktic foraminifera, 16 species of benthic foraminifera and 19 species of ostracods. The samples were processed using the standard marl washing technique. Microfauna analysis was carried out on 50 g of washing residue. All ostracod and foraminifera specimens were sorted from the fraction greater than 63 µm. The microfauna was observed using a Scanning Electron Microscope (SEM) taken at the Water Research and Technology Center of Borj Cédria, Tunisia.

Result/Discussion

The vertical distribution of the ostracod species, has enabled us to distinguish five successive ostracod assemblages spanning the Santonian, Campanian and Palaeocene. The Maastrichtian is absent. These assemblages represent the most favorable living environments for the diversity of the ostracofauna. This is due to the exceptional qualities of adaptation of these species to various environments. This work indicates that ostracods are useful for biostratigraphic correlation. Overall, the study of ostracods in the Fguira Salah section contributes to our understanding of palaeoecological factors, including changes in salinity, water depth, temperature, and hydrodynamic over geological timescales. This research enhances our knowledge of paleoenvironmental evolution in the region and its broader implications for paleoecology.

Faunal relationships between the northern and southern Tethyan margins and the African and European Atlantic margins are controlled by global eustatic movements, which has enabled us to classify the ostracofauna into provinces.

Conclusion

The study of ostracod assemblages presents a new approach to additional dating of planktic and benthic foraminifera for the Terminal Cretaceous in northern Tunisia. These microorganisms are also good indicators of the depositional environment. Thus, the deep marine environment proved to be the most favorable for the moderately rich and diversified ostracofauna under stable environmental conditions. The inventory of ostracod taxa testifies to their importance in palaeogeographic reconstruction.

Keywords: Ostracods, Foraminifera, Biostratigraphy, Palaeoenvironment, Late Cretaceous Paleocene, Tunisia.

Geo-Po-03

New insights into the subsurface structure of Mornag plain using geophysical data

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Introduction

The complexity of the Mornag Plain subsurface structure has been the subject of several studies (Chekirbane et al., 2022; Farhat, 2011; Fougeirol et al., 2012), they dealt with various issues such as aquifer hydrochemistry, groundwater suitability, aquifer characterisation and artificial recharge. However, detailed geological characterization is not yet carried out. A subsurface model is often built using geophysical data (Cox et al., 2020) such as seismic reflection, well-log data (Wu, 2017), and gravity (Araffa et al., 2018). The seismic reflection and gravity, combined with well logging, play the key role in predicting subsurface structures in large-scale basins and in developing high-resolution vertical model (Ayari et al., 2023; Farfour et al., 2021) . Geographically, the area of interest is located in North Tunisia 20 Km to the southeast of Tunis city, in the governorate of Ben Arous. It contains a large irrigated area of about 12000 hectares, intensively using and overexploiting the groundwater resources (Jarraya-Horriche et al., 2022).

The current research aims to analyse and interpret the gravity and 2D seismic data to delineate the lateral and vertical structures of the Plio-Quaternary to Miocene aquifer system.

Methodology

The workflow adopted for this research incorporates the interpretation of nine 2D seismic lines provided by the Tunisian Enterprise of Petroleum Activity (ETAP). The seismic and gravity data are processed using the Petrel and Geosoft Montaj softwares, respectively. Due to a lack of information in a calibration well in the study area, the outcrops derived from the geological maps are used to improve the seismic data analysis. Later, geological and structural field trips will be done to report the stratigraphic unit thicknesses, strata contact, and faults mapping.

In parallel, wells and piezometers reports (localization, GR, lithology) are used to reconstitute the well logs lithology highlighting the sand from the clays. These reports are collected from the General Directorate of Water Resources (DGRE) and the Regional Office of Agricultural Development (CRDA) of Ben Arous Governorate.

Results and discussion

Picking the seismic horizons and their lateral distribution, the composite seismic profiles show dipping of Bou Dabbous formation towards the NE. The seismic sections confirm the presence of deep faults controlling the depositional system with the development of complex deep structures of horst and graben located in the SW. In the central part, a system of normal faults was picked generating thinking of the Quaternary sediment.

The Reconstitution of the lithological logs based on GR values shows the abrupt changes and facies heterogeneity. Those facies and structures play an important role in water flow and water table recharge.

Conclusion

The combination of different approaches in the present research allowed a better understanding of the Mornag plain subsurface. The gravity data analysis is in progress; it will be calibrated using the seismic profiles and the geological outcrops.

Keywords: Seismic data, gravity data, geological modelling, Mornag plain.

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Geo-Po-04

Geological and geophysical applied for prospecting the surface and subsurface structure in the Ghar el Melh region (North of Tunisia): Investigations for Prospecting Potential Deep Groundwater Resources

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Introduction/Objective

The study area is located in the north of Tunisia (Fig. 1 a). The geomorphology of the study area is determined by Digital Elevation Models. It is characterized by variation of topography (fig. 1 a). The high topography relief is characterized by NE-SW trending such as such as from the south to the north: Jebel el Besbassia, Jebel el Kechabta... The low topography relief is characterized by lowland zones such as El Bhira el Alia, Utique region… The Ghar el Melh region is affected by brittle and ductile structures at several directions N-S, E-W, NE-SW and NW-SE. The study area shows complex tectonic structures which are the result of several tectonic events. The aim of this work is to identify the geometry of subsurface structures and to determine the most important deep groundwater reservoirs. In fact, the importance of these water reservoirs was inferred from their lithologic character and their thickness of the sedimentary series in study area.

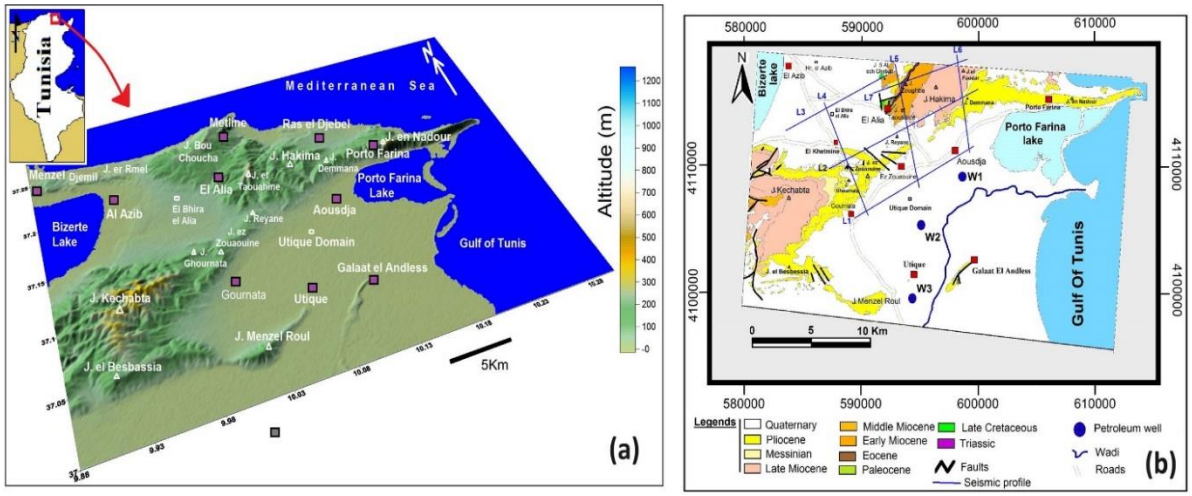

Figure 1: (a) Digital Elevation Model of Study area. (b) Geological map of Ghar el Melah.

Methodology

The following paper presents an integrated approach of field, outcrops data, seismic reflexion profiles and wire line logging of petroleum wells data. The seismic data consisted of 7 seismic lines from petroleum two companies (fig. 1 b). Using the Midland Valley "move" software, several reflectors of the sedimentary series of Late Miocene to Quaternary deposits bottoms and tops were identified in the seismic sections and used to draw the Two-Way Traveltime (TWT). Seismic horizons were calibrated using the Time-Depth conversion curve of the petroleum wells (Fig.1 (b)) and the outcrops section in the region. All georeferenced subsurface and surface data are integrated, calibrated and analyzed using Move software.

Result/Discussion

The interpretation of these sections highlighted the structural control of the thickness variations in the study area such as the first section L1 trending NE-SW (**Figs. 2 and 3**), located north part of the study area, crosses in its northeastern part the Aousdja region and the southwestern part of the Jebel Ghournata. The thickness of Pliocene-Early Quaternary and Late Miocene M2 series is relatively thick in the Aousdja region and decreases in Jebel Ghournata. The three-dimensional of sections seismic profiles at north view direction (**Figs. 2**), show a high and subsiding structures limited by different faults in El Alia. The Miocene series are limited by listric faults and formed tilted blocks in Gournata, ez Zouaouine and Aousdja regions. These blocks are formed by important thickness of Miocene to Actual sedimentary series.

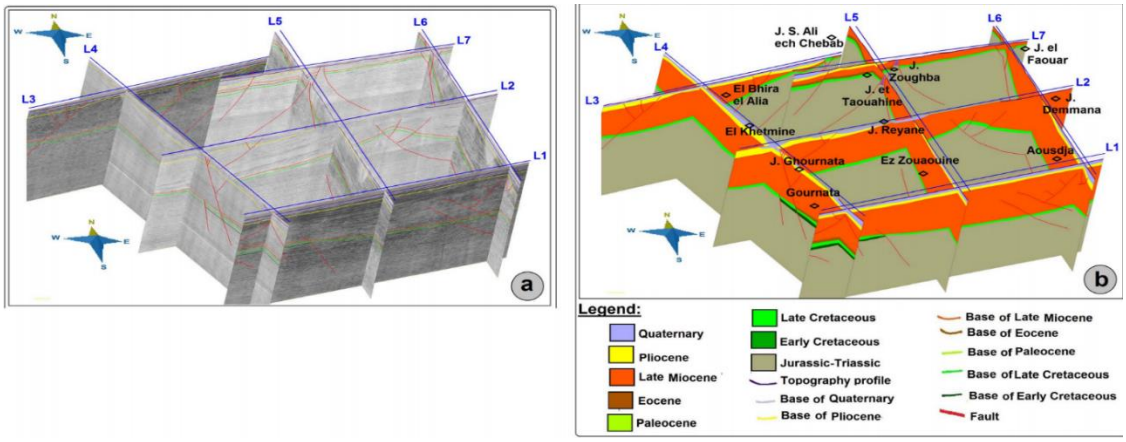

Figure 2: (a) 3D view interpretation from seismic profiles. (b) Important deep aquifer corresponding the Miocene reservoir.

Conclusion

Integration geological and geophysical data to provide new insights into the geometry of the geologic surface and subsurface structure of the Ghar el Mleh region region. The aim of this research is to define the structural geometry in order to identify the major structural directions and trends of the study area and to determine sedimentary series cropping out in the study area shows important deep aquifers corresponding the late Miocene reservoir.

Keywords: Surface and subsurface data, geometry structure, Late Miocene aquifer, Ghar el Melh region, North of Tunisia.

Geo-Po-05

Dynamic modeling in the El Borma Field: Petroleum Implications

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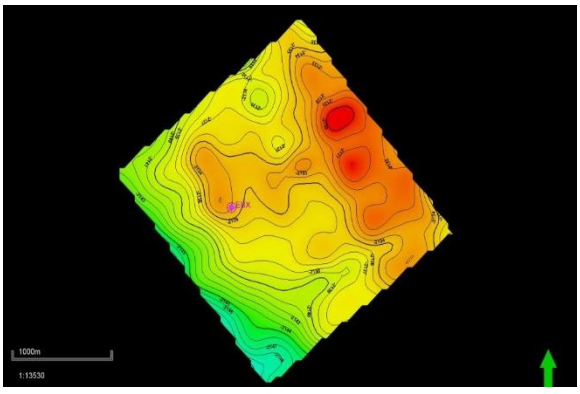
Introduction/Objective

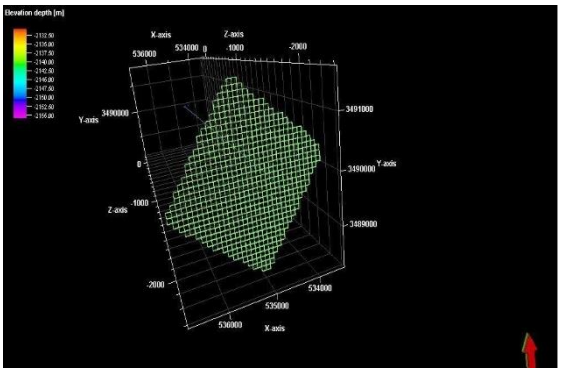
In the petroleum field, dynamic modeling is considered the most fundamental and decisive step. It is widely applied to: the evaluation and simulation of petroleum reservoirs, the design of oil and gas production facilities, production strategies, the estimation of reserves, as well as the characterization of petroleum fluids. This has been the subject of much research in recent decades. In a second step, the optimization of the exploitation requires the elaboration of the development plans of the hydrocarbon reservoirs, which seem essential in order to meet the spectacular growth in the demand for energy.

Methodology

It is within this framework that this work falls, the objective of which is to study an oil reservoir of an specific structure in the El Borma field by the dynamic simulation of a Black Oil model in order to estimate the hydrocarbons reserves in place and to subsequently develop the right development strategies to ensure optimal productivity; durable and less expensive.
The methodology of the work consists in the construction, through Petrel modeling software, of a 3D digital model from a geological model and data from the wells, the aim of which is to achieve such a real characterization as possible from the reservoir. This 3D model will then be initialized in dynamic mode under an Ecilipse 100 Black oil simulation interface in order to estimate the hydrocarbon reserves and understand the behavior of the reservoir. Finally, forecast scenarios will be established.



Picture1: Isobath map and location of the study well



Picture 2: Simulation grid

Result/Discussion

The choice of the reservoir development plan through the developed production forecast evokes the following findings to recommend:

-A static model update in order to improve the geological knowledge of the structure studied.

-The use of an enhanced recovery technique as early as possible in order to preserve the reservoir energy.

-The application of a moderate production regime that targets the economic needs of the company and that stabilizes the behavior of the reservoir.

-The gas injection method constitutes an adequate solution from an economic and not technical point of view given the absence of a gas lift injection station. In this case, a solution must be found to inject the gas without forgetting to recommend the construction of a pipeline that connects the gas source to the proposed production well, otherwise the secondary recovery method of water injection must be applied

-The perforation of the Alpha level will accelerate the natural depletion and does not manage to actually produce this quantity with its own reservoir energy. It is therefore recommended to use a lifting method if possible to exploit the likely reserves.

It is advisable to return to the EBX well and re-complete it by a means of lifting. In other part, the balance pumps could be the solution for this well in order to maximize the profits.

An economic study is necessary in order to maintain the performance of the reservoir to exploit these reserves.

Conclusion

We can conclude to say that it is necessary to choose between two proposals to make. It is either to -Perforate a new borehole, with the injection of gas to improve and have a maximum recovery rate or;

-Keep the recovery in the case of natural depletion of the old EBX well and the proposal of the installation of a balance pump in the future when the reservoir pressure is exhausted

Keywords: Reservoir, Dynamic Modeling, Simulation, Production, Forecasting.

Geo-Po-06

Events associated with Cretaceous-Paleocene transition in North Africa (Tunisia, Algeria, Morocco and Libya). Synsedimentary and tectonic record; evidence of a margin activity

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Introduction

The Cretaceous/Tertiary transition is well documented in the world; More sections considered complete, are distributed in several regions of the peri-Tethyan domain. However frequently, this transition is associated with a more or less marked stratigraphic gap due to tectonic and halotectonic activity. In terms of depositional systems, the authors considered stratigraphic gaps to be associated with either non-deposition or erosion, without however specifying the geodynamic context (tectonic-sedimentary). Now the limits of the El Haria and the intra El Haria formation are often surfaces of submarine erosion, sub-continental, it is also the same for.

Result/Discussion

All these surfaces can be telescoped in the marine environment especially on an exhaussed area, in favor of a pellicular sedimentation, which is qualified as condensed level, well described in Tunisia (region of Enfidaville). The tectonic factor has thus generated distant analogues that are distributed across the sedimentary basins in northern and southern Tethys. This factor was responsible for the different configurations generating depositional areas that were the seat of differential subsidence in several regions of Tunisia and peri-Tethyan basins.
This block tectonics feature also prevailed in Algeria. A continental series is interposed between two successive marine cycles, described locally in the El Kantara section. This would be a continental series probably contemporary with Bouloufa (Southern Tunisia). In offshore, at the TANIT borehole, the continental Eocene or even Paleocene is discordant with the Santonian. In Morocco, a major discontinuity separates the Lower Maastrichtian from the Upper Palaeogene in various areas: the Atlas domain, the Chott Tigri, Tendrara and the astern external Rif. Also in Libya, in the Sirte Basin, lacunar contacts have been described in several boreholes. An intra-Maastrichtian erosion surface was materialised at the interface between the ElWaha and Kalash formations.

Conclusion

Ultimately, the signatures associated with the K/Pg transition are multiple and varied. The duality between eustatism, tectonics and climate episodically has generated analogues in peri-Tethyan basins.

Keywords: K/Pg transition, synsedimentary tectonics, margin activity, peri-Tethyan basins.

Treasure Network Event : Reuse Opportunities Through Treasure Network

TrN-Or-01

The Euromed TREASURE research network and its extensions

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Introduction/Objective

The Euromed "treatment and sustainable REUSE of water under semi-arid climate" research network is dedicated to the modeling and control of biological systems for water reuse in the mediterraean rim. (cf. https://treasure.hub.inrae.fr). Founded in 2006 with the support of INRIA and INRA as part of the support program “3+3 project”, it operates on an informal basis, bringing together a dozen laboratories from countries bordering the Mediterranean. At times project leader, at other times organizer of research schools, it has to its credit around 25 co-supervised PhD theses, and a scientific output of 2 to 4 research articles per year, associating at least 2 researchers of different nationalities, members of the network's laboratories. This paper presents the TREASURE network, its origins, activities, successes and ramifications in France and around the Mediterranean.

Methodology

The network's initial focus was solely on the modeling and control of bioprocesses for water treatment, cf. for example (Benyahia et al., 2012). Recently, the rise of digital approaches in agriculture (digital farming, precision irrigation, AI, sensor implementation, system optimization) on the one hand, and issues of resource valorization and circularity on the other, have led the network to broaden the research questions of interest. Three distinct axes now characterize TREASURE: mathematical ecology (Abdellatif et al., 2016; Fekih Salem, 2025), automatic control for bioprocesses (Bouhafs et al., 2014; Khedim et al., 2015; Ghouali et al., 2015) and reuse of treated wastewater (Kefi et al., 2023; Ellouze et al., 2023), it being understood that these axes are highly connected.

Result/Discussion

The network's driving forces are concentrated around Montpellier, for the French players (Univ. Montpellier, INRAE, AMU...), in Tunisia, at ENIT-LAMSIN and CERTE, in Algeria, at the University of Tlemcen and Sidi Bel Abes, and in Morocco, at the University of Kénitra. They are complemented by several close collaborators, notably around the Mediterranean basin (Spain, Italy, Lebanon, Egypt)... Among the network's outstanding achievements are the participation of its members in a number of bilateral and European projects, including the instrumentation of a membrane pilot at ENIT-LAMSIN and the instrumentation of an experimental site for irrigating olive trees with treated wastewater. The network has strong links with INRAE's REUSE national research network[1], the ICIREWARD UNESCO water center in Montpellier [2] (which supported ANUMAB [3] and IDEFIX [4] projects), the SIMEV UNESCO chair[5] and the Water key challenge of the Occitanie region (which supports the WOc WoD

project[6]). These structuring collaborations enabled the network to submit the UNESCO DEE (Waste-Water-Energy) Chair project, financially supported by the ICIREWARD center through the IDéE (Intrégration-Déchets-énergie-Eau) project. To further strengthen its integration on the international scene, we are counting heavily on the recently approved COST Action CA23104[7] "Mainstreaming water reuse into the circular economy paradigm", which includes most TREASURE members as partners.

Conclusion

Launched in 2006 by Tewfik Sari and Claude Lobry, two mathematicians specializing in dynamical systems and professors at the Universities of Mulhouse and Nice respectively, the TREASURE network is an example of an informal structure that enables players from North and South to collaborate on major issues and challenges for all societies around the Mediterranean, proving that modeling as a common language can overcome all divisions and advance science.

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TrN-Or-02

UNESCO Chair Project DEE - Waste, Water, Energy

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Abstract.

The Waste Water Energy Chair is a Chair where different scientific disciplines intersect to achieve sustainable development goals in connection with water, waste and energy. The Chair project was submitted in April 2024 and we hope to see it come to fruition. By working on the 3 axes of waste, water and energy, we are working on the 3 pillars of sustainable urban development. In Tunisia, waste management has remained outdated until now, and current waste management practices fall short of what was legislated. The country is water-stressed (430 m3/person/year) and the reuse of treated wastewater is not sufficiently widespread, and legislation is lacking to make the recycling of treated water a solution to water scarcity. The energy situation is marked by declining resources and growing needs. Photovoltaic solar energy has not been adequately developed for a country as sun-drenched as ours. Today, solutions are needed to develop the electricity mix, free ourselves from dependence on fossil fuels and develop green and renewable energies. The Chair is made up of 15 partners. It brings together researchers from research laboratories in several countries, decision-makers from government agencies, private companies and civil society to work on these 3 axes and design a model of sustainable cities adapted to the Tunisian way of life, to rethink water management, sustainable waste treatment and the energy transition in a more efficient way.

Keywords. environmental protection, research and innovation, public policy, sustainable cities, education for sustainable development, sustainable engineering.

Chair presentation

The Waste Water Energy Chair is a science chair where different disciplines come together to achieve sustainable development objectives in relation to water, waste and energy. With the constitutionalization of the right to a healthy environment, the right of access to healthy water, the preservation of these resources for future generations and the need to increase the country's energy capacities through the integration of renewable and green energies, Tunisia has a duty to work on these aspects and implement research and innovation work in the city.The project envisaged by the UNESCO Chair has the potential to become a catalyst for change, inspiring similar actions on a global scale, while respecting local and cultural particularities. Through its holistic and integrated approach, this project aims to strike a balance between technological progress, socio-economic well-being and the preservation of cultural heritage, thus making a significant contribution to a more sustainable future for all.

The sustainable development of cities represents a major societal challenge. According to the World Bank, the rate of urbanization in Tunisia is 70%, a figure that highlights the importance of the urban question. Nevertheless, while the importance of sustainable and resilient cities is indisputable, various obstacles persist in integrating these requirements into national development policies and programs. The proposed approach, which looks at the sustainable development of cities through the interconnected context of waste, water and energy, invites us to reflect on various aspects such as planning, construction, production, treatment and reuse. A multidisciplinary UNESCO Chair dedicated to these issues has the potential to catalyse positive change on many fronts. It can serve as a research center facilitating interdisciplinary collaboration between scientists, decision-makers and experts. In addition, the Chair can play a key role in promoting public education and awareness, training a generation of leaders committed to sustainable development.

We are considering two cities cases of study:

- The town of Ariana, a high-density urban city, adjoining the capital.
- The picturesque historic village of Toujane, founded by Berbers in the 12th century, in southern Tunisia, with its new town.

Objectives of the chair and contributions to UNESCO's missions

The specific objectives of the Chair are (i) training vocational training professionals in the concepts of sustainable engineering, environmental management and urban planning as part of capacity-building programmes to ensure sustainable planning and management of resources,

(ii) organizing annual events in collaboration with partners on sustainable cities such as hackathons on urban innovation and seminars on emerging technologies to encourage knowledge sharing and the creation of innovative solutions, (iii) fostering interdisciplinary and international collaboration by facilitating exchanges between universities, businesses, local authorities and civil society organizations to stimulate innovation and accelerate the transition to more sustainable and resilient cities, and (iv) contributing to the adoption of public policies and regulations favouring urban sustainability by providing evidence-based recommendations and advocating research-based policy changes.

Thus, the aim of the DEE Chair is to mobilize knowledge and science in the service of sustainable development which is perfectly consistent with the objectives of the UN's Agenda 2030. The theme of the Chair is directly linked to ODD11: to ensure that cities and human settlements are inclusive, safe, resilient and sustainable. It will draw on its experts and resources to rethink the model of sustainable cities, integrating more efficient water management, sustainable waste treatment and the energy transition.

However, as a multi- and interdisciplinary structure, the Chair DEE will be able to contribute to other sustainable development goals: ODD3, ODD4, ODD6, ODD7, ODD9, ODD11, ODD12, ODD13 and ODD17.

TrN-Or-03

On some Anaerobic Digestion models: Mathematical Approaches, and Applications

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Introduction/Objective

The anaerobic digestion (AD) process is of increasing interest since it can generate renewable energy while treating waste and wastewater. Understanding and optimizing this process is a key challenge in addressing current issues in wastewater treatment.

Methodology

The study of interactions within microbial communities is one of the most important issues in the AD process. These interactions, such as mutualism and syntrophy, can have neutral, beneficial, or harmful effects on the microorganisms involved. A mathematical analysis of a three-tiered model of anaerobic digestion, including syntrophy, is performed in [1]. The model simulate the interactions among different microbial groups in an AD system. This study highlights the importance of trophic relationships and led to the establishment of operational diagrams, [2]. The focus on the effects of syntrophic relationships and substrate inhibition reveals complex dynamics in the AD process, [3]. The mathematical analysis of a competition model incorporating mutualistic interaction, [4], provides insights the coexistence and the synergy among different species in AD systems. Mathematical study of AD models also contribute to the optimization of the process by determining operational conditions to maximize biogas yield, [5].

Result/Discussion

Our results are described by operating diagrams (OD). The coordinates of the OD are the operating parameters, such as the input concentrations of substrates and the dilution rate. These parameters are under the control of the experimenter. All other parameters have biological meaning and are fitted using experimental data. The various regions of the OD correspond to qualitatively different asymptotic behaviors when we vary the control parameters. The benefit of this approach is that it highlights the similarities between the models and shows the novel behaviors that can arise when new assumptions are incorporated.

Conclusion

These research efforts have yielded significant results regarding the factors influencing anaerobic digestion efficiency and optimal conditions for biogas production. They pave the way for practical applications in waste management and renewable energy production.

Keywords: Anaerobic digestion, Syntrophy, Mutualism, Biogas, Operating diagrams

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TrN-Or-04

Model-Based Optimization of Fertirrigation with Treated Wastewater for Sustainable Agriculture

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Introduction/Objective

In Tunisia, the preservation of conventional water resources is a national priority, especially given the increasing frequency of droughts. In response, the use of non-conventional water sources, such as treated wastewater (TWW), for olive tree fertirrigation has become crucial. This study focuses on optimizing irrigation and nitrogen fertilization strategies to maximize olive yields while minimizing the environmental impact of TWW use in agriculture.

Methodology

A dynamic crop model was developed based on the "ToyCrop" model [1] and the model by Pelak et al. [2]. This model simulates the interaction between three key components: soil watercontent S(t), total nitrogen content in the soil N(t), and olive production B(t), operating at a daily scale over the growing season.To calibrate the model, data were collected from various sources, including local farmers in Sousse Msaken policymakers, field observations, and both field and laboratoryexperiments. Model parameters were estimated using the least squares method, with the experimental data fitted through MATLAB's optimization function "fminsearch". A sensitivityanalysis was also conducted, introducing random variations of ±10% in the calibrated parameters to evaluate the robustness of the model under uncertain conditions.

Result/Discussion

The calibration process showed that the model provided a satisfactory fit to the field data. The sensitivity analysis identified the key parameters influencing model performance, indicating that nitrogen stress had minimal impact on olive biomass, while water stress was the primary limiting factor. Through this analysis, optimal irrigation rates and total water requirements werederived to achieve maximum olive yield.

Conclusion

This study highlights the critical role of mathematical modeling as a decision-support tool for local stakeholders, facilitating informed decisions and encouraging the adoption of wastewaterreuse practices by farmers. It also demonstrates the feasibility of using treated wastewater to enhance agricultural productivity, provided that appropriate safety measures are implementedto mitigate environmental risks.

Keywords: Treated wastewater reuse, Fertirrigation optimization, Crop modelling

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TrN-Or-05

Modeling and parameter identification of bioprocesses in bioreactors

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Introduction/Objective

The general objective is to integrate knowledge on modeling, control, and optimization of dynamic systems for wastewater treatment and reuse in countries with semi-arid climates under both socio-economic and agronomic constraints. Indeed, the planning of wastewater treatment facilities represents an opportunity to address the impacts of climate change and allows for treating the problem of diminishing water resources. More precisely, my specific objective is to validate mathematical models from real experimental data and to develop new mathematical and numerical methods for determining the behavior of the various processes. These methods are innovative and original and can be applied to multiple biological processes that allow for maximizing productivity or minimizing the concentration of harmful matter at the process outlet.

Methodology

We propose models of flocculation of one or more microbial species in a chemostat that compete on a single nutrient. The species are present in two forms, isolated and aggregated bacteria. The mathematical analysis consists of determining the conditions of existence and local stability of the equilibrium points as a function of the operating parameters. The operating diagrams as a function of two operating parameters are studied theoretically from the mathematical results and numerically by continuation using MATCONT software in MATLAB. In the second part, the theory of parameter identification is presented, together with maximum likelihood principal component analysis (MLPCA), which enables us to determine a minimum number of reactions, while ensuring in-depth interpretation of the data up to a given confidence level. An application to the Fructo-oligosaccharides (FOS) production process is then presented, illustrating the theoretical results obtained.

Result/Discussion

Considering that the most competitive species flocculates with the same dilution rates, we have highlighted the common effects of the flocculation phenomenon and substrate inhibition on the emergence of limit cycles by Hopf bifurcations. However, under the joint effect of flocculation and mortality, the model can present Hopf and homoclinic bifurcations corresponding to the appearance or disappearance of stable periodic orbits. From experimental data of a FOS-producing bioprocess, we determined a mechanistic model that provided satisfactory predictions in forward and cross-validation. Furthermore, sensitivity analysis, Fisher information matrix, and parameter subset selection based on QR decomposition can be used as systematic tools to drastically reduce detailed biological models to representations that are practically identifiable. Using MLPCA, we determined the appropriate number of reactions and the corresponding stoichiometry. In addition, the products of Monod factors are chosen to describe the reaction kinetics. The model parameters are estimated using a weighted least squares method, and the model simplification obtained by eliminating parameters associated with large uncertainties is performed in a systematic, step-by-step manner. The reduced model provides a satisfactory prediction and can be convincingly cross-validated.

Keywords : Modeling, MLPCA, MATCONT, Operating Diagram

TrN-Or-06

Modelisation and optimal control of membrane filtration system

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Introduction/Objective

Membrane bioreactors (MBRs) are increasingly used in wastewater treatment due to their high efficiency and ability to produce quality effluent, despite requiring less space and producing less sludge. However, membrane fouling remains a significant challenge as it decreases the filtration efficiency and increases operational costs. physical cleaning methods such as backwashing, relaxation and aeration are commonly used to manage the transmembrane pressure increase or flux decrease (the main indicators of membrane fouling). The cleaning effectiveness depends on several parameters (backwash flow, backwash duration, filtration duration,…) that have to be optimized to mitigate the fouling impact. Recent studies focus on optimizing cleaning strategies through mathematical models anticipating the dynamic behavior of the membrane system to enhance system performances. For instance, optimal control approaches using the Pontryagin Maximum Principle were applied to predict the optimal times for switching between filtration and backwashing, maximizing net water production or minimizing energy demand of the system. The optimal control strategy was experimentally implemented in a constant flux MBR system to evaluate its efficiency to reduce energy consumption comparing to conventional strategies. This could offer practical insights into reducing fouling and energy costs, advancing the efficiency and sustainability of MBR technologies.

Experimental Methodology

The experimental study was conducted using an aerobic submerged membrane bioreactor equipped with a hollow fiber membrane (Polymem, 0.01 µm). The MBR was fed with the real sewage from WWTP aeration tank (table 1). The air flow rate was fixed at 2 CFM in the reactor to maintain the dissolved oxygen above 1.5 mg/L and create a shear for fouling mitigation. The SMBR was first operated in the classical mode (a periodical backwash of 45s applied every 10 min of filtration). Then, the operation was switched in the optimal control mode. The target permeate volume was selected as 0.04 m3 .m-2 corresponding approximatively to the volume collected after 5h of operation with the classical strategy. The experiments were carried out at constant permeate flux (8.5 ± 0.5 L.m-2 .h) and the transmembrane pressure (TMP) was recorded every 10 s.

Result/Discussion

The optimal solution is synthesized to minimize the hydraulic energy demand to produce a predefined net permeate volume. First, a simple fouling model is used to capture the dynamic behavior of the system, enabling the determination of the suitable optimal strategy. The employed model describes with satisfactory results the TMP obtained with classical strategy with R2 of 86%. The optimal control parameters were then calculated with the identified fouling model parameters using the appropriate equations from the optimal control synthesis [1, 2]. The

optimal backwash strategy consists first in a filtration phase during 16 min until reaching a singular arc corresponding to an optimal critical accumulated mass on the membrane. The cake mass (m) was maintained at during the singular arc volume interval which corresponds to a filtration/backwash duration of 4 hours and 12min. A final filtration cycle for 48 min is set up until produce the target volume. Compared to the classical backwash scheduling, the optimal strategy resulted in a 14% decrease in total resistance, particularly in residual fouling, and a 7% reduction in energy pumping consumption.

Conclusion

This study addresses one of the key challenges in membrane system and particularly in MBR technology: fouling control, which significantly impacts operational costs due to increased pumping requirements. An optimal control backwash strategy was developed to reduce these supplementary costs by managing fouling more effectively. The study demonstrates clearly the potential of mathematical tools to better control membrane fouling. To scale this approach to industrial applications, further research is underway including the development of adaptive feedback control systems that can dynamically adjust the model parameters to account for changes in system variability over extended periods.

Keywords: fouling, modelling, optimal backwash control, energy optimization

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