



# PROCEEDINGS OF

## The 4<sup>th</sup> International Conference

### Participatory and Integrated Management of Water Resources in Arid Zones

November 23rd-25th, 2023, Laayoune - Morocco





## ***Conference general presentation:***

Arid regions are known for their limited potentiality of water resources. The sustainable management of water resources in these areas is a permanent challenge, due to the growing demand, linked to population growth coupled with the negative impacts of climate change. The edition 2023 of GIRE3D is an opportunity for all water stakeholders to exchange methodologies adapted to the exploitation and management of water in such contexts. This edition will allow, among other things, to:

- Promote the dialogue between scientific research and professionals in the water sector.
- Create a platform for debate and exchange of experiences between the various national and international stakeholders on the theme of water in arid zones.

## ***Organisation:***

The GIRE3D International Congress is co-organized by the Moroccan Committee of the **International Association of Hydrogeologists (CM-AIH)** and the **Hydraulic Basin Agency of Sakia El Hamra and Oued Eddahab**, in partnership with the **Directorate of Research and Water Planning**.

## ***Conference Thematics:***

- ✓ **Water resources and climate change: adaptation and resilience;**
- ✓ **Coastal aquifers, quality, diagnosis and monitoring;**
- ✓ **Alternative resources and water technologies: desalination, artificial recharge, wastewater and reuse, collection of rainwater and fog;**
- ✓ **Water saving in agriculture: new technologies and management strategies,**
- ✓ **Exploration and exploitation of deep-water resources;**
- ✓ **Quality, Vulnerability and Protection of Water Resources;**
- ✓ **Chemical and isotopic tracers: contribution to the functioning of hydrological systems;**
- ✓ **Numerical Modeling, Geo-information, Remote sensing, Geomatics, Artificial Intelligence;**
- ✓ **Water Heritage, Governance and Future Challenges at the Basin Scale;**
- ✓ **Water and Society: The Need for Participatory Water Management and a Sustainable Society;**



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### **Conference Proceeding-Publication**

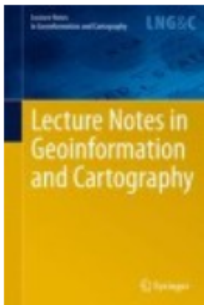
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## Topic:

# Water resources and climate change: adaptation and resilience



## Evaluation of the degradation of the draa oasis to open avenues of reflection for the preservation of water potential and agricultural heritage in the valley

A. MESKOUR<sup>1</sup>, J. AHATTAB<sup>1</sup>, M. AACHIB<sup>1</sup> & M. D. HASNAOUI<sup>1</sup>

1- 1- Laboratoire de recherche LAGCET, Ecole Hassania des Travaux Publics, Casablanca, Morocco

\* Email: [alimeskour11@gmail](mailto:alimeskour11@gmail.com)

### Abstract:

The Draa Oasis, a vital ecological and agricultural region situated in the Draa Valley in Morocco, is facing degradation caused by persistent water scarcity due to climate change. Indeed, disruption of the hydrological cycle and high temperatures in these areas exacerbate water scarcity. Groundwater resource is overexploited and starting to deplete due to surface water shortage, which can be seen in the significant continuous degradation of palm trees in the region. The situation in the oasis is bound to get worse in the future due to climate change. The reduction of the irrigated agricultural area and the adoption of low-water consumption in agriculture are the key factors for a sustainable solution, which can make a significant contribution to saving surface water and groundwater from excessive exploitation. However, with economic development, population growth and agricultural traditions, recourse to these solutions seem unlikely. The objective of our work is to assess the degradation of the Draa oasis in recent decades to help policy makers decide on the management of water resources in the area. So, the research aims to evaluate and analyse the degradation of agriculture in the Draa valley oasis during the last decades through the GIS and Remote Sensing technics using NDVI time series and land cover. The overall objective is to develop avenues of reflection for the safeguarding of water potential and agricultural heritage of the valley.

**Keywords:** Arid and semi-arid watersheds, Draa oasis, Degradation of oasis, NDVI time series, Land cover.



## Climate risk analysis and development of a climate change adaptation plan in the agri-food sector: the case of a citrus unit.

Y. JAOUHARI<sup>1\*</sup>, L. STOUR<sup>1</sup> & A. AGOUMI<sup>2</sup>

<sup>1</sup>Process and Environment Engineering Laboratory, Faculty of Sciences and Techniques of Mohammedia, Hassan II University of Casablanca, Morocco

<sup>2</sup>Civil Engineering, Hydraulics, Environment and Climate Change Laboratory, Hassania School of Public Works, Casablanca, Morocco

\* Email: [youssef.jaouhari@gmail.com](mailto:youssef.jaouhari@gmail.com)

### Abstract:

The food industry sector is one of the leading sectors of the Moroccan economy. Nevertheless, it is subject to a set of constraints that prevent its full development, particularly the insufficiency of exportable offers, irregularities in agricultural campaigns, and an unstructured domestic market. Increasingly, Climate Change (CC) is becoming a significant challenge that is revealing the structural vulnerability of agricultural production models due mainly to the exacerbation of declining water resources. The present research was conducted on a citrus unit using a participatory approach, combining a CC risk and vulnerability assessment that affects the unit's activity and an economic analysis approach. This approach is inspired by the Climate-Expert tool, a practical adaptation approach developed by the German Agency for International Cooperation (GIZ). The analysis results were used to define an adaptation action plan at the citrus unit scale. The unit's supply chain is particularly sensible to the CC, especially with declining water resources and excessively high production costs. This requires the implementation of urgent adaptation measures, such as solar pumping, techniques for rational management and valorization of irrigation water, and capacity building in water use efficiency.

**Keywords:** Climate Change, Moroccan economy, water resources & irrigation water.



## Assessing the impact of climate and land use change on soil water erosion in the Loukkos watershed, northwestern Morocco.

*S. Acharki*<sup>1\*</sup>, *F. El Qorch*<sup>2</sup>, *Y. Arjda*<sup>3</sup>, *H. Ben Aissa*<sup>2</sup>, *M. Amharref*<sup>1</sup> & *A.S. Bernoussi*<sup>1</sup>

<sup>1</sup>GATE Team (Géoinformation, Aménagement du Territoire et Environnement), Faculty of Sciences and Technologies of Tangier, Abdelmalek Essaadi University, Tetouan, 93000, Morocco,

<sup>2</sup>Laboratory of Water, Biodiversity and Climate Change (WBCC), Department of Biology, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, 40000, Morocco,

<sup>3</sup>Natural Resources and Sustainable Development Laboratory, Faculty of Sciences, Ibn Tofail University, BP 133, Kenitre, Morocco.

\* Email: [sacharkis@gmail.com](mailto:sacharkis@gmail.com)

### Abstract:

Water soil erosion is a critical challenge with profound implications for ecosystem sustainability and agricultural productivity. This research aimed to assess the influence of climate and land use change on soil water erosion in the Loukkos watershed, located in northwestern Morocco. This watershed is renowned for its intense agricultural activity and experiences a Mediterranean climate. To quantify soil erosion under both current (1981–2017) and future climate scenarios (2025–2055), we utilized the Revised Universal Soil Loss Equation (RUSLE) model in conjunction with remote sensing and Geographic Information System (GIS) technology. The future climate data predicted by the CNRM-ALADIN63 model, specifically precipitation, was downscaled using the CMhyd statistical downscaling model. The research findings revealed that the average annual soil erosion rate in the Loukkos watershed was approximately 3.0 tons per hectare, with a standard deviation of 6.2. Notably, 92% of the watershed exhibited soil loss below 10 tons per hectare per year, indicating a relatively low erosion risk. Nevertheless, it is recommended to prioritize attention and implement soil conservation practices for the remaining 7.1% of the area that experienced soil erosion exceeding 10 tons per hectare per year. Additionally, the analysis indicated that compared to the baseline period (1981–2017), the average annual soil loss could potentially increase by 3.9% and 8.4% under medium and high Representative Concentration Pathways (RCP 4.5 and RCP 8.5), respectively. These findings underscore the vulnerability of the Loukkos watershed to future climate change and the potential intensification of soil erosion rates. Assessing soil erosion and land use change provides valuable insights for decision-makers to develop effective strategies for long-term water and soil resource planning, risk mapping, and sustainable agriculture practices in the face of diverse climate change scenarios.

**Keywords:** Soil water erosion, land use change, climate change; RUSLE model, remote sensing.





## Evaluation of tidal energy potential across different water depth layers in a coastal lagoon: a case study of Khenifiss lagoon (southern Morocco).

H. El Behja<sup>1\*</sup>, A. El M'rini<sup>1</sup>, D. Nachite<sup>1</sup>, M. Bouchkara<sup>2</sup>, K. El Khalidi<sup>2</sup> & B. Zourarah<sup>2</sup>

<sup>1</sup>L Research Laboratory in Applied and Marine Geosciences, Geotechnics and Geohazards, Department of Geology, Faculty of Sciences, Abdelmalek Essaadi University, Tetouan, Morocco

<sup>2</sup> Associated Unit URAC 45, Marine Geosciences and Soil Sciences Laboratory, Department of Geology, Faculty of Sciences, University Chouaïb Doukkali, El Jadida, Morocco

\* Email: [h.elbehja@gmail.com](mailto:h.elbehja@gmail.com) / [hamza.elbehja@etu.uae.ac.ma](mailto:hamza.elbehja@etu.uae.ac.ma)

### Abstract:

The global industrial economy is heavily reliant on fossil fuels, but their depletion and environmental impact require a rapid shift to low-carbon energy sources. In Morocco, the National Energy Strategy envisaged putting the country on the pathway for a real energy transition, aiming for 52% of electricity production to come from renewable sources by 2050. Coastal lagoons offer a potential sustainable energy source through the extraction of energy from tidal currents at different water depth layers. Therefore, measurement of currents in each depth layer is crucial for determining suitable locations and studying the feasibility of harness this renewable energy through tidal power generation technologies. This study focuses on evaluating the potential of tidal currents for generating marine renewable energy in the Khenifiss Lagoon, south of Morocco. The lagoon's hydrodynamics are primarily dominated by tides, with the semi-diurnal component (M2) dominating the tidal cycle (period of 12 h 25) with 1.5 to 3.2 m of tidal range. The Multicell Argonaut-XR ADCP is employed to measure current velocities during a period of two days at each station in the lagoon. Current velocities are measured at two specific stations. Station 1 has 1 m intervals across an 8 m depth, and Station 2 has 0.5 m intervals across a 5 m depth. The results reveal that at Station 1, layers 2, 3, 4, and 5 (-2 to -5 m depth) exhibited consistent current velocity conditions, making them well-suited for power density conversion. The average power density range in these layers ranged from 54.926 W/m<sup>2</sup> to 65.223 W/m<sup>2</sup>. Similarly, at Station 2, layers 2, 3, 4, 5, and 6 (-2.5 to -4.5 m depth) displayed favorable current velocity conditions for power density conversion, with an average power density range of 23.911 W/m<sup>2</sup> to 36.630 W/m<sup>2</sup>. This work establishes a foundation for more detailed tidal current resource assessments for future tidal energy development in the Khenifiss lagoon and in such a semi-enclosed natural system.

**Keywords:** Tidal current; renewable energy; ADCP; power density; Khenifiss lagoon.



## An integrated environmental assessment of Khenifiss lagoon in southern Morocco: a path to sustainable development and conservation.

H. El Behja<sup>1\*</sup>, A. El M'rini<sup>1</sup>, D. Nachite<sup>1</sup>, M. Bouchkara<sup>2</sup>, K. El Khalidi<sup>2</sup> & B. Zourarah<sup>2</sup>

<sup>1</sup>L Research Laboratory in Applied and Marine Geosciences, Geotechnics and Geohazards, Department of Geology, Faculty of Sciences, Abdelmalek Essaadi University, Tetouan, Morocco

<sup>2</sup> Associated Unit URAC 45, Marine Geosciences and Soil Sciences Laboratory, Department of Geology, Faculty of Sciences, University Chouaïb Doukkali, El Jadida, Morocco

\* Email: [h.elbehja@gmail.com](mailto:h.elbehja@gmail.com) & [hamza.elbehja@etu.uae.ac.ma](mailto:hamza.elbehja@etu.uae.ac.ma)

### Abstract:

Coastal lagoons are important ecosystems that support human populations and biodiversity while also providing socioeconomic benefits. These systems, however, face a number of challenges, making them vulnerable to both natural and human factors. In this study, we applied the Driver Pressure-State-Impact-Response (DPSIR) Approach to conduct a comprehensive socioeconomic and environmental assessment of the Khenifiss lagoon, located on the southern Atlantic coast of Morocco, to promote sustainable development and support decision-making. This study represents the first attempt to conduct a comprehensive global and multidisciplinary environmental assessment of the lagoon by using a wide range of data sources, including relevant publications and reports, satellite im-ages and remote sensing data, field observations, and interviews, all analyzed under the DPSIR framework. Our findings show that both natural and human factors have an impact on the eco-system. Natural factors cause the lagoon's silting, which is intensified by a large shipwreck stuck at its inlet, whereas human factors include population growth (at a rate of 2% per year), tourism, aquaculture, fishing, shellfish harvesting, and salt extraction. Our results reveal significant changes in the lagoon's condition in recent years, including a decrease in depth and an increase in the accumulation of solid waste, plastics, and wastewater in three sectors spanning a total surface area of 464 hectares (equivalent to 7% of the lagoon), a substantial expansion of the salt mining area encompassing 368 hectares, and a remarkable loss of biodiversity manifested in declining fish stocks and seabird populations. This study showed that the lagoon is positioned as a potential site for economic growth and serves to alert stakeholders and the local population to the ecosystem's environmental issues. Based on the findings of this study, we highly recommend regulating human activities within the lagoon, the removal of the wreck at the entrance, proper waste management, community awareness programs, and strict monitoring and enforcement of regulations to protect the environment.

**Keywords:** Coastal lagoon; Khenifiss; DPSIR; environmental assessment; sustainable development.



## The impact of climate change on surface water resources in arid zones - the case of the ykem watershed in the central plateau of Morocco.

M. Gramz<sup>1\*</sup>, M. Batchi<sup>1</sup>, J. El Bouziani<sup>2</sup>, M.H. Azagane<sup>2</sup>, A. El-boukhari<sup>3</sup> & Y. Elharrari<sup>1</sup>

<sup>1</sup> Ibn Tofail University, Territory, Environment and Development Laboratory, Morocco

<sup>2</sup> National Department of Planning Territory, Morocco

<sup>3</sup> Ibn Tofail University, Literature, Arts and Pedagogical Engineering Laboratory, Morocco

\* Email: [h.elbehja@gmail.com](mailto:h.elbehja@gmail.com) / [hamza.elbehja@etu.uae.ac.ma](mailto:hamza.elbehja@etu.uae.ac.ma)

### Abstract:

Given the importance of natural resources for integrated development, it is necessary to adopt adaptation strategies in the face of disturbances affecting the globe. Particularly, climate change, with a particular impact on water potential. The aim of this article is to highlight the impact of this phenomenon on surface water resources in the Ykem watershed in the northwest of the central Moroccan plateau, which is characterized by predominantly arid conditions. The monitoring of the spatio-temporal evolution of surface water using a methodology based on geospatialization techniques, i.e. remote sensing through the acquisition of satellite images available over the period 1992 to 2021, and the analysis of these data via a GIS geographic information system, and then to map the evolution of surface water resources, in time and space, giving a variation between reference years especially 2012 and 2021, from 132 ha to 32 ha, and of course interpreting the results by climate elements, based on rainfall in the study area, as well as temperature values in this geographical location.

**Keywords:** Climate change, arid zone, GIS, water resources, Ykem watershed.



## Impacts of climate change on water resources in the maghreb: what are the strategies for adaptation.

*R. Ech-Choudany<sup>1</sup> & My. H. HAFID<sup>1</sup>*

<sup>1</sup> Laboratoire d'Analyse Économique et Modélisation FSJES-Souissi, Université Mohammed V de Rabat

\* Email: [rachid.echchoudany@um5s.net.ma](mailto:rachid.echchoudany@um5s.net.ma)

### Abstract:

In the face of a global food crisis and climate change, ensuring access to water resources becomes a critical concern for human activities. The Maghreb region, encompassing Morocco, Algeria, and Tunisia, is particularly susceptible to ecological vulnerabilities. The environmental degradation in this region has already led to adverse effects on the well-being of populations and hindered economic development. While demographic projections provide some clarity, the uncertainties surrounding climate change projections persist due to inadequate climatological data, both in terms of quantity and quality.

Nonetheless, numerous climate projections for Southern Europe indicate a worrisome trend of increasing temperatures and decreasing precipitation. The Maghreb countries, due to their geographical proximity, are expected to face significant repercussions. This challenge is further compounded by the presence of the hyper-arid Sahara, which exacerbates the impact of climate change. Consequently, the Maghreb states recognize the imminent climate evolution as a major concern.

This study aims to present an overview of the current climate evolution projections in the Maghreb region and explore their potential consequences on water resources. It encompasses an analysis of the various aspects of climate change, while emphasizing the necessity of implementing adaptation strategies to mitigate the adverse impacts on water resources.

**Keywords:** Maghreb, water resource, climate change, adaptation strategies, ecological vulnerabilities.



## Drought assessment by multi-index based on AGMERRA and weather station data.

*S. Dafouf<sup>1\*</sup>, A. Lahrach<sup>1</sup>, H. Tabyaoui<sup>2</sup> & L. Benaabidate<sup>1</sup>*

<sup>1</sup> Laboratory of Functional Ecology and Environment Engineering, Faculty of Sciences and Techniques, University of Sidi Mohammed Ben Abdellah, Fes 30000, Morocco,

<sup>2</sup> Laboratory of Natural Resources and Environment, Polydisciplinary Faculty, University of, Sidi Mohammed Ben Abdellah, Taza 35000, Morocco

<sup>3</sup>Ibn Tofail University, Literature, Arts and Pedagogical Engineering Laboratory, Morocco

\* Email: [safae.dafouf@usmba.ac.ma](mailto:safae.dafouf@usmba.ac.ma)

### Abstract:

Drought monitoring and characterization are utterly essential for all climate regimes, thus far allows us to predict the serious aftermaths of this risk, more often than not it mitigates its impact and maintain the sustainability of water resources. In this context, the present study is established for monitoring the meteorological drought in the Guir basin (South-East Morocco) throughout the periods between 1980 and 2010, hence, by applying a multi-index approach which are Standardized Precipitation Index (SPI), China-Z index (CZI), Modified CZI (MCZI), Z-Score Index (ZSI), Rainfall Anomaly Index (RAI), in addition to the Percent of Normal Index (PNI), calculated on two data bases: precipitation from meteorological stations and AgMERRA gridded precipitation data from the study area, and yet a comparison is introduced of the index results according to data type, in order to determine whether AgMERRA data could be useful for areas where data is lacking.

**Keywords:** Meteorological drought, AGMERRA data, drought monitoring.



## Water scarcity challenges and drought resilience in the Souss Massa basin, Morocco.

*S. Gouahi<sup>1\*</sup>, M. Hssaisoune<sup>1,2,5</sup>, M. Ait Elkadi<sup>1</sup>, C. Aglalg<sup>1</sup>, M. Qurtobi<sup>3</sup>, M. Nehmadou<sup>4</sup>, B. Bouaakaz<sup>4</sup>*

*H. Boudhair<sup>1</sup> & L. Bouchaou<sup>1,5</sup>.*

<sup>1</sup> Applied Geology and Geo-Environment Laboratory, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco.

<sup>2</sup> Faculty of Applied Sciences, Ibn Zohr University, Ait Melloul, Morocco.

<sup>3</sup> Centre National de l'Energie, des Sciences et des Techniques Nucléaires, Rabat, Morocco.

<sup>4</sup> Hydraulic Agency of Souss-Massa Basin, Morocco.

<sup>5</sup> Mohammed VI Polytechnic University (UM6P), International Water Research Institute (IWRI), Ben Guerir, Morocco..

\* Email: [Soumia.gouahi@edu.uiz.ma](mailto:Soumia.gouahi@edu.uiz.ma)

### Abstract:

The Souss Massa basin in Morocco is currently facing an alarming meteorological and groundwater droughts due to climate and human pressure. In response to this pressing issue, this study highlights Managed Aquifer Recharge (MAR) as a vital strategy to address groundwater drought challenges in the Souss-Massa basin. Utilizing direct recharge techniques like retention sills and rainwater harvesting, MAR offers an effective means of underground storage for seasonally variable surface runoff. Sustainable water resource management practices, particularly during drought periods, are emphasized to safeguard the regions water supply and promote long-term resilience. The findings highlight the significance of proactive interventions in vulnerable areas to ensure effective groundwater resource management. Additionally, groundwater risk modeling, utilizing the Standardized Precipitation Index (SPI) and Standardized Water Level Index (SWI), contributes to understanding drought occurrences in the Souss Massa basin and informs policymakers about potential risks. By integrating the MAR program with groundwater risk modeling, this work provides valuable insights for policymakers and water resource managers, enhancing water security in the Souss Massa Basin, Morocco.

**Keywords:** Managed Aquifer Recharge, Groundwater Risk Modeling, Drought Assessment, Water Resource Management, Souss River Basin, Morocco.



## Socio-economic and environmental impact of the Chtouka desalination plant.

C. Aglal<sup>1\*</sup>, M. Hssaisoune<sup>1,2,3</sup>, S. Gouahi<sup>1</sup> & L. Bouchaou<sup>1,3</sup>

<sup>1</sup> Applied Geology and Geo-Environment Laboratory, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco.

<sup>2</sup> Faculty of Applied Sciences, Ibn Zohr University, Ait Melloul, Morocco.

<sup>3</sup> International Water Research Institute, Mohammed VI Polytechnic University, Ben Guerir, Morocco.

\* Email: [Chaima.aglal@edu.uiz.ac.ma](mailto:Chaima.aglal@edu.uiz.ac.ma)

### Abstract:

Access to water is critical for the socio-economic development and environmental sustainability of regions worldwide, including the Chtouka region. Water resources are vital in supporting agriculture, industry, and domestic needs in the area. However, concerns are rising about the availability and quality of water resources due to population growth, climate change, and increasing water demand.

The Chtouka region is facing significant overexploitation of groundwater resources, primarily driven by the expansion of greenhouses and agricultural activities. Recently, 9000 water extraction points are reported within the Massa plain, whose 7,400 are used for agriculture, resulting in a yearly deficit of more than 90 million cubic meters since 2014. This overexploitation has severe consequences for the environment and local communities, leading to declining groundwater levels, reduced stream and well flows, degradation of aquatic ecosystems, and soil salinization, negatively affecting long-term agricultural productivity.

To address the overexploitation of groundwater and water scarcity challenge, a significant development was the establishment of a desalination plant in 2020. This plant converts seawater into fresh water, providing an alternative water source and potentially relieving the strain on existing water sources to meet the region's growing demands. Understanding the socio-economic and environmental implications of the desalination plant is crucial for effective planning, policy-making and sustainable development. Our study aims firstly to analyze the situation of the area before the desalination project and secondly to examine the effects of the introduction of the desalination plant by means of questionnaires and surveys to be carried out among project beneficiaries.

By evaluating the pre-project and post-project socio-economic and environmental dimensions, the research aims to provide valuable information on the overall impact of the desalination plant in the Chtouka region. This information can guide policymakers, water resource managers, and stakeholders in making informed decisions to promote sustainable water management and support the region's long-term well-being. Implementing water-efficient agricultural practices, smart irrigation techniques, and diversifying water supply sources are crucial steps towards ensuring the long-term availability and quality of water in the region.

**Keywords:** desalination; climate change; water demand; Water scarcity; Seawater; Sustainable development.



## Analysis of the effect of climatic variability and increasing water demand on the Saïss aquifer, Morocco.

*M. El Garouani<sup>1\*</sup>, H. Radoine<sup>2</sup>, A. Lahrach<sup>3</sup>, H. J. Oulidi<sup>4</sup> & M. S. Chaabane<sup>5</sup>*

<sup>1</sup> FST of Fez, Sidi Mohamed Ben Abdallah University, P.O. Box 2202, Fez, Morocco.

<sup>2</sup> School of Architecture, Planning and Design, UM6P, P.O. Box 43150, Benguerir, Morocco.

<sup>3</sup> ENSA, Sidi Mohamed Ben Abdallah University, P.O. Box 72, Fez, Morocco.

<sup>4</sup> Hassania School for Public Works Engineering, P.O. Box 8108, Casablanca, Morocco.

<sup>5</sup> Direction de l'Aménagement du Territoire, MATUHPV, Rabat, Morocco

\* Email: [Chaima.aglaqal@edu.uiz.ac.ma](mailto:Chaima.aglaqal@edu.uiz.ac.ma)

### Abstract:

Climate variability has a significant impact on the water table of the Saïss plain, which relies heavily on groundwater for agricultural irrigation and drinking water supply. The study of the spatio-temporal evolution of the groundwater level requires a global and integrated approach that considers both natural processes and human activities. Satellite imagery has provided information on land use and land cover that influences groundwater recharge. The GIS has facilitated the integration of different datasets, allowing spatial analysis, mapping and identification of vulnerable areas to depletion. Geostatistical techniques are used to analyze collected data, identify trends and quantify the relationship between groundwater levels and various influencing factors. The results of this study have shown that the depth of the water table of the Saïss plain between 2000 and 2020 has generally decreased by several metres in the NW and the centre zone, but has improved by a few metres or remained constant in the other areas. This information is valuable for developing sustainable water management plans that take into account both environmental and societal needs.

**Keywords:** Climate variability, water table, GIS, spatio-temporal evolution, Geostatistical techniques & Saïss plain.





## Long-Term reference evapotranspiration assessment: Does the ERA5 Land reanalysis dataset have the potential to bridge the gap in ground-based agrometeorological data across a North African basin?

Y. Ouassanouan<sup>1</sup>, V. Simonneaux<sup>3</sup>, Y. Fakir<sup>1,2</sup>, M. H. Kharrou<sup>4</sup>, B. Ait Hssaine<sup>1</sup> & A. Chehbouni<sup>1,3,4</sup>

<sup>1</sup> Center for Remote Sensing Applications (CRSA), Mohammed VI Polytechnic University (UM6P), Ben Guerir 43150, Morocco.

<sup>2</sup> Department of Geology, Faculty of Sciences–Semlalia, Cadi Ayyad University, Marrakech 40001, Morocco.

<sup>3</sup> Centre d'Etudes Spatiales de la Biosphère (CESBIO), Université de Toulouse, CNES/CNRS/INRAE/IRD/UPS, 31400 Toulouse, France.

<sup>4</sup> International Water Research Institute (IWRI), Mohammed VI Polytechnic University (UM6P), 43150 Ben Guerir, Morocco.

\* Email: [youness.ouassanouan@um6p.ma](mailto:youness.ouassanouan@um6p.ma)

### Abstract:

A reliable estimate of reference evapotranspiration (ET<sub>0</sub>) requires several meteorological inputs, which may be unavailable in regions with limited data availability. In this regard, this study aimed to address the following objectives: First, to evaluate the effectiveness of ERA5\_L weather forecasts in providing daily agrometeorological variables for the period 2003-2021 at 10 study sites distributed over both plain and mountainous areas in a North African basin. Second, to investigate whether downscaling the ERA5\_L data (10 km) to station scale (250 m) using a quasi-physical based model, MicroMet, could improve the reliability of the meteorological variables. Third, to compare the performance of the original ERA5\_L reanalysis data and the disaggregated ERA5\_L data (MicroMet) as potential sources for accurate estimation of ET<sub>0</sub> on a daily time scale. Finally, to assess the long-term spatiotemporal changes in ET<sub>0</sub> across the Tensift basin over the period 1950-2021, and, the influence of climate variables and topography on ET<sub>0</sub> variability. The findings of the study revealed that the original ERA5\_L estimates of air temperature (T<sub>air</sub>) were the most accurate among the studied variables, followed by solar radiation (R<sub>s</sub>), relative humidity (RH), and wind speed (u<sub>2</sub>). When considering the disaggregated daily ERA5\_L data, T<sub>air</sub> exhibited the highest performance, followed by RH, u<sub>2</sub>, and R<sub>s</sub>. T<sub>air</sub> and especially u<sub>2</sub> demonstrated an improvement across the plain and mountainous sites. However, R<sub>s</sub> was generally degraded after MicroMet. Then, a comparison was conducted between daily ET<sub>0</sub> obtained considering both datasets and show similar correlations between ground and simulated data but with an overestimation of ET<sub>0</sub> after MicroMet. Finally, the retrospective analysis of ET<sub>0</sub> showed three main phases with a decrease of ET<sub>0</sub> between 1950 and 1970, a nearly steady period during 1970-2000, and a significant increase from 2000-2021. This study provides a comprehensive insight about the potential and limitations of ERA5\_L products in arid North African regarding irrigation and water management under climate variability.

**Keywords:** ERA5\_Land, downscaling, MicroMet, Reference evapotranspiration, Data-scarce basins, North Africa.



## Sustainable Water Management in the Souss Basin: Challenges and Strategies for Adaptation.

*O. Attar<sup>1\*</sup>, Y. Brouziyne<sup>2</sup>, L. Bouchaou<sup>1,3</sup>, Y. Ait brahim<sup>1</sup>, M. Hssaisoune<sup>1,2,4</sup> and A. Chehbouni<sup>1,5</sup>*

<sup>1</sup> Mohammed VI Polytechnic University (UM6P), International Water Research Institute, Benguerir, 43150, Morocco.

<sup>2</sup> International Water Management Institute (IWMI), MENA Office, Giza 12661, Egypt.

<sup>3</sup> Laboratory of applied Geology and Geo-Environment, Faculty of Sciences, Ibn Zohr University, BP/8106, Cité Dakhla, Agadir, 8000, Morocco.

<sup>4</sup> Faculty of Applied Sciences, Ibn Zohr University, Ait Melloul 86150, Morocco.

<sup>5</sup> Institut de recherche pour le développement (IRD), unité mixte de recherche (UMR) Centre d'études spatiales de la biosphère (Cesbio), Toulouse, 31400, France.

\* Email: [Yassine.AITBRAHIM@um6p.ma](mailto:Yassine.AITBRAHIM@um6p.ma)

### Abstract:

The Souss basin in Morocco is a strategically important region for agricultural growth, facing a semi-arid climate with uneven rainfall distribution. The basin suffers from a severe water deficit, with competing demands from irrigated agriculture, agro-industry, urbanization, and tourism, necessitating the provision of reliable insights for sustainable management strategies. This study focuses on extensive data collection and the implementation of a modelling concept to develop a solid reference for the scientific community, aiming to reproduce historical processes and guide future water management decisions. The setup and calibration consider multiple factors, including dams' evaporation, rivers' bed infiltration, and other relevant basin characteristics. The incorporation of monthly discharge records, temperature, precipitation, crop surfaces, evapotranspiration, irrigation system types, and evaporation rates from dams enables the modeling network to represent crucial elements such as reservoirs, demands, and non-storage nodes for inflows and diversions accurately. The coefficient of determination indicates the effectiveness in simulating monthly inflows to reservoirs and flows recorded at stations in the Souss River. The Souss basin faces limited and highly irregular surface water resources, with strong interannual variability in river flows. Agricultural water demand experiences significant seasonal increases between May and September, primarily fulfilled through groundwater pumping, causing depletion of the basin's groundwater resources. Despite the construction of dams and the establishment of new private-public partnerships for agricultural irrigation, water demands remain unmet, and shortages are on the rise. These challenges can be attributed to climatic conditions, including decreased and irregular inflows from the dams. Given the current situation, it is crucial to study and implement policies and management strategies that can adapt to the risks associated with expected changes. Future scenario assessments of potential imbalances between water supply and demand must be conducted to guide decision-making. By integrating extensive data collection, advanced modeling techniques, and stakeholder collaboration, sustainable water management practices can be developed and implemented in the Souss basin, ensuring the resilience and water security of the region in the face of evolving environmental and socio-economic factors.

**Keywords:** Climate change; Water resources modelling; Agri-water demand; Souss basin; Water demand.



## Global precipitation product to evaluate climate change impacts in the Oued El Abid basin, Morocco.

*El. M. El Khalki<sup>1\*</sup>, Y. Trambly<sup>2</sup>, L. Hanich<sup>3,4</sup>, A. Marchane<sup>4</sup>, A. Boudhar<sup>4,5</sup> & B. Hakkani<sup>6</sup>*

<sup>1</sup> International Water Research Institute, Mohammed VI Polytechnic University (UM6P), Benguerir, Morocco.

<sup>2</sup> HydroSciences Montpellier (University Montpellier, CNRS, IRD).

<sup>3</sup> Georesources, Geoenvironment and Civil Engineering Laboratory, Cadi Ayyad University, Marrakech Morocco.

<sup>4</sup> Center for Remote Sensing Applications, Mohammed Vi Polytechnic University (UM6P), Benguerir, Morocco.

<sup>5</sup> Research Team of Water and Remote Sensing, Sultan Moulay Slimane University, Beni Mellal, Morocco.

<sup>6</sup> Oum Er Rbiaa Hydraulic Basin Agency, Beni Mellal, Morocco

\* Email: [elmahdi.elkhalki@um6p.ma](mailto:elmahdi.elkhalki@um6p.ma)

### Abstract:

The Mediterranean region is widely regarded as a prominent area affected by climate change. The purpose of this study is to examine various climate change scenarios which may impact the surface water supply to Morocco's largest hydropower producer, the Bin El Ouidane dam. To provide confidence intervals on simulated discharge, this study utilises a water balance model with a stochastic calibration method to predict fluctuations in surface run-off due to future climate scenarios. In order to evaluate the potential uncertainties of utilising global precipitation products in climate change impact research, we conducted a comparison between the forecasts acquired through bias-corrected ECMWF Reanalysis 5th Generation (ERA5) rainfall (WFDE5) and observed precipitation data retrieved from the Oum Er Rbia Hydraulic Basin Agency. Five regional climate models from the EURO-CORDEX initiative were utilized to estimate the impact of climate change on surface run-off for the Representative Concentration Pathway (RCP4.5) and RCP8.5 scenarios. The findings indicate a future reduction in precipitation (by 16 to 34%) accompanied by an increase in evapotranspiration (by 15 to 36%) in both climate scenarios. The hydrological estimates demonstrated a substantial decrease in the run-off (by 57 to 86%). According to WFDE5 findings, the decline in surface water resources is more severe than the reduction in observed precipitation. Thus, it is imperative to modify water resource management approaches for hydropower production and local agriculture, in order to adapt to the upcoming climatic conditions.

**Keywords:** Climate change, Water resources, WFDE5, Euro-CORDEX, Morocco.



## Projection analysis of future drought characteristics in upper Draâ catchment (southern Morocco).

*F. El Qorchi<sup>1</sup>\*, M. Y. Khebiza<sup>1</sup>, A. Karmaoui<sup>2</sup> & S. Acharki<sup>3</sup>*

<sup>1</sup> Laboratory of water, biodiversity and climate change (WBCC), Department of biology, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech 40000, Morocco,

<sup>2</sup> Bioactives (Health and Environmental, Epigenetics Team), Faculty of Sciences and Techniques (Errachidia, UMI); & Moroccan Center for Culture and Sciences, University Moulay Ismail (Meknès), Meknes, Morocco,

<sup>3</sup> Department of Earth Sciences, Faculty of Sciences and Technologies of Tangier, University Abdelmalek Essaadi, Tetouan 93000, Morocco.

\* Email: [fadoua.elqorchi@ced.uca.ma](mailto:fadoua.elqorchi@ced.uca.ma)

### Abstract:

The consequences of global warming will aggravate the impacts caused by droughts. Future drought patterns is important for policy making to face drought risks and prolonged water crises. In this context, this study aims to examine the future SPI-3 and SPI-12 standardized precipitation indices from seven meteorological stations in the Upper Draa Catchment (UDC) during the period from 1980 to 2016. The future climate scenarios were predicted by the model CNRM-ALADIN63 for three periods (2025–2049, 2050–2074, and 2075–2099). The changes were examined based on two Representative Concentration Pathways scenarios, namely: RCP4.5 and RCP8.5. The findings indicated that increasingly extreme droughts are anticipated to occur during (2050-2074) followed by (2025-2049) than (2075-2099) under both scenarios. The results reveal a contrast in drought event frequency between historical data and projections with a noticeable variation of patterns of droughts characteristics across stations and time periods. This accentuates how urgent it is for the Upper Draa Catchment to implement proactive water resource management and adaptive strategies.

**Keywords:** Draa Catchment, proactive water, water crises & meteorological stations.



## Spatial analysis of fracturing and slope data and impact on the correlation between fracturing, slope and surface water circulation: case of the Rommani region.

*O. Ould saltana<sup>1\*</sup>, J. Chao<sup>1</sup>, A. Mridekh<sup>1</sup> & B. El Mansouri<sup>1</sup>.*

<sup>1</sup> Laboratory of Natural Ressources and Sustainable Development, Ibn Tofail University, Faculty of Sciences, Kenitra, Morocco, Morocco.

\* Email: [oumaima.ouldsaltana@uit.ac.ma](mailto:oumaima.ouldsaltana@uit.ac.ma)

### Abstract:

Paleozoic outcrops in the Rommani region were structured during the Hercynian orogeny. This region is located in central Hercynian Morocco. Its dense hydrographic network is hierarchically organized into five orders.

The present study aims to investigate the role of geology, particularly fracturing, and geomorphology in the surface water circulation in the Rommani region.

The integration of slope and fracturing maps, derived from bibliographic data, satellite imagery, and topographic maps within a Geographic Information System (GIS), allowed for the development of correlation maps between different directions of the hydrographic network orders and fracturing on one hand, and with slope on the other. The application of directional data analysis techniques, including the random character test, confrontation of the HN statistical data with those of the lineaments and analysis of variance, reveals that the majority of watercourses are influenced by geological structures, particularly fracturing. The region's topography also has an impact on water flow. The effects of fracturing and geomorphology are complementary, their influence varying from one order to another.

**Keywords:** Fracturing, Slope, Hydrographic Network, GIS, Statistics.



## Topic:

Coastal aquifers, quality,  
diagnosis and monitoring

&

Alternative resources and  
water technologies:  
desalination, artificial  
recharge, wastewater and  
reuse, collection of  
rainwater and fog



## Contribution of continuous measurements of piezometry and electrical conductivity to the characterization of recharge and salinity of the coastal aquifer of Sidi Moussa.

*A. El Achheb<sup>1</sup>\*, S. El Maliki & N. Mdiker*

<sup>1</sup> Faculty of Sciences El Jadida, Université Chouaib Doukkali

\* Email: [elachheb.a@ucd.ac.ma](mailto:elachheb.a@ucd.ac.ma)

### Abstract:

These permeable formations allow the transit of infiltration waters, which are sometimes in high saline load, toward the groundwater.

To verify the hypothesis of a marine influence, some electrical conductivity measurements as a function of depth (salinity Log) have been performed using a parametric probe in wells located along the Sidi Moussa Sahel coastal line. These measures have enabled to locate directly in depth and with precision the fresh water/salt water interface.

The monitoring of piezometric level and salinity of the Sidi Moussa Sahel coastal aquifer was carried out with the aid of a device of continuous control installed in a piezometer located at 800m from the Atlantic ocean. This monitoring permitted to estimate the entries of water which concern mainly the water inflow from the precipitation fraction that infiltrates to replenish the aquifer and the quantity of soil salts leached by these infiltration waters.

The diffusivity computation at different periods during the years 2008, 2009, 2014 and 2015 allowed to better evaluate this hydrodynamic parameter. The obtained result is very satisfactory It has also permitted to have an idea on the aquifer hydrodynamic behavior regarding the oceanic tides.

**Keywords:** aquifer of Sidi Moussa, electrical conductivity, piezometric level, diffusivity & salinity Log.



## The use of artificial intelligence to optimise water resources: a comprehensive assessment.

*F. Dimane<sup>1\*</sup>, Y. El Hammoudani<sup>1</sup>, L. Benaabidate<sup>2</sup>, K. Haboubi<sup>1</sup>, A. Bourjila<sup>1</sup>, C. Benaissa<sup>1</sup>, I. Achoukhi<sup>1</sup>, H. A. Touzani<sup>1</sup>, A. & Faiz<sup>1</sup>.*

<sup>1</sup> National School of Applied Sciences of Al-Hoceima, Department of Energy and Environmental Civil Engineering / Engineering Sciences and Applications Laboratory / Abdelmalek Essaâdi University, Tetouan, Morocco.

<sup>2</sup> Laboratory of Functional Ecology and Environment Engineering, University of Sidi Mohammed Ben Abdellah, Fez 30500, Morocco

<sup>3</sup> Faculty of Science and Technology of Tangier, Department of Earth Sciences / Geosciences research team on natural risks / Abdelmalek Essaâdi University, Tetouan, Morocco.

\* Email: [dimane.fouad@gmail.com](mailto:dimane.fouad@gmail.com)

### Abstract:

The issue of water management is at the heart of debates in many international forums. To meet the growing demand for water due to the current global crisis, it is essential to focus more on water management techniques applied in different applications. Taking into account population density, it becomes imperative to implement intelligent water management mechanisms for efficient distribution, preservation of water quality, and its use for various purposes. Our work addresses several key areas required for efficient water management, including wastewater recycling, water distribution, rainwater harvesting and irrigation, using artificial intelligence (AI) models. The data required for these applications is unique and varies according to context, so it is crucial to use a versatile model or algorithm capable of providing solutions for all these cases. AI, deep learning and Internet of Things techniques can facilitate the design of an intelligent water management system for the sustainable use of natural resources. Our work explores different approaches to water management using AI, DL and IoT, drawing on case studies and statistical analysis to develop a successful water management system.

**Keywords:** artificial intelligence, water resources, water management, IoT & statistical analysis.





## Smart water: an innovative approach to integrated water management at the Faculty of Sciences Ben M'sick (Casablanca, Morocco) in the face of water stress.

*K. Grimah<sup>1\*</sup>, A. Nahli<sup>1</sup> & M. Chlaida<sup>1</sup>.*

<sup>1</sup> Laboratory of Ecology and Environment, Hassan II University of Casablanca, Ben M'sik Faculty of Science, Casablanca, Morocco.

\* Email: [khaoulagr76@gmail.com](mailto:khaoulagr76@gmail.com)

### Abstract:

The integrated management of water resources at the level of various human activities is today imperative for individuals and organizations. This study investigates the possibilities of applying a responsible and sustainable water management approach at the Ben M'sik Faculty of Sciences (FSBM) in Casablanca through rainwater collection/reclamation, groundwater exploitation and decentralized treatment/internal wastewater reuse. To this end, physicochemical characterization of these three types of water was carried out, with preliminary results showing that the wastewater quality complied with the discharge limits recommended by Lydec for all the parameters determined, except for Chemical Oxygen Demand (COD) and Total suspended solids (TSS), with average values for COD, BOD<sub>5</sub>, and TSS of around 1010.12 mg L<sup>-1</sup>, 87.27 mg L<sup>-1</sup> and 370.48 mg L<sup>-1</sup> respectively. In parallel, average values for COD/BOD<sub>5</sub> (33.19), TSS/BOD<sub>5</sub> (6.03) and oxidizable matter (360.72 mg L<sup>-1</sup>) revealed that these wastewaters are heterogeneous and poorly biodegradable. As for rainwater and groundwater, the results show that they comply with the quality grid for water intended for irrigation, except for chloride (715.23 to 884.72 mg L<sup>-1</sup>) and nitrate for groundwater (61.45).

**Keywords:** Smart water, innovative approach, water management, water stress, BOD<sub>5</sub> & COD.



## Current research priorities on fog harvesting as a clean water resource: a bibliometric approach.

H. Boutracheh<sup>1\*</sup>, A. Moumen<sup>1</sup>.

<sup>1</sup> Engineering Sciences, National School of Applied Sciences, University of Ibn Tofail, Kenitra, Morocco.

\* Email: [hicham.boutracheh@uit.ac.ma](mailto:hicham.boutracheh@uit.ac.ma)

### Abstract:

Access to fresh water is considered one of the major challenges of our time. According to the World Resources Institute, by 2050, more than half of the world population will face water stress. Global demand for drinking water will also increase due to economic development, population growth and the resulting needs (health, hygiene, food, agriculture, industry, etc.). Water scarcity would thus cause social, economic and political problems, particularly in arid or semi-arid regions (MENA, South Asia, Subsahara, etc.). Furthermore, water stress is not just about water scarcity. It also concerns the quality of the water available, operating costs and the sustainability of the techniques used. This is why water is a structuring issue on the UN agenda for sustainable development. To alleviate this problem, now chronic and growing, the scientific community is expressly called upon to explore all potential water resources and develop the appropriate technologies to exploit them sustainably. One of these promising resources is fog, especially if it is collected sustainably when conditions are favourable (topography, relative humidity, temperature, wind, etc.) and when nearby conventional resources are insufficient. Given the potential of fog, scientific publications on the subject have seen a remarkable increase. Several attempts have been made to establish the state of the art in this area. However, bibliometric studies on this subject are rare. An attempt to understand current research directions in this sector would make it possible to identify promising avenues and better construct a vision of the priority questions in which researchers should be interested.

**Keywords:** Fresh water, water stress, MENA & bibliometric studies.



## Topic:

**Water saving in agriculture:  
new technologies and  
management strategies.**



## WATER ORIGINS AND AGRICULTURAL PRODUCTIONS UNDER SEMI-ARID CONDITIONS: THE CASE OF SEFROU PROVINCE, MOROCCO.

*S. Boumakrat<sup>1\*</sup>*

<sup>1</sup> Département des Productions et Biotechnologies Animales, IAV Hassan II, Rabat, Morocco.

\* Email: [s.boumakrat@gmail.com](mailto:s.boumakrat@gmail.com)

### **Abstract:**

The aim of this study is to determine the origin and volumes of water used in agriculture, over three crop years: 2018/2019, 2020/2021, 2021/2022. The study was carried out in Morocco, in the province of Sefrou, a piedmont area characterized by a semi-arid climate. A sample of six farms was periodically monitored through interviews and measurements, in order to estimate the volumes of water used for each agricultural production practiced (livestock, market gardening, cereals, orchard, etc.). The results revealed that, in the water mix received by each farm, the proportion of groundwater is higher on farms where fruit trees are grown and market gardening is practiced (from 44% to 89%). While the virtual water is associated with livestock farming, supplemented by rainwater or groundwater, depending on whether the farm is rain fed (89%) or irrigated (2%). A downward trend was also observed in the volume of water used on the farms monitored, with reduced rainfall resulting in a year-on-year decrease in the volume of water used per unit area. In the 2020/2021 year, in order to compensate for the drop in rainfall, farmers made greater use of strategic groundwater reserves for irrigation (a maximum value of 89% of the total volume used was calculated to be of groundwater origin on one of the farms), especially when the productions practiced were fruit trees and market gardening. Similarly, we observed a greater contribution from virtual water, notably through the purchase of animal feed on livestock farms. Finally, the 2021/2022 campaign was marked by an unprecedented level of inflation, with excessively high cost for agricultural raw materials, forcing farmers who usually use virtual water to supplement their animals to reduce the number of herds they operate, with all the repercussions this has had on the national milk and red meat sectors. Faced with this situation, farmers have taken a number of adaptive measures, including reducing the area under market garden crops, particularly onions, and returning cereal crops to farms previously considered irrigated, with the use of supplemental irrigation to offset the effects of delayed rainfall during critical phases in the cycle of these crops, and lastly the valorization of agricultural by-products into non-conventional food resources for livestock, thus improving the circularity of material flows within farms.

**Keywords:** agriculture, water mix, water origin, adaptive measures, circularity.



## Using aquacrop for irrigation and water productivity assessment of table grapes in arid region of Mexico.

*S. Er-Raki<sup>1,3\*</sup>, E. Bouras<sup>1</sup>, J. C. Rodriguez<sup>2</sup>, F. Cruz-Bautista<sup>2</sup>, C. Watts<sup>2</sup>, C. Lizarraga-Celaya, A. Chehbouni<sup>1,3</sup>.*

<sup>1</sup>ProcEDE/AgroBiotech Center, Faculty of Sciences and Technologies, Cadi Ayyad University, Marrakech, Morocco

<sup>2</sup> Departamento de Agricultura y Ganadería, Universidad de Sonora, 83000, Hermosillo, Mexico,

<sup>3</sup>Center for Remote Sensing Applications, Mohammed VI Polytechnic University, Ben Guerir, Morocco,

\* Email: [s.erraki@gmail.com](mailto:s.erraki@gmail.com)

### Abstract:

The aim of this work is to use the AquaCrop model for irrigation and water productivity assessment of Table grapes in arid region of Mexico during 2005 and 2006 cropping seasons. The irrigation efficiency was investigated by comparing the irrigation scheduling design used by the farmer to the AquaCrop model recommendations. Data analysis showed that the farmer irrigates almost every day, which results in the water content in the root zone always exceeding the soil moisture at field capacity (FC). This generates substantial losses of water through deep percolation. By using the AquaCrop model, the optimization of irrigation water scheduling in order to avoid both water stress and deep percolation was about 547 mm and 510 mm, which it is about half of what was applied by the farmer (1006 mm and 930 mm) during 2005 and 2006, respectively. This large difference, lost through deep percolation, reduces the water productivity (WP) by about 45%.

**Keywords:** aquacrop model, irrigation, water productivity & Mexico.



## Water use and carbon sequestration by perennial crops in arid region of Mexico.

*J.C. Rodriguez*<sup>1\*</sup>, *S. Er-Raki*<sup>2,3</sup>, *F. Cruz-Bautista*<sup>1</sup>, *A. Meddich*<sup>2</sup>, *J.E. López-Avenidaño*<sup>4</sup>, *L. Ech-Chatir*<sup>2</sup> & *F. Errouh*<sup>2</sup>.

<sup>1</sup>Departamento de Agricultura y Ganadería, Universidad de Sonora, 83000, Hermosillo, Mexico

<sup>2</sup>ProcEDE/AgroBiotech Center, Faculty of Sciences and Technologies, Cadi Ayyad University, Marrakech, Morocco

<sup>3</sup>Center for Remote Sensing Applications, Mohammed VI Polytechnic University, Ben Guerir, Morocco

<sup>4</sup>Facultad de ciencias agropecuarias, Universidad de Sinaloa, Culiacán, México.

\* Email: [julio.rodriquez@unison.mx](mailto:julio.rodriquez@unison.mx)

### Abstract:

Some crops behave as a carbon source or sink. Perennial crops due to their long growing season and longevity are considered as a sink. However, management can change the trend of flow. In this direction, a series of experiments are being carried out in perennial crops in northwest Mexico. For this purpose, Eddy covariance (EC) system were installed in pecan walnut, asparagus and table grapes. After several years of measurements, the results show that all crops behave as sinks and the magnitude depends on management and environmental conditions. In the case of table grapes, the NEE range from -382 to -616 gC m<sup>-2</sup> year<sup>-1</sup>, in pecan walnut from -788 to -1006 gC m<sup>-2</sup> year<sup>-1</sup>, and in asparagus in the two years studied, it was -733 and -874 gC m<sup>-2</sup> year<sup>-1</sup>. On the other hand, it was observed that in asparagus and pecan walnut there is potential to reduce the annual applied water irrigation by about 30%, maintaining its yield and quality of shoots in the case of asparagus; while in table grapes their annual irrigation is lower than evapotranspiration. Finally, we can conclude that it is possible to increase the WUE (GPP/ET) in pecan walnut and asparagus, but not in table grapes.

**Keywords:** Water, carbon sequestration, perennial crops, arid region & Mexico.



## Spatio-temporal characteristics of meteorological and agricultural drought indices and their dynamic relationships in the Marrakech-Safi region of Morocco.

C. Elair<sup>1\*</sup>, K. Rkha Chaham<sup>1</sup> & A. Hadri<sup>2</sup>.

<sup>1</sup> DLGR Laboratory, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech 40000, Morocco

<sup>2</sup> International Water Research Institute (IWRI), Mohammed VI Polytechnic University (UM6P), Benguerir 43150, Morocco.

\* Email: [elairchaima@gmail.com](mailto:elairchaima@gmail.com)

### Abstract:

The Marrakech-Safi region in southwest Morocco is characterized by a semi-arid climate with increasingly severe drought periods, which have major consequences for water resources, agriculture, livestock farming, ecosystems, and human health.

Our study proposes using various indices and data to approach the phenomenon. The Standardized Precipitation Index (SPI) was calculated from monthly precipitation data from 18 rainfall stations from 1980 to 2018. The Vegetation Condition Index (VCI), Temperature Condition Index (TCI), and Vegetation Health Index (VHI) are calculated using monthly NDVI (Normalized Difference Vegetation Index) and LST (Land Surface Temperature) data collected from the TERRA/AQUA satellite with its MODIS sensor for the period 2000 to 2018. A correlation analysis was also carried out to determine the relationship between drought monitoring indices derived from satellite data and those derived from terrestrial data.

The results reveal that the Marrakech-Safi region is globally exposed to drought, varying degrees from mild to extreme. During the period covered by this study, we observed high percentages of extreme drought in 2001, affecting 81.86% of the region's total area. In 2000, severe drought affected 42.24% of the region's total area. The spatiotemporal distribution of agricultural drought is approximated using satellite drought indices. They reveal a significant correlation between vegetation health, precipitation, and temperature, with average correlation coefficients of 0.67 and 0.66.

The importance of our study, which describes current and global drought conditions in the Marrakech-Safi region, provides important data for farmers and policymakers to develop future drought mitigation strategies.

**Keywords:** Drought, SPI, VCI, TCI, VHI.



## Balancing urban growth and the sustainability of groundwater and agricultural land: case of Berrchid-Settat area.

*Y. Laalaoui<sup>1\*</sup>, N. EL Assaoui<sup>2</sup> & O. Ouahine<sup>3</sup>.*

<sup>1</sup>PhD Student, Geosciences, Water and Environment laboratory, Earth Sciences Department, Faculty of Sciences, Mohammed V University in Rabat, Morocco

<sup>2</sup> Professor, Geosciences, Water and Environment laboratory, Earth Sciences Department, Faculty of Sciences, Mohammed V University in Rabat, Morocco

<sup>3</sup> PhD Student, Geosciences, Water and Environment laboratory, Earth Sciences Department, Faculty of Sciences, Mohammed V University in Rabat, Morocco.

\* Email: [laalaoui.youssef@gmail.com](mailto:laalaoui.youssef@gmail.com)

### Abstract:

Urbanization is an inevitable global phenomenon characterized by the exponential growth of urban areas in terms of both population and infrastructure. However, this rapid urban expansion often comes at a significant environmental cost. This article explores the multifaceted consequences of urbanization, shedding light on its role in contributing to desertification, compromising water quality, and depleting groundwater resources. To assess the scale of urbanization's impact, comprehensive land-use studies are crucial. Geographic Information Systems (GIS) and remote sensing techniques offer valuable tools for mapping and monitoring land-use changes over time. These methods enable the quantification of the conversion of agricultural land into urban areas and identify trends in urban sprawl, providing essential data for understanding the scale of the issue. Water quality assessments are equally vital; we can employ water sampling and laboratory analyses to quantify pollutant concentrations in urban runoff and groundwater. Monitoring the presence of contaminants such as oil, chemicals, and litter, as well as their effects on water quality; helps measure the environmental impact of urbanization. Groundwater studies can utilize hydrogeological investigations, including the use of monitoring wells and geophysical methods, to evaluate changes in groundwater levels and quality. These data are instrumental in gauging the depletion of groundwater reserves and their potential contribution to water scarcity issues. In conclusion, the consequences of urbanization extend far beyond the confines of urban areas, affecting agriculture, ecosystems, and water resources. As urbanization continues to advance, it is imperative to develop sustainable urban planning and management strategies that mitigate its environmental impact, preserve agricultural land, protect groundwater resources, and ensure the long-term health of the planet.

**Keywords:** urban growth, groundwater, agricultural land & Berrchid-Settat area.





## Topic:

Exploration and exploitation  
of deep-water resources.



## Comparaison de la faisabilité de la tomographie de résistivité électrique dans deux contextes hydrogéologiques différents : cas du Sahel des Doukkala et Fom El Oued de Laayoune.

A. Ouchbani <sup>1,\*</sup>, A. Larabi <sup>1</sup>, A. Aarab<sup>1</sup>, S. Sassioui <sup>1</sup>, M. Darbali<sup>1</sup>.

<sup>1</sup>LAMERN, Centre Régional de l'Eau du Maghreb, Université Mohammed V de Rabat,

\* Email: [aliouchbani@gmail.com](mailto:aliouchbani@gmail.com)

### Abstract :

La tomographie de résistivité électrique 2D fait partie des méthodes géophysiques les plus adaptées pour caractériser l'invasion marine dans les aquifères côtiers. Elle est plus efficace quand le contraste de résistivité mesurée le permet, dans le cas contraire la technique de polarisation provoquée pourrait être utilisée comme complément de la méthode de résistivité électrique afin de différencier entre les différents niveaux indéfinis.

Dans le cadre du suivi et de cartographie de l'invasion marine, des profils de tomographies électriques ont été réalisés perpendiculairement à la côte dans les régions du Sahel des Doukkala et de Fom El Oued à Laayoune au sud du Maroc. Les modèles de résistivité obtenus dans la région du Sahel des Doukkala ont montré un fort contraste de résistivités surtout dans les deux premiers aquifères plio-quadernaire et hauterivien moyen. Leurs valeurs de résistivités vont de moins de 10 Ohm.m du côté de la mer dans leur partie contaminée par les eaux très salées à plus de 1000 Ohm.m quand ils sont à l'abri de l'invasion marine. Dans la région de Fom El Oued, où l'aquifère est un système multicouche, les modèles obtenus ont montré deux niveaux, un résistant correspondant aux formations sèches de surface (sup. à 20 Ohm.m) et un conducteur (inf. à 7 Ohm.m) correspondant à la partie envahie par les eaux très salées (60 000 ms/cm). Ce conducteur s'approfondit graduellement en s'éloignant de la mer. Deux remontées du substratum conducteur ont été cartographiées, en absence d'activité d'exploitation de la nappe traversée par le profil, ces remontées ne peuvent être attribuées qu'à la lithologie par la présence d'argiles ou de marnes. La réalisation d'un profil de la polarisation provoquée à cet endroit a montré une anomalie coïncidant avec les deux remontées, ce qui confirme la présence de terrains plus argileux ayant une chargeabilité supérieure à 4 mv/v. Les terrains sableux de surface ont montré une chargeabilité presque nulle (inf. à 0.4 mv/v). Just après ces remontées on note la présence d'un niveau intermédiaire entre le résistant de surface et le substratum conducteur il correspond d'après les mesures de salinité aux couches de sables renfermant une eau de salinité inférieures à 17000 ms/cm. D'où l'hypothèse d'un blocage partiel de l'avancée de l'invasion marine par ces remontées de substratum conducteur.

La tomographie de résistivité électrique a permis de caractériser l'invasion marine dans deux contextes hydrogéologiques différents. Cependant, en présence d'un substratum conducteur d'origine lithologique il faut faire appel à un complément technique telle que la polarisation provoquée afin de définir son origine.

**Keywords :** Tomographie 2D, Polarisation provoquée, Résistivité, Chargeabilité, Invasion marine & Aquifère côtier.



## Optimizing the Hydrogeological Borehole Site using 3D Electrical Resistivity Tomography: A Case Study of a Desalination Station in the Cap Ghir Region, Agadir.

*A. Ouchbani<sup>1,\*</sup>, A. Larabi<sup>1</sup>, A. Aarab<sup>1</sup>, S. Sassioui<sup>1</sup>, M. Darbali<sup>1</sup>.*

<sup>1</sup>LAMERN, Centre Régional de l'Eau du Maghreb, Université Mohammed V de Rabat,

\* Email: [aliouchbani@gmail.com](mailto:aliouchbani@gmail.com)

### Abstract :

Electrical resistivity tomography (ERT) is a prime geophysical technique for assessing seawater intrusion in coastal aquifers, with its utility amplified in 3D applications, particularly for calcareous fractured aquifers such as those found in the Cap Rhir region, south of Agadir-Chtouka.

This study aimed to identify the optimal location for a hydrogeological borehole to supply a future desalination plant in the Cap Ghir region. Geological and hydrogeological investigations, employing boreholes of depths less than 40m, revealed areas where limestones demonstrated high productivity (flow at 70 l/s) the piezometric levels during pinging at the same flow remain stable while the salinity concentrations were between 32 and 35 g/l. This indicated a possible hydraulic connection to the sea via faults.

The 3D ERT was facilitated by creating ten 2D ERT lines, oriented East-West. In order to get accurate results a maximum 20m spacing between ERT lines was respected while the inter-electrode spacing used is 10m. The Wenner array with 72 electrodes and the roll-along techniques were applied to achieve a length of 1070m for each profile and a maximum depth of 120m. The 3D inversion of the collected data confirmed the hydrogeological findings, highlighting various conductive anomalies (resistivity less than 14 Ohm.m) associated with fractures infiltrated by seawater. Notably, the most significant anomaly detected corresponded with the exploratory hydrogeological borehole's location.

Consequently, adopting this method is highly recommended in similar environments to guide decision-makers in optimizing local water resource management and exploitation.

**Keywords:** Cap ghir, tomography, resistivity, limestone, fractures & marine invasion.



## Geophysical study and structure mapping for hydrogeological reconnaissance of the boudenib cretaceous basin errachidia region, morocco.

*A. ElKourchia<sup>1\*</sup>, M. Bouloul<sup>1</sup> & M Hilali<sup>1</sup>.*

<sup>1</sup>Geoengineering and Environment Laboratory (L.G.I.E.), Faculty of Science, My Ismail University, Meknès (Morocco)

\* Email: [elkourchia78@gmail.com](mailto:elkourchia78@gmail.com)

### Abstract:

The present study constitutes a contribution to the hydrogeological and structural reconnaissance of the aquifer of the Cretaceous Boudenib Basin, which is located at the boundary of two vast structural areas: The Anti-Atlas and the High Atlas, and which presents an increased demand for water. In order to address this issue, key objectives are to characterize and quantify the geometry of the aquifer formations, by determining the thickness and lateral extensions of the various aquifer entities.

The Boudenib basin is located at an altitude of between 900 and 1100 m, in the lower valley of the Oued Guir, which crosses it from west to east between the High Atlas Mountains to the north and the Hammada du Guir plateau to the south-west.

Knowledge of the structure of this reservoir and its hydrogeological functioning is of great importance for the integrated management of water resources in this basin.

To meet the objectives of this study, we used geophysical data for the "Boudenib Basin" zone, available from the Guir-Ziz-Rheris Water Basin Agency d'Errachidia (ABHGZR) and the Water Research and Planning Department (DRPE), Rabat. One is a piezometric survey to update hydrogeological data. The other is a geoelectrical geophysical campaign. Over 140 vertical electrical boreholes (S.E.V) were drilled, with a line length AB = 10,000 m.

The reinterpretation of these S.E.V. data coupled with borehole data, using the GIS tool to manage spatially referenced data, made it possible to establish the most appropriate models, to produce geoelectric sections showing the evolution of electrical resistivity levels and quantitative maps relating to the roofs and walls of the various resistant levels that would form the aquifers.

The results of the geophysical survey clearly show that the Boudenib basin is a vast asymmetrical syncline, with three permeable formations forming the three superimposed aquifers: the Senonian aquifer, the Turonian aquifer and the Infra-Cenomanian aquifer, the deepest in the Boudenib basin.

**Keywords:** Hydro geophysics, Aquifer, Piezometry & Boudenib basin.



## Study of the geometry of the Turonian aquifer in the Souss-Massa plain.

*M. Riggui<sup>1</sup>, Y. Ait Brahim<sup>2</sup>, M. Hssaisoune<sup>1,2,3</sup>, H. Boudhair<sup>4</sup>, M. Abioui<sup>5</sup> & L. Bouchaou<sup>1,2</sup>.*

<sup>1</sup> LAGAGE, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco

<sup>2</sup> Mohammed VI Polytechnic University, IWRI, Benguerir, Morocco

<sup>3</sup> Faculty of Applied Sciences, Ibn Zohr University, Agadir, Morocco

<sup>4</sup> SOMATEP, Agadir, Morocco

<sup>5</sup> GEGL, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco

\* Email: [rigguimohamed45@gmail.com](mailto:rigguimohamed45@gmail.com)

### Abstract:

The Souss-Massa plain contains several aquifer formations, including a shallow Plio-Quaternary unconfined aquifer primarily composed of fluvio-lacustrine sediments. Additionally, there are two deeper aquifers: the first located within continental Neogene conglomerates and the second within Turonian limestone.

In recent decades, climate change and increasing water demand have had a significant impact on the groundwater of the Plio-Quaternary aquifer, leading to a decline in its piezometric level. Faced with this challenge, authorities and farmers have begun to utilize the deep Turonian aquifer as an alternative solution to exploiting the Plio-Quaternary aquifer. However, this Turonian aquifer appears to be a potential target capable of providing valuable exploitable flow rates.

The objective of our study is to identify the depth and geometry of the Turonian aquifer and to create a 3D model of it. To achieve this goal, direct and indirect methods based on the analysis and interpretation of data from hydraulic and oil wells, as well as geo-electric sections established in the Souss-Massa plain, were used. The results obtained reveal an evolution of the Turonian aquifer system only in the northern part of the Souss plain and in the western Chtouka region, in the form of a syncline oriented E-W. The uppermost levels of the Turonian aquifer are found near the Cretaceous cuestas, at a depth of about 10 meters. In contrast, between the High Atlas and the cuestas, the Turonian formation dips to depths of up to 920 meters, with an average thickness of about 100 meters.

The results of this study provide information for a better understanding of the deep aquifer in the region, with the aim of more effectively managing the groundwater resources of the Souss-Massa plain. This includes identifying suitable areas for the placement of future drilling sites.

**Keywords:** Souss-Massa plain, geometry, Turonian aquifer, geo-electric, 3D model.



## Electrical resistivity tomography applied to drilling in the deep Guenfouda aquifer, Eastern Morocco.

A. Taibou <sup>1\*</sup>, H. Jounaid<sup>1</sup>, A. Bouaziz <sup>2</sup> & F. Amraoui<sup>1</sup>.

<sup>1</sup> Laboratoire géosciences appliquées à l'ingénierie de l'aménagement, Université Hassan II, faculté des sciences Ainchok,

<sup>2</sup> Office national de l'électricité et de l'eau potable-Branche eau, Avenue Belhassan El ouazzaniBP.Chellah 10002, Rabat.

\* Email: [taibou.anouar@gmail.com](mailto:taibou.anouar@gmail.com)

### Abstract:

The Guenfouda plain, located north-est of Morocco, contains a deep aquifer which is an alternative to the scarcity of rainfall and the destocking of surface aquifers in the Eastern region. However, the use of this aquifer requires a thorough knowledge of its hydrogeological potential. The objective of this work is i) to contribute to the exploration of the aquifer's productivity through pumping tests. ii) To identify favorable areas for implementing new boreholes, using electrical resistivity tomography. Test pumping carried out on 3 boreholes in the study area provided flow rates of 30 L/s, 47 L/s and 60 L/s. The transmissivities deduced are respectively  $1.9 \times 10^{-2}$  m<sup>2</sup>/s,  $2.7 \times 10^{-2}$  m<sup>2</sup>/s and  $1.32 \times 10^{-3}$  m<sup>2</sup>/s. Regarding tomographies, fifteen tomography profiles were established using a multi-electrode acquisition system with the Wenner-Schlumberger configuration. The inversion was carried out using Res2Dinv program. The resistivity profiles obtained are calibrated on existing drilling data and on the results of electrical sounding previously carried out. The real resistivity models obtained highlighted numerous discontinuities that separate the resistant ranges, which would correspond to the unfractured dolomitic limestones of the Domerian and Aaleno-Bajocian, and the conductive ranges, which would represent the marls and clays of the Bathonian-Callovian. These electrical discontinuities would correspond to the faults affecting the Jurassic carbonate formations that would serve as drains for groundwater. The geoelectric images obtained and the data from the boreholes carried out made it possible to propose ten sites for setting up new boreholes at the level of the fault zones, represented by the intermediate resistivity ranges.

**Keywords:** Guenfouda, Deep aquifer, Tomography , Pumping test, Water security, Eastern Morocco.



## Assessing groundwater resources in the Morocco Mauritania transboundary aquifer: a multidisciplinary approach for sustainable water quality management.

Y. Arjdal<sup>1\*</sup>, A. Mridekh<sup>1</sup>, M. Kili<sup>1</sup>, S.M. El Kanti<sup>2</sup>, S. Acharki<sup>3</sup>, S. Taia<sup>1</sup> & B. El Mansouri<sup>1</sup>.

<sup>1</sup>Natural Resources and Sustainable Development Laboratory, Faculty of Sciences, Ibn Tofail University, BP 133, Kenitra 14000, Morocco,

<sup>2</sup> Saquia El Hamra and Oued Eddahab Hydraulic Basin Agency, Lâayoune 70000, Morocco

<sup>3</sup> Department of Earth Sciences, Faculty of Sciences and Techniques of Tangier, Abdelmalek Essaadi University, Tetouan 93000, Morocco.

\* Email: [youssef.arjdal@uit.ac.ma](mailto:youssef.arjdal@uit.ac.ma)

### Abstract:

Managing marine intrusion in coastal aquifers is a substantial challenge that affects the sustainable management of Bir Guendouz-Boulanoir transboundary aquifer. This aquifer serves as a vital water source for Boulanoire, Nouadhibou (Mauritania), and the Bir Guendouz region (Morocco). To preserve this precious resource, it is crucial to establish an effective extraction plan, considering the increasing water demand in this coastal area. To address this, our innovative study aims to comprehensively characterise the aquifer, both qualitatively and quantitatively, by differentiating between freshwater and saltwater zones. Thus, we conducted extensive data collection using 750 vertical electrical soundings (VES) to estimate subsurface resistivity values. Additionally, to distinguish freshwater and saltwater zones, we utilized Dar Zarrouk parameters, along with chemical analyses and statistical tests.

The results revealed a significant marine intrusion in the Bir Guendouz-Boulanoir aquifer, with varying degrees of salinization observed in different zones. Specifically, freshwater zones are characterised by a transverse resistance ( $Tr$ ) exceeding  $4450 \Omega \cdot m^2$ , a longitudinal conductance ( $S$ ) below  $41.7 S$ , and a longitudinal resistivity ( $\rho_l$ ) higher than  $8.7 \Omega \cdot m$ . These findings will assist in improved resource management shared by both countries, preventing saltwater intrusion and ensuring the sustainable use of groundwater resources. Furthermore, the study's implications extend to environmental preservation and the sustainability of these transboundary water resources. Therefore, this study stands as an essential reference for researchers, practitioners, and decision-makers involved in the sustainable management of transboundary groundwater.

**Keywords:** Marine intrusion, Dar Zarrouk, Transboundary aquifer, Coastal aquifer, Resistivity, Bir Guendouz, Morocco.



## Preserving the transboundary aquifer: societal impact analysis and realistic strategies for the Morocco Mauritania region.

*Y. Arjidal<sup>1\*</sup>, A. Mridekh<sup>1</sup>, M. Kili<sup>1</sup>, S.M. El Kanti<sup>2</sup>, S. Acharki<sup>3</sup> & B. El Mansouri<sup>1</sup>.*

<sup>1</sup>Natural Resources and Sustainable Development Laboratory, Faculty of Sciences, Ibn Tofail University, BP 133, Kenitra 14000, Morocco,

<sup>2</sup> Saquia El Hamra and Oued Eddahab Hydraulic Basin Agency, Lâayoune 70000, Morocco

<sup>3</sup> Department of Earth Sciences, Faculty of Sciences and Techniques of Tangier, Abdelmalek Essaadi University, Tetouan 93000, Morocco.

\* Email: [youssef.arjidal@uit.ac.ma](mailto:youssef.arjidal@uit.ac.ma)

### Abstract:

Seawater intrusion into the coastal aquifer poses a significant challenge, particularly due to the increasing water demand in the coastal region. This study focuses on the shared Bir Guendouz-Boulanoir transboundary aquifer, which plays a vital role in supplying drinking water to Bir Guendouz, Boulanoir, and Nouadhibou - Mauritania's economic capital. The aquifer's significance is reinforced by the region's hyper-arid continental climate and scarce surface water resources.

Our previous findings indicate that marine intrusion occurs in different zones with varying salinization levels. Furthermore, detailed geophysical data analysis identified distinct freshwater and saltwater zones, forming a robust foundation for sustainable aquifer management.

This research highlights the substantial societal impact of managing the Morocco-Mauritania transboundary aquifer. To ensure sustainable groundwater usage, the proposed management guidelines encompass both regulatory and incentive-based measures. By prioritizing the drinking water supply and safeguarding aquifer quality, the proposed guidelines aim to provide local communities with reliable access to clean water, thus enhancing health and well-being. Maintaining the region's water security depends on international cooperation and hydro-diplomacy. Policymakers, researchers, and practitioners can use these findings to develop effective and responsible strategies that ensure the aquifer's long-term stability.

**Keywords:** Bilateral agreements, Hydro-diplomacy, Initiative, Management, Saltwater, Morocco.





## Characterization and hydrogeological implications of the transboundary aquifer complex at Bir Guendouz (southern Morocco).

Y. Arjdal<sup>1\*</sup>, A. Mridekh<sup>1</sup>, M. Kili<sup>1</sup>, S.M. El Kanti<sup>2</sup>, S. Acharki<sup>3</sup>, H. Cherfaoui<sup>1</sup> & B. El Mansouri<sup>1</sup>.

<sup>1</sup>Natural Resources and Sustainable Development Laboratory, Faculty of Sciences, Ibn Tofail University, BP 133, Kenitra 14000, Morocco,

<sup>2</sup> Saquia El Hamra and Oued Eddahab Hydraulic Basin Agency, Lâayoune 70000, Morocco

<sup>3</sup> Department of Earth Sciences, Faculty of Sciences and Techniques of Tangier, Abdelmalek Essaadi University, Tetouan 93000, Morocco.

\* Email: [youssef.arjdal@uit.ac.ma](mailto:youssef.arjdal@uit.ac.ma)

### Abstract:

Facing arid climate constraints and recurrent drought periods in Morocco's southwestern region, the demand for groundwater resources at Bir Guendouz is escalating. To effectively exploit these resources, a comprehensive analysis of the aquifer's hydrogeological properties is imperative. Therefore, our research aims to identify the aquifer's potential, specifically concerning Senegal-Mauritanian and Moroccan coastal Basin Cenozoic deposits.

To achieve this objective, we conducted 750 vertical electrical soundings (VES) in conjunction with water drilling data and well log records, using a maximum current electrode spacing of 1,000 to 6,000 m. Our study focused on two aquifer levels: the Continental Terminal sandy and sandstones dating from the upper Miocene to Pliocene, and the Paleocene sand to shaly sand.

Integrating log analysis with lithological data, we successfully identified and correlated two distinct electrically resistive levels (R1 and R2) across the study area, calibrated with the main hydrogeological units. Using iterative computer modeling, we derived six to nine geoelectric horizons through qualitative and quantitative inversion of VES data.

The findings revealed the two aquifer levels' authentic geometry. The upper aquifer's thickness ranged from 20 m in the East to approximately 100 m in the West, near the coastline, while the lower aquifer ranged from 100 to 400 m in the same direction. The resistivity values showed considerable variability, ranging from 5 to 240  $\Omega$ .m, with a mean of 120  $\Omega$ .m. Additionally, we detected four discontinuities in these sections, suggesting potential lateral facies changes or syn-sedimentary fault activity.

The newly developed structural and hydro-stratigraphic model offers new perspectives for characterising groundwater quality. Thereby, our research provides valuable insights into the aquifer's hydrogeological characteristics, enabling informed decisions for sustainable resource management. Lastly, this study intends to contribute to the appropriate use of water, a vital resource, while also addressing the region's water-related challenges.

**Keywords:** Transboundary aquifer, Senegal-Mauritanian Basin, Cenozoic, Continental Terminal, Geometry of deposits, Morocco.







## Feasibility study of underground hydrogen storage in aquifers.

I. El Aichouni <sup>2\*</sup>, N. Nabil<sup>1</sup>, S. Rachidi<sup>1</sup>, H. El Hamraoui<sup>3</sup>, B. El Mansouri<sup>1</sup>, O. Souid Ahmed<sup>1</sup>, A. Mridekh<sup>1</sup>.

<sup>1</sup> Natural resources and sustainable development laboratory; Hydro informatics Team, Ibn Tofail University, Faculty of Sciences, Maâmora Campus, BP.133,14000 Kenitra, Morocco,

<sup>2</sup> L'Institut de Recherche en Énergie Solaire et Énergies Nouvelles (IRESEN), Morocco,

<sup>3</sup> Hydrogen de France (HDF), France.

\* Email: [ibthal.elaichouni@uit.ac.ma](mailto:ibthal.elaichouni@uit.ac.ma)

### Abstract:

Underground hydrogen storage has emerged as a critical alternative for reducing reliance on fossil fuels and mitigating climate change, exploiting its vast storage capacity and wide availability in sedimentary basins globally. This study emphasizes aquifers' vital role in supplying base load needs and managing energy demand concerns, providing a comprehensive review of this innovative technology. The investigation considers both technical and economic aspects, diving into the critical geological requirements for safe hydrogen storage in aquifers.

These porous and permeable rock formations, initially filled with fresh or saline water at significant depths (between 500 to 2500 m), necessitate well-confined structures bound by impermeable cap rock (layer of clay, claystone, etc) to securely accumulate with minimal losses the hydrogen that is trapped in a geological structure due to its low density. Despite the potential, several challenges affect Underground Hydrogen Storage (UHS) via aquifers, including undetected leakage along faults, biological reactions, and hydrogen reactivity with minerals in the reservoir rock.

Economic viability is a crucial aspect of the study, encompassing cost estimates for infrastructure development, monitoring systems, and operational expenses. This study evaluates the feasibility of UHS in aquifers by considering these economic factors alongside technical challenges. Additionally, this review not only identifies challenges and advancements highlights the comparison between aquifer storage and salt cavern storage technologies, providing a comprehensive overview of advancements and challenges in both methods. This comparative analysis offers valuable insights into the strengths and limitations of different underground hydrogen storage approaches, aiding in the decision-making process for adopting suitable and sustainable storage solutions.

**Keywords:** aquifer, underground hydrogen storage, leakage, biological reactions, hydrogen reactivity, salt cavern.



## Characterization of Plio-Quaternary deposits in the Souk El Arbaa region: Integration of surface and subsurface data.

*A. Logbani<sup>1\*</sup>, A. Mridekh<sup>1</sup>, M. Killi<sup>1</sup>. B. El Mansouri<sup>1</sup> & M. El Bouhaddioui<sup>1,2</sup>*

<sup>1</sup> Natural resources and sustainable development laboratory; Hydro informatics Team, Ibn Tofail University, Faculty of Sciences, Maâmora Campus, BP.133,14000 Kenitra, Morocco,

<sup>2</sup> équipe Génie Géologique, Civil et Minier, école Nationale Supérieure des Mines de Rabat, Hadj Ahmed Cherkaoui – B.P 753 Agdal – Rabat

\* Email: [assia.logbani@uit.ac.ma](mailto:assia.logbani@uit.ac.ma)

### Abstract:

This study focuses on understanding the geodynamic changes in the Souk El Arbaa located in the Rharb Basin of northwestern Morocco. The data collected from several researchers in the field, aims to characterize these changes by analyzing various geophysical data sources, including subsurface data such as reflection seismic, well logs, and surface data, also used sedimentological analysis, chronostratigraphic correlation based on seismic profiles and well logs, as well as subsurface structural analysis to reach their conclusions.

The key findings of this study indicate that the upper layer of the marly substratum has an irregular morphology, with high and low areas, which affects the thickness of the Plio-Quaternary cover. The sedimentary deposits show variation in grain size, with coarser grains in the northern and eastern regions, and finer grains in the southern and western regions. This variation is attributed to the erosion and dismantling of the Pre-Rif mountains. Correlating lithological well logs is complex due to the heterogeneity of deposits and rapid changes in facies, including the presence of multiple channels.

The interpretation of seismic profiles reveals two phases of geodynamic evolution. This study provides a detailed analysis of the geodynamic evolution in the Souk El Arbaa area (Rharb Basin). The findings offer valuable insights for understanding the petroleum and gas potential of the region, highlighting its stratigraphic and structural characteristics.

**Keywords:** Geodynamic, Souk El Arbaa, Rharb basin, Sedimentological analysis, Chronostratigraphic correlation, Subsurface structural analysis.



## Nouvelle interprétation des données diagraphiques du complexe aquifère, cas de sous-bassin de Bel Kciri, Maroc NW.

*M. El Bouhaddioui,<sup>1,2\*</sup> A. Mridekh<sup>1</sup>, S. Dadi<sup>2</sup>, H. Azidane<sup>3</sup>, M. Achalhi & A. El Basbas.*

<sup>1</sup> Équipe Génie Géologique Civil et Minier, ENSMR, Maroc,

<sup>2</sup> Laboratoire des ressources naturelles et du développement durable ; Équipe d'informatique hydraulique, Université Ibn Tofail, Faculté des sciences, Campus Maâmora, BP.133,14000 Kenitra, Maroc,

<sup>3</sup> Faculté des sciences, Département de géologie, Université Ibn Tofail, B.P. 133 Kenitra, Maroc.

\* Email: [elbouhaddioui@enim.ac.ma](mailto:elbouhaddioui@enim.ac.ma)

### Abstract :

Dans la majeure partie du Bassin du Rharb, le Néogène-Quaternaire est une époque où les conditions de sédimentation et l'histoire géodynamique ont été largement étudiés depuis les années 1950 et qui, de ce fait, peu paraître bien connue aujourd'hui. Les corrélations des dépôts post-néogènes et leur cartographie dans l'ensemble du bassin étaient établies de proche en proche en forages, en se basant sur la reconnaissance de faciès à l'exception de travaux récents. Les nombreuses études qui ont été menés révèlent, d'une part, que cette région fait partie d'un bassin d'avant-pays délimité par la ceinture montagneuse du Rif et constitue une dépression subsidente apparue au Miocène, et dont l'affaissement persiste durant le Quaternaire jusqu'à l'époque historique. D'autres part, ces études montrent l'existence de la nappe du Rharb qui occupe une place privilégiée dans la gestion des ressources en eau dans le NW marocain, d'où la nécessité d'en analyser les caractéristiques en vue d'évaluer les potentialités hydrogéologiques.

Dans le présent travail, la combinaison de des données paléogéographiques, géologiques et géophysiques (SEV, Diagraphies et données de forages) a permis d'établir un nouveau cadre électrostratigraphique des unités Plio-Quaternaires du bassin du Rharb dont le sous bassin de Bel Kciri. L'intégration de l'ensemble des données dans un SIG a permis de tracer un nouveau modèle tri-dimensionnel du toit de substratum marneux d'âge mio-pliocène. Un tel modèle montre l'existence de trois grandes dépressions, l'équivalent de micro-bassins et /ou bassins satellites, d'extension et architecture étroitement liées à celles du substratum des nappes pré-rifaines.

Les coupes de corrélations hydrogéophysiques réalisées au niveau de sous bassin de Bel Kciri montrent que la distribution des aquifères suit une tendance séquentielle. En effet, les électroséquences montrent une géométrie progradante tantôt vers le NNW tantôt vers l'Ouest surmontées par des électroséquences aggradantes à rétrogradantes. Les attributions chronostratigraphiques basées sur les données de forages montrent qu'au-dessus des dépôts marneux de miocène supérieur (Tortonien supérieur au Messénien), qui correspondent à un environnement épibathyal, se dépose des formations d'âge pliocène à pléistocène. En effet, durant cette époque, on distingue la mise en place de dépôts continentaux et marins caractérisant une phase régressive et transgressive respectivement. En ce qui concerne la première, elle marquée par des dépôts de nature sableux, sablo-argileux, graveleux, gréseux et argileux, tandis que se caractérise par des formations sablo-argileux, des graviers/galet argileux avec des arilles et marnes.

Les nouveaux résultats obtenus ouvrent de nouvelles perspectives pour l'étude des aquifères du bassin du Rharb.

**Keywords :** diagraphie, électroséquences rétrogradantes, progradante & sous bassin Bel Kciri.





## Response surface methodology optimization of coagulation-flocculation process for water contaminated with cyanobacterial bloom using carpobrotus acinaciformis extracts.

W. El Bouaidi<sup>1\*</sup>, G. Enaime<sup>2</sup>, Z. Tazart<sup>1</sup>, K. Lazrak<sup>1</sup>, M. Douma<sup>4</sup>, A. Ounas<sup>5</sup>, A. Yaacoubi<sup>5</sup> & M. Loudiki<sup>1</sup>

<sup>1</sup> Laboratory of Water, Biodiversity and Climate Change; Phycology, Biotechnology and Environmental Toxicology Research Unit, Department of Biology, FSM Cadi Ayyad University, Marrakesh, Morocco,

<sup>2</sup> Department of Biology, University of Naples Federico II, Complesso Universitario di Monte Sant'Angelo, Naples, Italy,

<sup>3</sup> Institute of Urban Water Management and Environmental Engineering, Ruhr-Universität Bochum, Bochum, Germany,

<sup>4</sup> Polydisciplinary Faculty of Khouribga (FPK), Sultan Moulay Slimane University, Khouribga, Morocco,

<sup>5</sup> Laboratory of Applied Organic Chemistry, Faculty of Sciences Semlalia, Department of Chemistry, Cadi Ayyad University, Marrakesh, Morocco

\* Email: [soumia.saghiry1@gmail.com](mailto:soumia.saghiry1@gmail.com)

### Abstract:

The proliferation of Cyanobacterial Harmful Algal Blooms (CyanoHABs) has become a major problem, especially in water treatment plants. Chemical coagulants and flocculants are commonly used to sanitize water in water treatment facilities. However, due to environmental and health concerns, green coagulants have lately grown in popularity as an alternative to chemical coagulants and flocculants. In this study, Response Surface Methodology (RSM) was used to optimize the factors influencing the coagulation-flocculation process by using *Carpobrotus acinaciformis* extracts to remove toxic cyanobacterium *Microcystis aeruginosa* cells in drinking water. Three factors have been investigated for the RSM optimization study, including coagulant dose, water pH and sedimentation time. The effectiveness of *C. acinaciformis* extracts prepared according to the RSM study to remove cyanobacterial cells was evaluated as a function of the treated water's turbidity, chlorophyll a and carotenoid content. The optimal conditions found by using *C. acinaciformis* extracts were 38 mg/L for coagulant dosage, under pH 7.5 and sedimentation time of 1.5 h. These optimal conditions were able to achieve a removal efficiency of 79.59, 84.72 and 82.29% of turbidity, chlorophyll a and carotenoids, respectively. The correlation between predicted and experimental data was significant, indicating that the RSM optimization method used in this study is appropriate for modeling the factors influencing the coagulation-flocculation process. The obtained results indicate that using *C. acinaciformis* extracts as natural coagulant to sanitize water from cyanobacterial proliferation has a promising future.

**Keywords:** coagulation-flocculation, water contaminated, cyanobacterial & carpobrotus acinaciformis extracts.





## Contribution of geophysics and GIS to mapping seawater intrusion in the Souss Massa coastal area.

*Y. Ez-zaouy*<sup>1\*</sup>, *L. Bouchaou*<sup>1,2</sup>, *M. Hssaisoune*<sup>1</sup>, *A. Saad*<sup>4</sup>, *G. Busico*<sup>5</sup>, *O. Saadou Danni*<sup>2</sup> & *M. Nehmadou*<sup>6</sup>

<sup>1</sup> Mohammed VI Polytechnic University (UM6P), International Water Research Institute, Ben Guerir 43150, Morocco,

<sup>2</sup> Laboratory of Applied Geology and Geo-Environment, Ibn Zohr University, Agadir 80035, Morocco,  
<sup>3</sup> Faculty of Applied Sciences, Ibn Zohr University Agadir, Morocco,

<sup>4</sup> Laboratory of Geo-Bio-Environment Engineering and Innovation (2GBEI), Ibn Zohr University, PO BOX 271, Taroudant 83000, Morocco,

<sup>5</sup> University of Campania "Luigi Vanvitelli", Department of Environmental, Biological and Pharmaceutical Sciences and Technologies, Via Vivaldi 43, 81100, Caserta, Italy.

<sup>6</sup> Hydraulic Agency of Souss-Massa Basin, Agadir 80035, Morocco.

\* Email: [yassin.zawi@gmail.com](mailto:yassin.zawi@gmail.com)

### Abstract:

Groundwater resources present the main source for irrigation purposes in the Souss-Massa coastal area. This area has experienced successive years of drought, lack of rainfall, and over-exploitation. Therefore, groundwater trends toward depletion, which allows seawater to advance within the aquifer. This phenomenon presents the main risk which affects groundwater and degrades its quality in the coastal fringe. Hence, a detailed study is needed to explore seawater intrusion location, its depth, and probable sites which can contain it in the study area. To reach this objective, geophysical investigations, and GIS techniques were used to map seawater intrusion in the study area. Geophysical results show that seawater intrusion reaches 2500 meters from the coast, and its depth is around -35 meters above sea level. In addition, results of modified GALDIT show that the north part presents the most vulnerable site and seawater intrusion could reach 11 km from the coast. These findings offer new information to regional stakeholders, and they can be utilized as a basis for decisions supporting the Souss-Massa basin's water resources.

**Keywords:** Groundwater, Coastal area, Seawater intrusion, Geophysics, GIS, Souss-Massa.



## Evaluation de qualité des eaux de surface du bas de Sebou par une étude physicochimiques et microbiologiques et l'impact des activités anthropiques et des affluents versant (Oued Beht et Oued Swaret).

F. Z. Mekaoui <sup>1\*</sup>, A. Sahraoui<sup>1</sup>, N. Brhadda<sup>2</sup> & L. A. Lrhorfi<sup>1</sup>

<sup>1</sup> Laboratoire Ressources Naturelles et Développement Durable (LRNDD), Université Ibn Tofail (UIT) Faculté des Sciences Kenitra (FSK) BP 133, Kenitra 14000, Maroc.

\* Email: [Fatimazahra.Mekaoui@uit.ac.ma](mailto:Fatimazahra.Mekaoui@uit.ac.ma)

### Abstract :

Les ressources naturelles en eau au Maroc sont parmi les plus faibles au monde, et plus de la moitié de ces ressources sont concentrées dans les bassins du nord et le Sebou couvrant près de 30 % des eaux de surface du territoire national et contribue au développement économique et social à travers les différents usages domestiques, industrielles et agricoles. En effet, le bassin du Sebou traverse le Nord-est en Ouest du Maroc et reçoit les eaux usées de plusieurs villes et villages dont la ville de Fès et Kenitra. Ainsi il est impacté par Oued Beht, et Oued Swaret. L'objectif de cette étude consiste à évaluer la qualité des eaux de surfaces du Bas de Sebou, d'avoir une idée sur l'impact des activités anthropiques et de l'affluent versant dans le Sebou (Oued Beht et Oued Swaret) ainsi à estimer l'ampleur de sa pollution par rapport aux autres sous bassins, enfin de détermination les sources de pollution en vue d'établir une cartographie de la qualité de ces eaux qui va être déterminé par les analyses et le suivi des paramètres physico-chimique, bactériologique tels que : la température, le pH, la conductivité, MES, la turbidité, DCO, DBO5, phosphore total, NO<sub>3</sub><sup>-</sup>, NO<sub>2</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup>, SO<sub>4</sub><sup>2-</sup>, Cl<sup>-</sup>, Mg<sup>2+</sup>, Ca<sup>2+</sup>, l'alcalinité, les coliformes totaux et fécaux, les streptocoques totaux et fécaux. Les résultats obtenus qui sont basées sur des analyses statistiques, sont encourageants dont ils montrent une évolution temporelle de la qualité globale du bas Sebou : 23 % considèrent en excellente qualité en suite 28 % présentent une bonne qualité et 17 % ont une moyenne qualité. En revanche 14 % présentent une mauvaise qualité ainsi 18 % figurent dans la catégorie très mauvaise qualité.

**Keywords :** Bas de Sebou, Activité anthropique, pollution, bactériologie, physico-chimie.



## The effect of type of electrode using on the electrocoagulation process on the Vinasse treatment.

*S. Elbouatlaoui<sup>1\*</sup>, I. Chaouki<sup>1</sup>, R. Belakhmima<sup>2</sup> & N. Dkhireche<sup>1</sup>*

<sup>1</sup> Faculty of Sciences, Ibn Tofail University, Kénitra, Morocco.

\* Email: [elbouatlaouisamia@gmail.com](mailto:elbouatlaouisamia@gmail.com)

### Abstract:

Water pollution affects the ecosystem and makes the use of water dangerous on human health, For this, the purification and reuse of wastewater is nowadays an alternative solution to limit the shortage of water. In our case the sample of wastewater to be treated represents the vinasse which is the residue of the distillation of the molasses of the industry SOTRAMEG of transformation of the molasses of Gharb, the only distillery of ethanol in Morocco by fermentation of the molasses of beets and sugar cane. The treatment of industrial wastewater has undergone a remarkable evolution in terms of technologies implemented, electrocoagulation is one of the most responsive processes in this field due to its impressive performance on an industrial scale, this technique is based on redox reactions that takes place when applying a current density to the electrodes, This results in a dissolution of the sacrificial anode of the aluminum or the iron which releases coagulant forms, these last ones are going to support the agglomeration of the suspended matters in form of the flocs which are pulled by the bubbles of hydrogen generated by the reduction of the water at the cathode[1]. This process takes place in an electrochemical reactor which consists of two flat and parallel aluminium or iron electrodes totally immersed in the polluted effluent. Current densities of 10, 25 and 50 mA/cm<sup>2</sup> were applied to treat the effluent of the vinasse. And according to the graphs of abatement of our sample where we reach high abatement rates at 25mA/cm<sup>2</sup> and 50 mA/cm<sup>2</sup> turbidity was reduced with an efficiency of 69 % and the chemical oxygen demand was reduced with an efficiency of 86 %. We obtained by EC a semi-clean water, which needs a biological treatment and a treatment of disinfection so that it is purified to be thrown in the nature.

**Keywords :** Water pollution, EC: electrocoagulation, Vinasse, coagulation, pollution indicator, current density.



## Analysis of the sustainability of water resources in the Souss-Massa basin using the system dynamics approach.

*A. Guemouria<sup>1\*</sup>, A. Chehbouni<sup>1,2,3</sup>, S. Belaqqiz<sup>4,5</sup>, Y. Ait Brahim<sup>1</sup>, El. M. El Khalki<sup>1</sup>, D. Dhiba<sup>1</sup> & Lhoussaine Bouchaou<sup>1,6</sup>*

<sup>1</sup> International Water Research Institute, Mohammed VI Polytechnic University, Benguerir 43150, Morocco.

<sup>2</sup> College of Sustainable Agriculture and Environmental Sciences, Mohammed VI Polytechnic University, Benguerir 43150, Morocco.

<sup>3</sup> Institut de Recherche pour le Développement, Unité Mixte de Recherche, Centre d'études Spatiales de la Biosphère, 31400 Toulouse, France.

<sup>4</sup> Center for Remote Sensing Applications, Mohammed VI Polytechnic University, Benguerir 43150, Morocco.

<sup>5</sup> Laboratory of Computer Systems and Vision, Faculty of Science, Ibn Zohr University, Agadir 80000, Morocco.

<sup>6</sup> Laboratory of Applied Geology and Geo-Environment, Faculty of Science, Ibn Zohr University, Agadir 80000, Morocco.

\* Email: [ayoub.guemouria@um6p.ma](mailto:ayoub.guemouria@um6p.ma)

### Abstract:

Various social, economic and physical subsystems interact at the watershed scale. The implementation of integrated water management is essential to optimize economic and social well-being in an equitable manner, while preserving the sustainability of ecosystems. The Souss-Massa watershed, characterized by a semi-arid climate, faces a significant water demand. It represents a complex system in which a lack of understanding of the multiple interacting subsystems can lead to a quantitative and qualitative shortage of water resources. The objective of this research study is to develop a dynamic model for water resources management at the scale of the Souss-Massa basin, and to examine the interactions between the drivers involved in the supply and demand system at different stages, using a System Dynamics (SD) approach. The model developed promotes a holistic understanding of the interactions between the indicators influencing water resources management, thus supporting informed decision-making and facilitating successful water resources management on the scale of the Souss-Massa basin. The results show that current and future policies are not leading to sustainable water management in the Souss-Massa basin. Groundwater depletion will increase significantly, with an estimated average annual decrease of -337 Mm<sup>3</sup> for the period 2022 to 2050. Balance between water supply and demand will only be achieved in two rainy years, namely 2027 and 2044, without ever reaching sustainability. Sensitivity analysis reveals that the sustainability of water resources in the Souss-Massa basin is mainly influenced by surface water availability, irrigated area and irrigation efficiency. Various scenarios were simulated, and proposals for remedying the situation were formulated, including the consideration of groundwater recharge, and the need for a techno-economic study to select the most appropriate scenario. This study is of crucial importance for policy-makers, as it provides them with optimal and sustainable water management strategies based on a more efficient use of resources, thus contributing to the sustainable development agenda in arid and semi-arid regions.

**Keywords:** System Dynamics; Water resources management; Sustainable development; Climate change.



## Hydrogeological study of the Beni Amir deposit in the Oulad-Abdoun phosphate basin for water management and sustainable mining.

*O. Heddoun<sup>1</sup>, A. Ait Lemkademe<sup>1</sup> & M. Benzaazoua<sup>2</sup>*

<sup>1</sup> Geology & Sustainable Mining Institute, Mohammed VI Polytechnic University, Department, Benguerir, Morocco.

\* Email: [Ouissal.heddoun@um6p.ma](mailto:Ouissal.heddoun@um6p.ma)

### Abstract:

Industries around the world face significant water-related risks due to overexploitation of resources, climate change, social resistance, and water pollution. In the case of OCP, the risks extend beyond water scarcity for mining operations to the management of substantial water volumes that partially or completely submerge the phosphate series, especially in the Beni Amir deposit, which is in the southern part of the Oulad Abdoun phosphate basin. To overcome this challenge, a hydrogeological study has been conducted to address the challenges caused by groundwater in the Beni Amir deposit involved several key steps. First, geological and hydrogeological data were collected and analyzed to understand the aquifer system at the mine site. This information was crucial in developing a hydro-stratigraphic model that detailed the characteristics of the phosphate series and the aquifer. The model was based on data from 312 boreholes distributed across the study area. In addition, a series of cross-sections were generated based on the hydro-stratigraphic model to visualize the piezometric level above the phosphate layers. These cross-sections helped identify the extent of the drowned zone, where the phosphate layers were submerged, as well as the dry zone. The data collected were used also to create a delineation map of the drowned zone, providing valuable insights into the spatial distribution of the submerged and dry areas within the deposit. The hydrogeological study revealed that approximately 73% of the Beni Amir deposit is largely submerged by the aquifer, while the remaining 27% constitutes the dry zone. This understanding of the groundwater involved in the mine site is critical for devising effective control and prevention measures against water-related hazards, safeguarding the mining operations, and protecting vital water resources.

**Keywords:** Oulad Abdoun basin, Beni Amir mine, phosphate series, hydrogeology, Water management, hydrogeological conceptual model.



## Overview of the Evolution of Marine Intrusion Research from 2000 to 2022.

*Y. El Hammoudani<sup>1</sup>\*, F. Dimane<sup>1</sup>, K. Haboubi<sup>1</sup>, L. Benaabidate<sup>2</sup>, A. Bourjila<sup>1</sup>, C. Benaissa<sup>3</sup>, I. Achoukhi<sup>1</sup>, S. Bouhou<sup>1</sup>, H. Faiz<sup>1</sup>, A. El Abdouni<sup>1</sup>, C. Haboubi<sup>1</sup> & A. Touzani<sup>1</sup>.*

<sup>1</sup> National School of Applied Sciences of Al-Hoceima, Department of Energy and Environmental Civil Engineering / Engineering Sciences and Applications Laboratory / Abdelmalek Essaâdi University, Tetouan, Morocco.

<sup>2</sup> Laboratory of Functional Ecology and Environment Engineering, University of Sidi Mohammed Ben Abdellah, Fez 30500, Morocco

<sup>3</sup> Faculty of Science and Technology of Tangier, Department of Earth Sciences / Geosciences research team on natural risks / Abdelmalek Essaâdi University, Tetouan, Morocco.

\* Email: [dimane.fouad@gmail.com](mailto:dimane.fouad@gmail.com)

### Abstract:

The infiltration of saltwater into groundwater sources along coastal areas can cause a substantial rise in salinity, impacting the main water supply in these areas. The purpose of this paper is to deliver a comprehensive examination of contemporary research patterns in groundwater intrusion. The study concentrates on the period spanning 2000 to 2022, and it involved analyzing 1908 papers from the Scopus database utilizing the 'bibliometrix' package in the R programming language. The study's findings, which were visualized using 'biblioshiny' and 'VOSviewer', demonstrate that research on marine intrusion is on the rise. Interdisciplinary teams of researchers from various countries are working together to attain integrated outcomes. As evidenced by the investigation, the utilization of spatial data science and remote sensing has experienced a significant surge in this field. This paper aims to provide valuable insights to inspire researchers by presenting the current state of research on this topic, including popular research methods, the involvement of authors, and directions for future research.

**Keywords:** Authorship, Bibliometric analysis, Keywords, Marine Intrusion, Scopus.



## Contribution of continuous measurements of piezometry and electrical conductivity to the characterization of recharge and salinity of the coastal aquifer of Sidi Moussa.

A. El Achheb<sup>1\*</sup>, S. El Maliki<sup>1</sup> & N. Mdiker<sup>1</sup>

<sup>1</sup> Université Chouaib Doukkali, Faculty of Sciences El Jadida.

\* Email: [elachheb.a@ucd.ac.ma](mailto:elachheb.a@ucd.ac.ma)

### Abstract:

These permeable formations allow the transit of infiltration waters, which are sometimes in high saline load, toward the groundwater.

To verify the hypothesis of a marine influence, some electrical conductivity measurements as a function of depth (salinity Log) have been performed using a parametric probe in wells located along the Sidi Moussa Sahel coastal line. These measures have enabled to locate directly in depth and with precision the fresh water/salt water interface.

The monitoring of piezometric level and salinity of the Sidi Moussa Sahel coastal aquifer was carried out with the aid of a device of continuous control installed in a piezometer located at 800m from the Atlantic ocean. This monitoring permitted to estimate the entries of water which concern mainly the water inflow from the precipitation fraction that infiltrates to replenish the aquifer and the quantity of soil salts leached by these infiltration waters.

The diffusivity computation at different periods during the years 2008, 2009, 2014 and 2015 allowed to better evaluate this hydrodynamic parameter. The obtained result is very satisfactory it has also permitted to have an idea on the aquifer hydrodynamic behavior regarding the oceanic tides.

**Keywords:** electrical conductivity, piezometric level & Sidi Moussa Sahel coastal aquifer.







## Application of stable isotopes to understand groundwater salinization and recharge processes in the Essaouira coastal aquifer.

M. Ouarani <sup>\*1,2</sup>, Y. Ait Brahim <sup>1</sup>, D. Mulla <sup>2</sup>, A. Rafik<sup>1</sup>, L. Bouchaou<sup>1,3</sup> & and A. Chehbouni<sup>1</sup>.

<sup>1</sup> International Water Research Institute (IWRI), Mohammed VI Polytechnic University (UM6P), Hay My Rachid, Ben Guerir 43150, Morocco.

<sup>2</sup> Dep. of Soil, Water, and Climate, Univ. of Minnesota, Upper Buford Circle, St. Paul, MN 55108, USA,

<sup>3</sup> Laboratory of Applied Geology and Geo-Environment, Ibn Zohr University, Agadir, 80035, Morocco

\* Email: [ouarani.moh@gmail.com](mailto:ouarani.moh@gmail.com)

### Abstract:

Groundwater serves as a critical resource in arid and semi-arid regions, necessitating a comprehensive understanding of hydrogeochemical and hydrogeological processes to ensure sustainable management. In the context of the Essaouira coastal aquifer, this study employed a multidisciplinary approach, integrating multivariate statistical analyses, stable isotopes, hydrogeochemical, hydrogeological, and remote sensing data. Over a period of thirty years, a total of 223 groundwater samples were collected during ten sampling campaigns between 1990 and 2020, complemented by stable isotopes data from 80 groundwater samples within the same period. The study revealed that hyper-salinity due to evaporite dissolution occurred throughout the period from 1990 to 2020, mainly attributed to salt dissolution from the Triassic Tidzi diapir in the southeast of the aquifer. Seawater intrusion was detected only from 2009 to 2020 in a small area close to the ocean. The isotopic mass balance model showed that aquifer recharge from the Ksob river area is mainly located in the northeastern region, and rainfall higher than 54 mm contributed significantly to groundwater recharge, as confirmed by the water balance approach based on remotely sensed actual evapotranspiration data. In light of these significant findings, the study successfully constructed a comprehensive 3D model of the Essaouira coastal aquifer, presenting valuable insights for sustainable water resource management in analogous coastal regions. The research contributes essential scientific knowledge towards optimizing the management and preservation of groundwater resources in arid and semi- arid environments.

**Keywords:** Groundwater salinization, Seawater intrusion, Stable isotopes, Hydrogeochemistry, Essaouira, coastal aquifer, Groundwater recharge.



## Geometric architecture and hydrochemical characterization of the deep lower Jurassic aquifer, Saïss basin-Morocco.

*L. Bouib<sup>1\*</sup>, A. Jilali<sup>2</sup>, F. Amraoui<sup>1</sup>, A. Nait Bba<sup>2</sup>, A. Aabi<sup>3</sup> & L. Baidder<sup>4</sup>*

<sup>1</sup> Hassan II University, Faculty of sciences Ain-Chock, Laboratory of Geosciences Applied to Engineering Development, Scientific Research Team: Hydrology and Hydro-sciences, Casablanca, Morocco.

<sup>2</sup> Mohammed I University, Faculty of Science, Department of Geology, Laboratory of Geo-heritage, Geo-environment and Mining and Water Prospecting, Oujda, Morocco.,

<sup>3</sup> Mohammed-V University, Ecole Normale Supérieure, Department of Geology, Rabat, Morocco.

<sup>4</sup> Hassan II University, Faculty of sciences Ain-Chock, Laboratory of Geosciences, Casablanca, Morocco.

\* Email: [ouarani.moh@gmail.com](mailto:ouarani.moh@gmail.com)

### Abstract:

The Saïss Basin is one of Moroccan Cenozoic sedimentary basins, located between the Tabular Middle Atlas Mountains and the Rif's belt. The basin is of significant geological importance due to its complex formation and hydraulic resources. This basin characterized by a succession of sedimentary geological formations with age ranging from Paleozoic to Quaternary. The basin hosts two main aquifers: a Plio-Quaternary shallow aquifer and a Liassic deep one.

This study is particularly focused on the construction of a 3D geological modeling of the Saïss basin using several data, such as lithological sections of boreholes, geological maps, some borehole logs, seismic reflection and electrical sound vertical. In addition, a chemical investigation has been done to understand the hydro-geochemical process of the deep Liassic aquifer.

The 3D geological model and the cross sections show the compartmentalization of the basin into successive horsts and related grabens structures. This structuration is mainly observed in the Triassic and Liassic layers. They are structures-controlled faults. These faults are interpreted as inherited from the late-Devonian carboniferous Variscan belt and reworked during the Triassic-Liassic rifting phase.

The water facies along the basin, which the majority of the results of samples are bicarbonate-calcium-magnesium (HCO<sub>3</sub>-Ca-Mg) and calcium-magnesium-chloride-sulfate (Ca-Mg-Cl-SO<sub>4</sub>), these are in conformity of host rock constitutes by carbonates formations of Liassic-Pliocene age. The PCA analysis suggest the presence of two groups of water. The isotopic analysis (18O and δ2H), the results indicate significant groundwater evaporation in south and north part, and suggest the presence of confined or fossil aquifer (paleo-recharge) in the center of the study area.

The results allow the establishment a hydrogeological conceptual model. This one takes into account the recharge mechanisms in the unconfined part of aquifers to the north or south, or faults that allow interconnection between aquifers.

**Keywords:** 3D geological model, chemical, conceptual model, Liassic aquifer, Saïss Basin, Morocco.



## Unraveling recharge dynamics in semi-arid catchments of the Atlas Mountains using stable isotopes.

*N. Rhoujjati*<sup>1\*</sup>, *Y. Ait Brahim*<sup>1</sup>, *L. Hanich*<sup>1</sup>, *A. Rhoujjati*<sup>1</sup>, *A. Rafik*<sup>1</sup>, *H. Ouatiki*<sup>1</sup>, *A. Chehbouni*<sup>2</sup> & *L. Bouchaou*<sup>1,3</sup>

<sup>1</sup> Center for Remote Sensing Applications (CRSA), Mohamed VI Polytechnic University (UM6P)

<sup>2</sup> International Water Research Institute (IWRI), Mohammed VI Polytechnic University (UM6P), Hay My Rachid, Ben Guerir 43150, Morocco.

<sup>3</sup> Laboratory of Applied Geology and Geo-Environment, Ibn Zohr University, Agadir, 80035, Morocco

\* Email: [nadia.rhoujjati@um6p.ma](mailto:nadia.rhoujjati@um6p.ma)

### Abstract:

The Moroccan Atlas Mountains, renowned as a "water tower," store a significant snowpack that serves as the country's primary water supply, which requires thorough investigation and monitoring. This study aims to identify recharge processes within the semi-arid watersheds of the Atlas Mountains using stable isotopes. Monthly monitoring of snow, rainfall, surface water, and groundwater isotopes in Ourika and High Oum Er-rbiaa (HOER) revealed substantial variations in seasonal precipitation isotopes. The spatio-temporal distribution of groundwater and precipitation isotopes exhibited significant spatial heterogeneity, mainly influenced by geological variations in each aquifer. Temporally, direct recharge in response to winter precipitation was observed, whereas summertime recharge occurred later as snow replenished groundwater during the end of the melt season. These findings were further validated using the "Gravity Recovery and Climate Experiment" (GRACE) dataset, which indicates a significant correlation between total water storage and groundwater isotope values. This suggests an increased pumping between March and June to compensate for shortage of water supply. The application of the isotopic mass balance model on the HOER catchment reveals that 50% of snowmelt contributes to groundwater recharge in the upstream Liassic aquifer, whereas 80% of the Triassic-Paleozoic aquifers in the downstream are replenished by snowmelt. In the Ourika catchment, 30% of snowmelt contributes to groundwater recharge upstream, which increases to 50% downstream due to variations in melting rates. These findings underscore the role of lithology and altitudinal differences in recharge processes and highlight the groundwater over-pumping during dry seasons with scarce precipitation.

**Keywords:** recharge dynamics, stable isotopes, GRACE & Atlas Mountains.



## Topic :

Modélisation numérique,  
Géo-information,  
Télédétection, Géomatique,  
Intelligence artificielle.



## Planning aquaculture integration in Khenifiss lagoon using remote sensing and GIS.

*K. Jamous<sup>1\*</sup>, S. M. Malainine<sup>2</sup>, M. Wahbi<sup>1</sup>, H. Nhhala<sup>3</sup>, A. El M. & M. Maatouk<sup>1</sup>*

<sup>1</sup> Laboratory for Research and Development in Applied Geosciences, FSTT, Abdelmalek

<sup>2</sup> National Institute of Fisheries Research (INRH)- Regional Center of Laayoune, Morocco

<sup>3</sup> Expert and Consultant in Aquaculture Technical Sciences and Engineering, Tangier, Morocco.

\* Email: [kaoutar.jamous@etu.uae.ac.ma](mailto:kaoutar.jamous@etu.uae.ac.ma)

### Abstract:

Paralic ecosystems are coastal areas where freshwater from rivers mixes with saltwater from oceans, creating unique environments that are conducive to marine life. In Morocco, these ecosystems present an interesting potential for aquaculture, as they offer favorable environmental conditions for the development of various aquaculture species. To successfully carry out any type of aquaculture, it is essential to select areas with suitable environmental characteristics, such as temperature, salinity, pH, nutrients, dissolved oxygen, depth, and current strength, which can influence the growth and survival of aquaculture species.

The methodology proposed for the selection of aquaculture areas of interest in the Moroccan Khenifiss lagoon, the subject of the study, is based on an environmental approach. This approach involves the in-depth study of the marine environment, particularly the quality of seawater, through physico-chemical using in-situ measurements and simultaneous satellite data, followed by processing using GIS tools. In addition, an analysis of hydrodynamic characteristics was carried out using data on wind and current speed and direction to estimate the significant wave height generated in extreme situations. Furthermore, mapping of bathymetry, seabed nature, and land use was developed. The results indicate that the lagoon has significant aquaculture potential, which could give a socio-economic boost to the development of shellfish and seaweed farming in Morocco.

**Keywords:** Aquaculture, Water quality, Khenifiss Lagoon, Satellite data, GIS.



## Unraveling recharge dynamics in semi-arid catchments of the Atlas Mountains using stable isotopes.

A. Afquir<sup>1,2\*</sup>, A. Saad<sup>1</sup>, S.M. El Kanti<sup>1</sup>, R. Rotz<sup>3</sup>, M. Hssaissoune<sup>4,5,6</sup> & Y. Ez-Zaouy<sup>6</sup>

<sup>1</sup> Laboratory of Geo-Bio-Environment Engineering and Innovation (2GBEI), Ibn Zohr University, PO BOX 271, Taroudant 83000, Morocco

<sup>2</sup> Hydraulic basin agency of Sakia Elhmara and Oued Eddahab, Laayoune, Morocco.

<sup>3</sup> Department of Marine and Earth Sciences, 10501 FGCU Blvd. S. Office: Seidler Hall, 435 Fort Myers, FL 33965,

<sup>4</sup> Faculty of Applied Sciences, Ibnou Zohr University, Agadir 80035, Morocco,

<sup>5</sup> Laboratory of Applied Geology and Geo-Environment, Ibnou Zohr University, Agadir 80035, Morocco,

<sup>6</sup> Mohammed VI Polytechnic University (UM6P), International Water Research Institute, Ben Guerir 43150, Morocco.

\* Email: [ayoubafquir463@gmail.com](mailto:ayoubafquir463@gmail.com)

### Abstract:

Understanding the lithology of the Dakhla basin is an integral part of understanding the groundwater flow and the relation between aquifers, given that the previous studies consider, in modeling, only one aquifer, besides, imprecise boundary conditions. This study has been carried out to 1) build 3D geological and stratigraphic models of the Dakhla Basin; 2) identification of the geological units (GUs) and stratigraphic units (SUs) and their extensions and 3) calculate the volume of the main GUs and SUs which constitutes the reservoir aquifer of Dakhla basin, by the utilization of the Geographic Information System (GIS) and Geological modeling systems (GMS). The construction of the models was based on 93 boreholes, this includes an oil drilling site, E1-66, which reached a depth of 1613 m, as well as 65 hydraulic drillings with depths exceeding 100 m. The process of creating the geological and stratigraphic solids of each GU and SU involves assigning horizons to each formation contact and performing an inverse distance weighted interpolation. The study revealed that the Dakhla basin's major structure plunges toward the Atlantique Ocean, indicating a Monocline structure, the 3D lithological model highlights 10 Geological units, the very productive units represented in GU2 and GU3 which consist of, respectively, fine and medium sand and sandstone, which are widespread throughout the basin, reaches a volume of  $6,45 \times 10^{11}$  m<sup>3</sup>, GU10 represents the substratum, forming the impermeable base of the geological model. For the stratigraphic model, it Brings out 5 SU, from Quaternary to Precambrian. The SU3 corresponds to the Paleogene (Eocene) period it contains the deep aquifer of the Paleogene, primarily composed of GU2 and GU3, and the volume of this unit is estimated at  $1,71 \times 10^{12}$  m<sup>3</sup>, it's heavily exploited in the Dakhla region. The innovation of this work presents a first overview of the 3D subsurface geology of the Dakhla basin and aims to provide a comprehensive model of current geoscience data available and pathways for future studies to build an accurate hydrogeological model for water management in the Dakhla region.

**Keywords:** 3D geological modeling, GMS, coastal aquifer, modeling workflow.



## The application of machine learning approaches to the development of rating curve - case study: Tamgnounte spring (2001/2021) in high-atlas mountain, Morocco.

H. Bouyazri<sup>1\*</sup> & H. Rahali<sup>1</sup>

<sup>1</sup> Scientific Institute, Mohamed V University, Rabat, Morocco.

\* Email: [hanane\\_bouyazri@um5.ac.ma](mailto:hanane_bouyazri@um5.ac.ma)

### Abstract:

Streamflow measurements represent critical hydrological information for water resource planning and management but are costly, time-consuming, and tedious to collect; in comparison with water level measurements. A stage-discharge rating curve (RC) which establishes the link between recorded water levels and volumetric flow is commonly used to collect flow data at regular intervals. This kind of curve can be challenging to create since it necessitates discharge and stage measurements simultaneously throughout a broad range of stages. The classical RC methods involve several limitations and uncertainties induced by dynamic changes in river geometry and roughness. As a result, stage-discharge measurements will likely aggregate over a more extended period, for which different stage-discharge rating curves apply. In this study, a machine learning (ML) tool such as Multilayer perceptron (MLP) is explored and is expected to overcome its conventional statistical counter-part's limitations for processing stage-discharge measurements to obtain a better approximation of the relationship between them. We applied this approach using monitored water levels and flow rates from the Tamgnounte spring (2018-2021), supplemented by publicly available data (2001-2021). This approach has enabled improved flow measurements and thereby enhanced the reliability of rating curves as a suitable tool for practitioners for effective water resource management and mitigation of flood and drought risks.

**Keywords:** rating curve, water resource, statistical analysis, machine learning, LSTM, Tamgnounte spring, drought risks.



## Fusing machine learning algorithms and GIS-remote sensing methods for mapping groundwater potential zones: a case study of the Saiss basin in northern Morocco.

H. Ait-Ichou<sup>1\*</sup>, A. El Hmaidi<sup>1</sup>, M. Hssaissoune<sup>2,3,4</sup>, My H. Aouragh<sup>1</sup>, H. Ragraoui<sup>1</sup> & L. Bouchaou<sup>3,4</sup>

<sup>1</sup> Faculty of Sciences, Moulay Ismail University, Meknes, Morocco,

<sup>2</sup> Faculty of Applied Sciences, Ibn Zohr University, Agadir, Morocco,

<sup>3</sup> LAGAGE, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco,

<sup>4</sup> University Mohammed VI Polytechnic, Benguerir, Morocco.

\* Email: [hamza.ait-ichou@edu.uiz.ac.ma](mailto:hamza.ait-ichou@edu.uiz.ac.ma)

### Abstract:

Nowadays, Groundwater Potentiality (GWP) assessment plays a vital role in sustainable water resource management, especially in a region that knows continuous growth of freshwater demand for agricultural, industrial or drinking purposes. Decision makers are now forced more than ever to search for other water resources other than superficial water, especially for non-coastal areas such as our study area, Saiss basin in the North of Morocco. Nevertheless, prospecting groundwater can be challenging and very expensive, leading us to introduce new techniques such as remote sensing, GIS tools and Machine Learning (ML) in order to identify groundwater potential areas. 440 wells and springs' locations were identified in the study area for the shallow aquifer, that were randomly partitioned into 70% for the training phase (308 well and spring location) and 30% for the validation phase (132 well and spring location). In the current research, four machine learning models were implemented for mapping groundwater potential in the Saiss basin, including Random Forest (RF), Extreme Gradient Boosting (XGB), Artificial Neural Network (ANN) and Support Vector Machine (SVM). Twenty Groundwater Conditioning Factors (GCFs) were considered as potential predictors of GWP to which we have applied the Frequency Ratio method in order to determine the spatial relationship between them and wells and springs' locations. These GCFs were selected via multicollinearity analysis (VIF and Tolerance) and Information Gain (IG) test to include the most influential ones in the predictive models and to eliminate the redundant features. Based on the outcomes of this research, five GWP classes were identified in the Saiss basin; Very Low, Low, Moderate, High and Very High. GWP maps revealed that the capturing field of Haj Kaddour has a high to very high GWP, while the western and the northwestern parts have low to very low GWP. Regarding the ML models' performance, we observed that RF and XGB achieved the highest predictive accuracy, with an area under the receiver operating characteristic curve (AUC) of 93% and 92%, respectively. SVM and ANN also demonstrated competitive performance with an AUC of 87%.

**Keywords:** Groundwater potentiality, Saiss basin, Morocco, Machine learning, GIS.







## Groundwater mapping using GPI and machine learning models in the Souss upstream: a comparative study.

Z. Bouhamad<sup>1</sup>, M. Hssaisoune<sup>2,3,4</sup>, A. Akasbi<sup>1</sup>, El. Mili<sup>1</sup> & L. Bouchaou<sup>3,4</sup>.

<sup>1</sup> Faculty of Sciences, Moulay Ismail University, Meknes, Morocco

<sup>2</sup> Faculty of Applied Sciences, Ibn Zohr University, Agadir, Morocco,

<sup>3</sup> LAGAGE, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco,

<sup>4</sup> Mohammed VI Polytechnic University, IWRI, Benguerir, Morocco.

\* Email: [zineb.bouhamad@edu.uiz.ac.ma](mailto:zineb.bouhamad@edu.uiz.ac.ma)

### Abstract:

The world is going through a series of events related to climate change; in the past few years, a stern drought situation has been witnessed especially in arid regions around Morocco such as our study area, the Souss Upstream. The aim of this study is to employ Machine Learning (ML) models and Analytic Hierarchy Process (AHP) to generate a groundwater potential map because despite being a mountainous area, it has experienced a decrease in superficial freshwater availability making, in one hand, water supply for nearby villages less accessible, and the drilling for groundwater already being hard in such areas on the other hand. Thus, decision makers and scientists has abandoned the classical methods for groundwater prospecting and they have adopted these modern methods since they are less time consuming and financially affordable. This paper compares the performance of AHP and three supervised ML algorithms, including Support Vector machine (SVM), Random Forest (RF) and K-nearest neighbors<sup>2</sup> (KNN) for predicting the groundwater occurrence in the Souss upstream. Overall, about 397 groundwater springs were inventoried in the basin. The springs and non-springs inventory data was randomly divided into 80% (635 for training) and 20% (159 for testing). Twelve groundwater influencing factors (GIFs) were selected based on a multicollinearity test. These models were afterwards validated with the Receiver Operating Characteristics (ROC) curve alongside other accuracy assessment tests giving an AUC of 88% for RF, 83% for SVM and KNN models meanwhile an AUC of 72% for AHP was obtained.

The groundwater potential (GWP) maps were categorized into five classes —Very high, High, Moderate, Low and Very low—Based on the GWP maps, Immerguene valley and the downstream of Tifnout valley are characterized by high to very high GWP. In contrast, east and southeast parts are the less potential in terms of groundwater resources. According to the result of the applied evaluation metrics, the three ML models all have high prediction accuracy, among which the RF model performs more prominently with an accuracy of 79%.

The good prediction capabilities of these machine-learning technologies can provide a reliable scientific basis for spatial prediction of groundwater potential and management of water resources.

**Keywords:** Souss upstream, Groundwater potential sites, Hardrock, Machine Learning, AHP.



## Are raw satellite bands and machine learning all you need to retrieve actual evapotranspiration.

C. El Hachimi<sup>1\*</sup>, S. Khabba<sup>1,3</sup>, S. Belaqqiz<sup>1,2</sup>, B. Ait Hssaine<sup>1</sup>, M. H. Kharrou<sup>4</sup> & A. Chehbouni<sup>1,4</sup>.

<sup>1</sup> Center for Remote Sensing Applications (CRSA), Mohammed VI Polytechnic University (UM6P), Benguerir, Morocco,

<sup>2</sup> LabSIV Laboratory, Department of Computer Science, Faculty of Science, UIZ University, Agadir, Morocco,

<sup>3</sup> LMFE, Department of Physics, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakesh, Morocco,

<sup>4</sup> International Water Research Institute (IWRI), Mohammed VI Polytechnic University (UM6P), Benguerir, Morocco.

\* Email: [elhachimi.ch@gmail.com](mailto:elhachimi.ch@gmail.com)

### Abstract :

Accurately estimating latent heat flux (LE) is crucial for achieving efficiency in irrigation. LE represents the energy used by crops and the surface to convert water from a liquid state to a vapor state through transpiration and evaporation. This flux is a fundamental component in determining the actual evapotranspiration (ET<sub>a</sub>), which in turn, quantifies the amount of water lost that needs to be adequately compensated through irrigation. Several empirical and physics-based models are being used to estimate the LE. However, these models still face weaknesses, especially in their reliance on extensive input data, the simplification of assumptions regarding complex processes, and the need for parameterization and model calibration when changing the study site. In contrast, the emergence of data-driven techniques combined with remote sensing has shown promising results for LE estimation with minimal input data. This paper evaluates two machine learning-based approaches for estimating the LE. The first uses climate data, the Normalized Difference Vegetation Index (NDVI), and Land Surface Temperature (LST), while the second uses only climate data combined with all available raw satellite bands. In-situ data were sourced from a flux station installed in the Sidi Rahal region (centre of Morocco), a rainfed wheat field, chosen to evaluate the approach before generalization. The data include air temperature, global solar radiation, and measured LE for the period 2015–2018. The study uses Landsat 8 as a remote sensing data source. At first, 12 raw bands were downloaded. The LST is then derived from thermal bands using the Split Window algorithm (SW) and the NDVI from optical bands. During machine learning modeling, the CatBoost model is fed, trained, and evaluated using the two data combination approaches. Cross-validation of 3-folds gave an average RMSE of 27.54 W.m<sup>-2</sup> by using the first approach and 27.05 W.m<sup>-2</sup> by using the second approach. Results raise the question: do we need additional computational layers when working with remote sensing products combined with machine learning? Future work is to validate the approach in areas with different environmental conditions and test it for other applications such as soil moisture retrieval, and yield prediction.

**Keywords:** machine learning, evapotranspiration, NDVI & Sidi Rahal region.







## Assessing the future climate change impacts on the Fom El Oued groundwater aquifer in Laâyoune, Morocco: a numerical modeling approach.

A. Larabi<sup>1\*</sup>, M. Jalal El Hamidi<sup>1</sup> & M. Faouzi<sup>1</sup>.

<sup>1</sup> 1Regional Water Center of Maghreb, LAMERN, EMI, Mohamed V University in Rabat, Rabat-Morocco,

\* Email: [larabi\\_abdelkader@yahoo.fr](mailto:larabi_abdelkader@yahoo.fr)

### Abstract :

Water resource management in arid regions requires the provision of decision support tools that consider the impact of climate change as a structural reality. In the Laâyoune region, located in the south of Morocco, the Fom El Oued aquifer serves as a significant fresh water reservoir in a coastal area and plays a vital role in supplying water to the city of Laâyoune and neighboring municipalities. This study focuses on understanding and preserving this essential water resource, which is extensively utilized for drinking water supply, agriculture, and industrial purposes. However, due to the combination of reduced natural replenishment from the infiltration of Oued floods and increased pumping activities, groundwater has been overexploited, leading to the degradation of water quality and a considerable decline in the piezometric level. Consequently, an imbalance has emerged at the natural saltwater interface, resulting in seawater intrusion into the freshwater to compensate for the created depression. To address this issue, the objective of this work is to develop a finite difference hydrodynamic and seawater model that considers the effects of future climate change on the Fom El Oued aquifer, based on available hydrogeological data. The simulation results reveal that by 2050, under the projected conditions, the interface toe would have advanced by a distance of 6.5 kilometers. At this time, the concentration of 10 g/l will reach a distance of 6.2 kilometers, and the highest concentration (35 g/l) will extend to 5.8 kilometers. This groundwater model serves as a crucial decision support system for water resource management, particularly for the population of Laâyoune and the irrigation of the Fom El Oued agriculture area. By implementing effective management strategies, the coastal area can be protected from contamination, ensuring its sustainable use and preventing abandonment due to increasing salinity levels in irrigation and pumping wells.

**Keywords:** Water resource management, Impact of climate change, Fom El Oued aquifer, Hydrodynamic and seawater model, Hydrogeological data, Water resource management.



## Système d'aide à la gestion des prélèvements par couplage sig - modèle mathématique (Modflow) dans la nappe de Berrechid (Maroc).

A. Zerouali, A. Larabi & O. Chafik<sup>1</sup>.

<sup>1</sup> Regional Water Center of Maghreb, LAMERN, EMI, Mohammed V University in Rabat, Rabat-Morocco,

<sup>2</sup> Agence du Bassin Hydraulique de Bouregreg et la Chaouia (ABHBC),

\* Email: [larabi\\_abdelkader@yahoo.fr](mailto:larabi_abdelkader@yahoo.fr)

### Abstract:

La modélisation hydrodynamique de la nappe de Berrechid par le code MODFlow a permis de comprendre le fonctionnement hydrodynamique de l'aquifère, en estimant les échanges latéraux de la nappe avec le plateau de Settat, Oued Mellah et la Chaouia côtière. Ainsi, le calage du modèle mathématique en régime permanent sur l'état piézométrique de 1980 a permis d'affiner la distribution spatiale de la perméabilité sur l'ensemble du domaine et de dresser le bilan de la nappe en régime permanent. De même que le calage du modèle en régime transitoire a permis d'affiner la distribution spatiale du coefficient d'emmagasinement de l'aquifère. Le bilan issu de ce calage s'est avéré déficitaire avec un rabattement de 2m /an en moyenne. Les sécheresses que la zone d'étude a connues au cours des dernières années ont affecté d'une manière considérable l'approvisionnement en eau des populations et l'agriculture. Cependant, ces sécheresses ont démontré la nécessité de développer un outil d'aide à la gestion des prélèvements qui consiste à intervenir directement au niveau des usagers pour économiser et conserver l'eau. Cet outil de gestion des prélèvements a été développé en couplant l'ArcGIS au modèle mathématique (MODFlow) de la nappe de Berrechid, qui interfèrent et interagissent entre eux. Les rabattements de la nappe sont calculés en tout point (ou par zone) en réponse à des prélèvements (présents ou futurs) pour satisfaire la demande en eau (potable, industrielle ou agricole). L'outil permet de cartographier/délimiter les secteurs à forte, moyenne et faible surexploitation en offrant au décideur un tableau de bord lui permettant de prendre les mesures requises quant aux autorisations de prélèvements par secteur.

**Keywords :** Nappe de Berrechid, Hydrogéologie, Surexploitation, Modélisation, Régime permanent- transitoire, Prélèvement, Outil de gestion, couplage ArcGIS-Modèle.



## Numerical modeling of the future climate change impacts on the Ghis-Nekkor aquifer under rcp4.5 and rcp8.5 (Al Hoceima, North of Morocco).

A. Larabi<sup>1\*</sup>, H. El Asri<sup>1</sup>, M. Faouzi<sup>1</sup> & M. J. El Hamidi<sup>1</sup>.

<sup>1</sup> Regional Water Center of Maghreb, LAMERN, EMI, Mohamed V University in Rabat, Rabat-Morocco,

\* Email: [larabi\\_abdelkader@yahoo.fr](mailto:larabi_abdelkader@yahoo.fr)

### Abstract :

The study area covers the Ghis-Nekkor plain on the Mediterranean coast located in the north of Morocco. This groundwater aquifer is a typical example of a coastal aquifer whose water resources are exposed to severe overexploitation combined with increasingly low water supplies. The Ghis-Nekkor aquifer is an area highly vulnerable to seawater intrusion (SWI), firstly, because of less natural recharge, mean sea level rise due to climate change combined to groundwater overexploitation. The Regional Climate Models (RCMs) indicate a decrease in precipitation (18%) and an increase of average temperature (0,5°C) in the Ghis-Nekkor area by 2050 under the RCP4.5 scenarios. These changes would have a direct impact on groundwater recharge of the aquifer. The results of the predicted groundwater recharge show a reduction of the mean annual recharge of 14% for (2021-2050) following the RCP4.5 scenario. Moreover, predicted values of future groundwater recharge under the RCP8.5 scenario would decrease more and would reach 30% less for the period (2055-2084). In view of the limited fresh water resources and degradation of water quality by sea water intrusion, effective management of ground water resources in this aquifer is necessary and can be made by developing a groundwater flow model taking into account seawater intrusion. Indeed, the outputs of RCMs for precipitation and SLR were used to assess the impact of pumping and climate change on the Ghis-Nekkor aquifer under the RCP4.5 and RCP 8.5 scenarios (2020-2040). The results show that the N-W sector of the coastal area would be more vulnerable to SWI. By 2040, the length of inland encroachment would reach 1km, with a significant salinity (25g/l) and a significant drop in hydraulic head (-15m) following the RCP4.5 scenario. The extreme case of groundwater recharge and SLR under the RCP8.5 scenario will cause more severe impacts. By 2040, the length of inland encroachment would be around 1,23 km in the N-W part, at a distance of 0,55 km from the nearest ONEE well field. The salinity would reach 33g/l and the SWI volume would increase by 48% (1,78Mm<sup>3</sup>/year) compared to the results under the RCP4.5 scenario.

**Keywords:** Ghis-Nekkor, Climate Change, Regional Climate Models, Seawater intrusion, salinity, Groundwater recharge, hydrogeology.





## Machine learning and deep learning guided assessment of groundwater reservoir hydrodynamic parameters and geometry: a case study of the El Haouz aquifer.

L. El Mezouary<sup>1\*</sup>, A. Hadri<sup>1</sup>, M. H. Kharrou<sup>1</sup>, Y. Fakir<sup>2,3</sup>, A. Elfarchouni<sup>4</sup>, L. Bouchaou<sup>1,5</sup> & A. Chehbouni<sup>1,3</sup>.

<sup>1</sup> International Water Research Institute (IWRI), Mohammed VI Polytechnic University, Ben Guerir 43150, Morocco,

<sup>2</sup> Department of Geology, Faculty of Sciences Semailia, Cadi Ayyad University, Marrakech 40001, Morocco,

<sup>3</sup> Center for Remote Sensing Application (CRSA), Mohammed VI Polytechnic University, Ben Guerir 43150, Morocco,

<sup>4</sup> Natural Resources and Sustainable Development Laboratory, Ibn Tofail University, Cam-pus Maamora, 14000Kenitra, Morocco,

<sup>5</sup> Laboratory of Applied Geology and Geo-Environment, Faculty of Science, Ibn Zohr University, 80035 Agadir, Morocco,

\* Email: [el.mezouary.lhoussaine@gmail.com](mailto:el.mezouary.lhoussaine@gmail.com) / [Lhoussaine.ELMEZOUARY@UM6P.MA](mailto:Lhoussaine.ELMEZOUARY@UM6P.MA)

### Abstract:

The Plio-Quaternary aquifer in the EL-Haouz-Mejjate region of Morocco is critical for water supply, necessitating accurate characterization for sustainable management. This study pioneers machine learning and deep learning techniques to elucidate the aquifer's properties and geometry.

Supervised algorithms, including random forest, regression, support vector machines, and neural networks, are trained on available hydrogeological data. Diverse features capture complex input-output relationships to predict key hydrodynamic factors like hydraulic conductivity and transmissivity fields. Aquifer architecture attributes, including substratum depth, thickness, and height, are also estimated.

Model outputs are validated with field measurements, demonstrating promising accuracy. Enhanced hydrodynamic insights improve the conceptual model and groundwater flow modeling confidence. Uncertainties are reduced through this data-driven approach, enabling optimized aquifer management.

Overall, this work shows how useful it is to combine machine learning and deep learning with traditional hydrogeology in order to get a better understanding of complicated aquifer systems. The techniques pioneered provide a pathway for sustainable management of this vital water resource.

**Keywords:** Groundwater reservoir, hydrodynamic parameters, reservoir geometry, machine learning and deep learning, water resource management, hydrogeology.



## Contribution of hydraulic modeling and hydrology to flood prevention and design of engineering structures: case study of a bridge over the oued Ourika – Morocco.

*A. Chakri <sup>1\*</sup>, N-d. Laftouhi <sup>1</sup>, M. Ibnoussina <sup>1</sup> & L. Mandi <sup>2</sup>.*

<sup>1</sup> Geoscience Semlalia laboratory, Department of Geology, Faculty of Science Semlalia, Cadi Ayyad University, BP. 2390 Marrakesh 40000, Morocco,

<sup>2</sup> National Centre for Studies and Research on Water and Energy, Cadi Ayyad University, Marrakech, Morocco,

\* Email: [achraf.chakri@ced.uca.ma](mailto:achraf.chakri@ced.uca.ma)

### Abstract:

Located downstream of the Ourika watershed near the commune of Chouiter, the studied bridge is built over the Oued Ourika at the level of the N9 (national road linking Marrakech to Ouarzazate). The flood event of November 2014, reaching a peak flow of 347 m<sup>3</sup> /s, destabilized the bridge's overall structure. Hence the need to rebuild a new bridge, taking into account the magnitude of these extreme events. Hydraulic modeling involves creating mathematical and computer-based representations of hydraulic systems. Its purpose is to simulate water flow behavior and map flood-prone areas. Before initiating any hydraulic simulation, it is imperative to conduct a hydrological study to provide the input data for the hydraulic model. Precipitation records, evaporation rates, soil permeability, historical peak flow data, and site topography constitute, on the one hand, the product of the hydrological study and, on the other, the inputs for the hydraulic model. The hydraulic model is based on Saint-Venant equations to solve the conservation of mass and momentum equations. The aim of this work is to determine the critical water level at the bridge for a 100-year flood in order to optimize the height of the new bridge.

**Keywords:** Hydrology, hydraulic modeling, Geographic information system GIS, engineering structures, flooding prevention.



## GIS and remote sensing coupled with analytical hierarchy process (ahp) for the prevention of landslides: a case study in the Tamdroust watershed, province of Settat, Morocco.

C. Ed. Bouiss<sup>1\*</sup> & E. N. El Assaoui<sup>2</sup>.

<sup>1</sup> Geoscience, Water and Environment Laboratory, Faculty of Sciences, Mohammed V University, Rabat Morocco,

\* Email: [achraf.chakri@ced.uca.ma](mailto:achraf.chakri@ced.uca.ma)

### Abstract:

Landslides are one of the natural hazards that many countries around the world face. In Morocco, they cause significant damage to the road network and infrastructure every year, especially in our study area, which is undergoing multiple road opening and construction projects. Therefore, it is necessary to predict and identify vulnerable areas in advance in order to propose appropriate measures and techniques for protection and reinforcement. The main objective of this study is to develop a landslide susceptibility map using a multi-criteria spatial assessment approach. To reduce subjectivity, we utilized a method of complex decision analysis, the Analytic Hierarchy Process (AHP), implemented in a Geographic Information System (GIS). Seven factors were considered as conditioning factors in landslide occurrence: lithology, fracture density, slope, slope aspect, land use, hydrographic network density, and elevation. The results showed that 38% of landslides occurred in areas with high to very high susceptibility, 40% in moderately susceptible areas, and 22% in very low-to-low susceptibility areas. The resulting map was then validated by comparing the location of mapped landslides with susceptibility classes. The analysis of the study's results demonstrates that the landslide vulnerability map is a powerful decision support tool for local community development plans in the Settat province.

**Keywords:** GIS and remote sensing, Tamdroust watershed, AHP & mapped landslides.



## Evaluation de l'érosion hydrique dans le bassin versant d'El Himer a l'aide du modèle EPM, du GIS et google engine.

A. Sirine<sup>1</sup>\* & N. El Assaoui<sup>2</sup>.

<sup>1</sup> Université Mohammed V, Faculté des sciences, 4 Avenue Ibn Battouta, Rabat, Maroc,

<sup>2</sup> Ministère de la transition énergétique et du développement durable, Rue Abou Marouane Essaadi, Agdal, Rabat, Maroc

\* Email: [achraf.chakri@ced.uca.ma](mailto:achraf.chakri@ced.uca.ma)

### Abstract:

L'érosion hydrique au Maroc menace les sols fertiles, mettant en péril l'agriculture et les écosystèmes. La préservation des terres arables et des ressources en eau est essentielle pour garantir la durabilité environnementale et nutritionnelle du pays. Cette étude se concentre sur la cartographie des zones sensibles à l'érosion hydrique dans le bassin versant d'El Himer, situé à l'ouest du Maroc. La méthodologie adoptée est basée sur l'exploitation des systèmes d'information géographique (SIG), de la télédétection et de l'intelligence artificielle pour créer une carte des différents facteurs impliqués dans le processus érosif. Ces facteurs sont la pluviométrie, la température, le couvert végétal, l'érodibilité du sol et la topographie, qui sont ensuite intégrés dans l'équation EPM. Les résultats révèlent une dégradation moyenne d'environ 66,55 T/ha/an, avec des pics à 2562,02 T/ha/an. Les zones les plus exposées se trouvent en aval du bassin, caractérisées par des sols vulnérables et des pentes accentuant l'écoulement des eaux de surface. Cette recherche souligne l'urgence de relever le défi de l'érosion pour préserver l'environnement, l'agriculture et la sécurité alimentaire à long terme au Maroc.

**Keywords:** L'érosion hydrique, bassin versant d'El Himer, SIG & télédétection et de l'intelligence artificielle.



## Quantification of water erosion using the Rusle model in the mazer watershed, Morocco.

H. Meziane<sup>1\*</sup> & N. El Assaoui<sup>1</sup>.

<sup>1</sup> Geosciences, Water and Environment Laboratory, Faculty of Sciences, Mohammed V University in Rabat,

\* Email: [meziane.hanane.97@gmail.com](mailto:meziane.hanane.97@gmail.com)

### Abstract:

Water erosion is the primary cause of soil degradation in Morocco, a phenomenon challenging to control in space and time due to natural and human factors. The consequences of this erosion are evident in the environment and have a negative impact on the country's economic and social development. The economic implications of erosion are significant for Morocco, especially in upstream and downstream watersheds. Economic losses resulting from soil degradation affect local communities, businesses, and the national economy as a whole. In Morocco, signs of water erosion risk are evident in natural areas such as agricultural and forested regions. Numerous studies have been conducted using various scientific methods and approaches to understand this phenomenon. The empirical approach of the Revised Universal Soil Loss Equation (RUSLE), developed by Renard et al. in 1997 and based on the Universal Soil Loss Equation (USLE) by Wischmeier and Smith in 1978, is one of the mathematical models used to quantify water erosion in agricultural and forested lands. The objective of this study is to model and map the risk of water erosion in the Mazer watershed using the Revised Universal Soil Loss Equation (RUSLE) by incorporating various causal elements of the equation into a Geographic Information System (GIS). The results reveal that the specific degradation has an average of approximately 77.15 (T/ha/year), with variations ranging from 0.61 T/ha/year to 885.21 T/ha/year. This method will help identify the different factors that control the erosion phenomenon in the study area. This approach aims to better understand soil erosion processes in the region and implement protective measures to preserve the environment and natural resources.

**Keywords:** Rusle model, mazer watershed, USLE, RUSLE & GIS.



## Using remote sensing and geographic information system for delineating suitable sites for artificial groundwater recharge: a multi-criteria decision-making approach.

*R. Fri, M. Kili, L. Erraioui, S. Taia, J. Chaou, A. Mridekh & B. El Mansouri.*

<sup>1</sup> Geosciences, Water and Environment Laboratory, Faculty of Sciences, Mohammed V University in Rabat,

\* Email: [rahma.fri@uit.ac.ma](mailto:rahma.fri@uit.ac.ma)

### Abstract:

The semi-arid region of Deraa Oued Noun in Morocco faces significant challenges related to water scarcity, which greatly affects the availability of groundwater resources. With recurring droughts and periods of water shortage, it is imperative to address these challenges and implement effective measures for sustainable groundwater resource management. Artificial groundwater recharge has proven to be a viable solution for alleviating water scarcity issues. By capturing and storing excess water during periods of heavy precipitation or surface water availability, artificial recharge can replenish depleted aquifers and provide a reliable water source during drought periods. However, the success of recharge projects depends on identifying suitable sites that meet specific criteria and maximize the efficiency of the recharge process. The identification of suitable sites for artificial groundwater recharge in Derâa Oued Noun, through the integration of remote sensing, GIS (Geographic Information System), and MCDM (Multi-Criteria Decision Making) techniques, offers a promising solution to address water scarcity challenges in the context of climate change. The proposed research project aims to provide valuable and spatially explicit information for strategic groundwater resource management.

This study was conducted in Deraa Oued Noun district since the water shortage was observed over the years. Geology, soil, land use and stream data along with Sentinel-2 and DEM images were utilized to develop the relevant thematic layers such as geology, geomorphology, soil, slope, lineament density, land use and stream density by integrating GIS and image processing techniques. The resultant thematic layers were utilized to prepare the groundwater recharge maps of the area through a weighted overlay method in a GIS platform. The results revealed that the artificial recharge was high in North and west part of the study area. By following a systematic and rigorous methodology, including data collection, remote sensing analysis, MCDM evaluation, and site validation, this project aims to contribute to the successful implementation of artificial recharge projects in the region. By maximizing the efficiency of the recharge method, these projects will help ensure sustainable water supply, mitigate the impacts of drought, and promote long-term water security in Derâa Oued Noun and similar semi-arid regions.

**Keywords:** MCDM, GIS, Derâa Oued Noun & remote sensing.



# Sessions Virtual 1 :

SV1

SV2

SV3







## Enhancing Precipitation Prediction in the Ziz Basin: A Comprehensive Review of Traditional and Machine Learning Approaches.

*S. Bouziane<sup>1\*</sup>, B. Aghoutane<sup>1</sup>, A. Moumen<sup>1</sup>, A. Sahlaoui<sup>1</sup> & A. El Ouali<sup>4</sup>.*

<sup>1</sup> Informatics and Applications Laboratory, Science Faculty of Meknes, Moulay Ismail, University, Meknes, Morocco,

<sup>2</sup> Ibn Tofail University, National School of Applied Sciences, Kenitra, Morocco,

<sup>3</sup> Laboratory of Geo-Engineering and Environment, Faculty of Sciences, Moulay Ismail, University, Meknes, Morocco,

<sup>3</sup> Department of Environment, Functional ecology and environmental engineering laboratory, Faculty of Sciences and Technology, Sidi Mohamed Ben Abdellah University, Fez, Morocco,

\* Email: [sa.bouziane@edu.umi.ac.ma](mailto:sa.bouziane@edu.umi.ac.ma)

### Abstract:

Accurate precipitation forecasting is paramount for various sectors, including agriculture, hydrology, urban planning, transportation, and disaster management. Traditional meteorological methods for rainfall prediction involve understanding the physical processes that lead to precipitation, combined with historical weather data and statistical models that simulate the atmosphere's behavior. These methods are based on weather observations from ground-based weather stations, satellites, and weather radars to assess the current atmospheric state and predict future precipitation events. However, due to the inherent complexity of rainfall, such as its non-linear behavior, accurate prediction remains a challenging task. In the past few years, machine learning (ML) algorithms have appeared as a promising approach to improving precipitation prediction accuracy. This research aims to provide an overview of both traditional methods and advanced ML models applicable to rainfall prediction, including regression, classification, and time series models. In addition, we have conducted a comprehensive review of related works that explore the impact of using machine learning algorithms for rainfall estimation. By analyzing the existing literature, we have observed and identified the strengths and limitations of ML models in this context and have highlighted the advancements made in rainfall prediction using these algorithms. We possess a comprehensive dataset comprising historical weather data from the Ziz basin, which serves as the designated study area for our research. This dataset contains five key meteorological features: precipitation, humidity, wind, temperature, and evaporation. The data span a significant period, from 1996 to 2015. In terms of the perspective of our study, we plan to utilize the provided dataset and conduct a comprehensive comparative study to evaluate the performance of different Machine Learning (ML) models. Our objective is to demonstrate the effectiveness and potential of these algorithms in improving weather forecasting capabilities and enhancing the accuracy of rainfall estimation methods in the specific study area.

**Keywords:** Rainfall prediction, Machine Learning models, Ziz basin, accuracy enhancement.



## spatiotemporal siltation patterns in Moroccan dam reservoirs: a geographic information system (GIS) approach.

*S. Mohafid<sup>1\*</sup>, L. Stour<sup>1</sup>, Benchara<sup>2</sup> & A. Agoumi<sup>3</sup>.*

<sup>1</sup> Process and Environment Engineering Laboratory, Faculty of Sciences and Techniques of Mohammedia, Hassan II University of Casablanca, Mohammedia, Morocco,

<sup>2</sup> Directorate General of Hydraulics / Moroccan Ministry of Equipment and Water,

<sup>3</sup> Laboratory of Geo-Engineering and Environment, Faculty of Sciences, Moulay Ismail, University, Meknes, Morocco,

<sup>3</sup> Civil Engineering, Hydraulics, Environment, and Climate Change Laboratory, Hassania School of Public Works, Casablanca, Morocco,

\* Email: [said.mohafid@hotmail.fr](mailto:said.mohafid@hotmail.fr)

### Abstract:

Reservoir siltation poses a significant challenge to water resource management worldwide. The present article aims to analyze the spatiotemporal distribution of mud accumulated in Moroccan dams using a Geographic Information System (GIS) developed as part of this research work. This GIS facilitates collecting, organizing, analyzing, and visualizing bathymetric data from dam reservoirs across Morocco. By representing the data on an interactive map annually, it will become effortless to identify heavily impacted regions experiencing sedimentation and observe the changes over time. Based on this GIS, an analysis is conducted to understand the variations in siltation over time and space. The obtained results provide a better assessment of the impacts of sedimentation on the storage capacity of dams and guide decisions regarding the management and optimization of water resources.

This research work that was carried out on Moroccan dam reservoirs joins the Mediterranean context, where similar problems related to the sedimentation of the reservoirs also arise.

Mediterranean countries face common challenges such as the limited availability of water resources and the need to effectively manage dams to ensure sustainable use of this resource.

Using a developed Geographic Information System (GIS), the spatial and temporal analysis of sediment deposits in Moroccan dam reservoirs can provide valuable information on the distribution of sediments in space and the evolution of the sedimentation phenomenon over time. This information should be valuable for other countries in the Mediterranean region facing similar challenges.

The results of this research work could also promote an exchange of good practices and contribute to the development of integrated water resources management strategies at the international level, thus guaranteeing the sustainable management of dams while preserving the river ecosystems of the Mediterranean region.

**Keywords:** Siltation, dam reservoirs, Morocco, Geographic Information System (GIS), spatial and temporal distribution, water resources management.







## Assessment of Climate Change Impact on Precipitation Using Machine Learning Based Statistical Downscaling Method.

Jazuli Abdullahi<sup>1</sup>, Ala Tahsin<sup>2</sup>, Mehmet Irfan Yesilnacar<sup>2</sup>, Abdullah İzzeddin Karabulut<sup>3</sup>, and Oluwatoyin Daramola<sup>1</sup>

<sup>1</sup> Baze University, Faculty of Engineering, Civil Engineering Department, Abuja, Nigeria

<sup>2</sup> Harran University, Environmental Engineering Department, Haliliye, Sanliurfa, Türkiye

<sup>3</sup> Harran University, Remote Sensing and Geographic Information Systems, Sanliurfa, Türkiye

\* Email: [jazuli.abdullahi@bazeuniversity.edu.ng](mailto:jazuli.abdullahi@bazeuniversity.edu.ng)

### Abstract:

Future predictions of precipitation are highly important for effective water resources management. The Global circulation models (GCMs) are commonly used to make such predictions. In this paper, the effect of climate change on precipitation was investigated for Damaturu station located in Yobe state, Nigeria from 2050-2080. For this purpose, the BNU-ESM GCMs under the emission scenario RCP 4.5 was used to downscale observed precipitation data via Artificial Neural Network (ANN). Various climatic predictors were considered and ranked according to their impact on precipitation using the mutual information (MI) method. A total of 5 ANN models were subsequently developed using different combinations of predictors as inputs to downscale the precipitation data. The Determination Coefficient (DC) and Root Mean Square Error (RMSE) performance indicators were then employed. M1 which used a combination of top 8 ranked predictors was found to have the best performance in both downscaling and projection phases. The final results from M1 showed that, over the specified period, the Damaturu region will generally experience a decrease in precipitation, which will be more prevalent in months that experience the most precipitation with the most decrease of 20% in monthly precipitation sum occurring during the wettest month of August, towards the end of the 21st century.

**Keywords:** Global Circulation Models, Climate Change, ANN, Nigeria.



## A GIS based approach for assessing water body change in a mountain wetland: case of Dayet Awwa, Morocco.

A. Abdenour, M. Sinan, B. Lekhlif & O. Belloulid.

<sup>1</sup> Equipe de Recherche, Hydrogéologie, Traitement et Épuration des Eaux et Changements Climatiques (HGT2E2C). Département Hydraulique, Environnement et Climat (HEC), Ecole Hassania des Travaux

<sup>2</sup> Living Planet Morocco, 281, bd Moulay Youssef. Résidence Azur 3. 3ème étage. Casablanca. Maroc.

\* Email: [assia25abdenour@gmail.com](mailto:assia25abdenour@gmail.com)

### Abstract:

According to the definition derived from the International Convention on Wetlands (Ramsar), wetlands are areas that cover a wide range of habitat types, including floodplains, marshes, streams, estuaries and offshore coastal areas. These natural habitats provide a variety of ecosystem services, for instance, they contribute to mitigate the impacts of climate change. Nevertheless, one of the most critical issues of our time is that mountain wetlands are particularly threatened by many changes, which have a profound impact on their ecosystem services. Hence, the main goal of this work in the Middle Atlas (Morocco), using a GIS based approach is to emphasize the threat to wetlands and their ecosystem services. In this study, Landsat satellite images uploaded from Earth explorer for the years 1985, 2008 and 2018 were used to calculate the NDWI (Normalized Difference Water Index) for the lake dayet Awwa. The calculation result shows that the surface area of the lake has decreased significantly between the years 1985 and 2018. This decline can be explained by natural and anthropogenic factors.

**Keywords:** Mountain Wetland, NDWI, Landsat satellite imagery, GIS based approach, Middle Atlas, Dayet Awwa.



## Modelisation numerique de l'intrusion saline de la nappe.

*Is. I. Anasse<sup>1\*</sup>, M. Killi<sup>1</sup>, J. Chao<sup>1</sup>, A. Mridekh<sup>1</sup> & B. El Mansouri<sup>1</sup>*

<sup>1</sup> Laboratory of Natural Ressources and Sustainable Development, Ibn Tofail University, Faculty of Sciences, Kenitra, Morocco, Morocco.

\* Email: [anasse.issifouissaka@uit.ac.ma](mailto:anasse.issifouissaka@uit.ac.ma)

### Abstract :

L'aquifère de Foum El Oued est situé dans une zone côtière à l'ouest de la ville de Laâyoune. S'étendant sur une superficie d'environ 250 km<sup>2</sup>, il constitue une ressource en eau vitale pour Laâyoune et les municipalités avoisinantes. Par conséquent, son étude et sa préservation revêtent une importance cruciale. Les prélèvements d'eau se concentrent principalement au niveau du champ captant de l'Office National de l'Électricité et de l'Eau Potable (ONEE), destinés à l'approvisionnement en eau potable, à l'agriculture et à l'industrie. La salinisation de cette unité hydrogéologique trouve principalement son origine dans l'avancée du biseau salin au niveau du champ captant, potentiellement influencée par des facteurs lithologiques. Le pompage intensif et les périodes de sécheresse contribuent à la contamination de cette précieuse ressource. Le recours à la modélisation grâce à l'outil Seawat, qui permet de suivre l'interface entre l'eau douce et l'eau salée sur la période de 1986 à 2021, a permis de simuler l'intrusion saline et de déterminer l'étendue de cette avancée en se basant sur les données enregistrées par les salinomètres installés dans les zones de captage. La position de l'interface entre l'eau douce et l'eau salée se caractérise par une variabilité spatio-temporelle irrégulière en relation avec les périodes d'exploitation de la nappe. Les résultats de cette étude ont permis de mettre en évidence l'emplacement planimétrique de l'interface entre l'eau salée et l'eau douce, notamment au niveau de cinq des forages les plus profonds.

**Keywords:** Modelisation numerique, l'intrusion saline, nappe & Seawat.



## Water and the territorialization of sdg 6 in the meknes prefecture.

*S. El Arroufi & A. Baguare<sup>1</sup>*

<sup>1</sup> Laboratoire des Études et Recherches Économiques et Sociales, Faculté des Sciences Juridiques, Économiques et Sociales, Université Moulay Ismail Meknès 50000, Maroc.

\* Email: sa.elarroufi@edu.umi.ac.ma

### **Abstract :**

Against the background of climate change, the water problems of the world are diverse and dynamic, constantly changing over time. They exhibit significant variations from one region to another, and even within a single country, as well as from one season to another. Based on research, the international approach agrees that there is no real sustainability without water inclusion (World Water Council, 2021). Morocco, as a developing country has been aware of the need to preserve its natural resources and respond to national and international ecological imperatives. By reinforcing its legal and institutional arsenal by engaging in international conventions to integrate the Clean Water and Sanitation (SDG 6th) in its strategies and their territorial development programs. The aim of this scientific paper is to explore the key issues related to territorial integration of water Management in Morocco, and to identify the specific challenges and opportunities it presents in the context of economic transition. The study also aims to draw up a summary table to define and analyze the degree of integration of clean water and sanitation dimensions in the Meknes prefecture. Mainly, the city has an essential of the natural resources of water. Finally, recommendations are made for strengthening water management, governance mechanisms, building the capacity of local players and raising public awareness of territorial dimensions water management.

**Keywords:** Water management, sustainable development, clean water and sanitation, territorial dimensions, Fes Meknes Region.







## Trace elements geochemistry and quality assessment of springs water in the semi-arid region, Morocco.

A. Alitane<sup>1\*</sup>, A. Essahlaoui<sup>1</sup>, A. V. Griensven<sup>2,3</sup>, S. Eisenreich<sup>2</sup>, N. Essahlaoui<sup>1</sup>, A. Elaaraj<sup>4,5</sup> & A. Essaied<sup>6</sup>.

<sup>1</sup> Geoengineering and Environment Laboratory, Research Group “Water Sciences and Environment Engineering”, Geology Department, Faculty of Sciences, Moulay Ismail University, Presidency, Marjane 2, Meknes BP 298, Morocco.

<sup>2</sup> Hydrology and Hydraulic Engineering Department, Vrije Universiteit Brussels (VUB), 1050 Brussels, Belgium

<sup>3</sup> Water Resources and Ecosystems Department, IHE Delft Institute for Water Education,

<sup>4</sup> Natural Resources and Environment Laboratory, Geology Department, Polydisciplinary Faculty of Taza, Route d'Oujda, P.O. Box 1223, Taza 35000, Morocco,

<sup>5</sup> Engineering Sciences and Techniques Center, Environment Department, Faculty of Science and Technology, Sidi Mohamed Ben Abdellah University of FEZ, P.O. Box 2202, Fes 30000, Morocco,

<sup>6</sup> Geoexploration and Geotechnics Research Team, Department of Geology, Faculty of Sciences, Moulay Ismail University of Meknes, Morocco. PO Box 11201 Zitoune, Meknes, Morocco

\* Email: [abdennabi.alitane@vub.be](mailto:abdennabi.alitane@vub.be)

### Abstract :

Water quality is strongly linked to human health and sustainable socio-economic development. Due to increasingly intense human activity, pollutants, and in particular trace elements, are entering the aquatic system and harming humans. The main objective of this study is to analyse and compare the impact of the trace elements on the water quality of the natural springs. The concentrations of ten trace elements were analysed by ICP-MS for 12 spring water samples collected in 2022, in order to define the spatial variability of natural water quality in the Ouislane watershed. Nine major trace elements were measured by using Inductively coupled plasma mass spectrometry (ICP-MS) technique (Boron, Cobalt, Chromium, Copper, Manganese, Nickel, Lead, Zinc and Vanadium). The average values of these elements descended in the trend of  $B > Ni > Cr > Co > Zn > Mn > V > Cu > Pb$  for springs water. Trace elements measured in some water samples exceed the upper limits established by Moroccan drinking water quality standards (NM) and the World Health Organization (WHO) standard. From the principal components analysis (PCA), 83% of the variation is explained by the first three main components. B, Co, Cr and Ni have a strongly impact on water quality explain by their strong correlation with CP1 ( $R^2 > 0.70$ ). The calculated water quality index (WQI) values ranged from 61.18 to 95.11, with an average of 78.47. About 17% of water samples were classified as water of excellent quality ( $WQI < 50$ ), while 83% of water samples were classified as water of good quality ( $50 < WQI < 100$ ). Based on the WQI index, all the natural spring waters studied are suitable for human consumption. Keywords: Water quality; trace elements; springs; Ouislane watershed; water quality index.

**Keywords:** Water quality; trace elements; springs; Ouislane watershed; water quality index.



## Assessing environmental impacts of a landfill and recovery center on water quality in Tangier, Morocco: a study of microbiological and metallic contamination in surface and groundwater sources.

S. A. El Gueriri<sup>1</sup> \*, I. Bakkali<sup>1</sup>, F. El Mansouri<sup>1</sup>, F. Achemlal<sup>1</sup> & J. Brigui<sup>1</sup>.

<sup>1</sup> 1- Materials, Environment and Sustainable Development, Faculty of Sciences and Techniques, Tangier, Morocco,

\* Email : sanae.ajbarelgueriri@etu.uae.ac.ma

### Abstract :

In Morocco, water quality degradation due to microbiological and metallic contamination has been the subject of extensive research. As a reply, Tangier City has implemented a new Landfill and Recovery Center (LRC) as part of the National Program of Management of Municipal Solid Waste. This study aimed to investigate the surface and groundwater quality near the LRC site. Microbiological and chemical parameters were analyzed for four community wells neighboring the LRC and five surface water sources from M'harar and Tahaddart Wadis, following international standard methodologies.

The findings revealed distinct spatial patterns of water quality, indicating the presence of a gradient of bacteriological and metallic contamination in groundwater sources (wells 1, 2, 3, and 4) surrounding the LRC. Samples collected near the site exhibited elevated concentrations of heavy metals and bacteria associated with fecal contamination. The mismanagement of the landfill and absence of environmental monitoring practices may have adverse effects on the Biological and Ecological Interest Site (SIBE) of the Tahaddart region and human health. These results underscore the urgent need for improved waste management strategies and robust environmental monitoring to protect the region's ecological integrity.

**Keywords:** Landfill and Recovery Center (LRC), Leachate, Water quality, Metallic contamination, Microbiological contamination, Landfill Management.



## Effect of carvacrol microspheres on *Microcystis* toxic blooms in aquatic ecosystems: mesocosm application trial under semi-natural conditions.

*L. Tebba<sup>1\*</sup>, Z. Tazart<sup>1</sup>, M. Douma<sup>2</sup>, K. Mouhri<sup>1</sup> & M. Loudiki<sup>1</sup>*

<sup>1</sup> Water, Biodiversity and Climate change laboratory. Phycology, Biotechnology and Environmental Toxicology Research Unit, Cadi Ayyad University, FSM, Marrakech, Morocco,

<sup>2</sup> Research unit in microbiology and environmental toxicology, Polydisciplinary Faculty of Khouribga (FPK), Sultan MoulaySlimane University, Morocco

\* Email: [lamiaatebba@gmail.com](mailto:lamiaatebba@gmail.com)

### Abstract:

Harmful Cyanobacterial Blooms (HCBs) are currently a global environmental issue due to their negative impacts on water quality, aquatic ecosystems and human health. The use of plantbased allelochemicals as natural algacides is an ecofriendly and promising approach for controlling the growth of harmful cyanobacteria. In this study, we prepared and characterized an anti-algal sustained-release granules, then studied its mode of action on *Microcystis aeruginosa* growth. The anti-algal sustained-release granules were prepared with carvacrol using alginate–chitosan microcapsules technology and characterized by a high-performance liquid chromatography, Fourier transform infrared spectral analysis, and a scanning electron microscope. These carvacrol sustainedrelease microspheres (CSMs) had a high encapsulation efficiency (up to 57 %) and good release properties (release time of more than 40 d). Growth experiments indicated that *M. aeruginosa* of an initial density could be inhibited immediately, chlorophyll-a content and carotenoids both showed significant decreases following exposure of cyanobacteria to a dosage of CSMs for 40 days. The algicidal mechanism of CSMs was tested through a suite of physiological parameters (antioxidant enzymes activity of superoxide dismutase, lipid peroxidation and soluble proteins). The mesocosm application test of an algacidal treatment using carvacrol sustained-release microspheres showed that carvacrol has strong anti-cyanobacterial activity and that microspheres could be used in situ as a green bioprocess to mitigate the proliferation of toxic cyanobacteria for a long time. Overall, the results highlighted that Moroccan medicinal plant-derived allelochemicals could be used as effective and sustainable natural alternative to control harmful algal blooms (HABs).

**Keywords:** Carvacrol sustained-release microspheres, Algicidal mechanism, Antioxidant enzyme, lipid peroxidation, Chlorophyll-a, Carotenoids & *Microcystis aeruginosa*.



## **Integrated water resource management in the decision-making of large firms in Morocco: case of managem group (hydraulic basin of tensift al haouz).**

*A. Banouar<sup>1\*</sup> & A. Bouslihim<sup>1</sup>.*

<sup>1</sup> LARMODAD, Faculty of Juridical, Economical and Social Sciences Souissi, University Mohamed V, Rabat, Morocco..

\* Email: [hicham.boutracheh@uit.ac.ma](mailto:hicham.boutracheh@uit.ac.ma)

### **Abstract:**

Water resources and economic growth are two preoccupations that take different senses. The overconsumption can be very costly in terms of the quantity and quality of water resources, which indulges many negatives impacts on water reserves. In arid zones, institutions and large national firms are obligated to deliver more efforts in term of adaptation to the area's hydraulic situation. In this article, we address the issue of integrating good governance of water resources into the decision-making process of large firms in Morocco. We will study the case of the Guemassa mine of the Managem group, located in the Tensift Haouz basin. In order to assess the efficiency of their strategy, we carried out an impact study of the company's mining activities on the quality and quantity of the region's water resources. At the same time, we provided key information on the hydraulic situation of the region in question. In conclusion, the company is monopolizing a large part of the water resources of the Haouz plain and their integrated water resource management strategy is deemed insufficient.

**Keywords:** Water scarcity, integrated water resource management, large firms, PRA.







## Effect of cadmium on Fenugreek germination parameters.

*S. Azzouzi<sup>1\*</sup>, M. Khamar<sup>1</sup>, A. Nounah<sup>1</sup> & E. Cherkaoui<sup>1</sup>.*

<sup>1</sup> Civil and Environmental Engineering Laboratory (LGCE), High School of Technology Salé, Mohammed V University Rabat, Morocco.

\* Email: [soukayna\\_azzouzi@um5.ac.ma](mailto:soukayna_azzouzi@um5.ac.ma)

### Abstract:

Since cadmium is not a necessary heavy metal, biological processes do not utilize it. It tends to collect in living things, notably in vertebrates, especially in organs like the kidney and liver; it also accumulates in invertebrates, algae, and plants in aquatic and terrestrial ecosystems. The kidneys are primarily affected in mammals and birds by effects.

Cadmium is mostly emitted in particulate form into the atmosphere, aquatic habitats, and terrestrial environments via a variety of natural and anthropogenic sources. Cadmium can be released into the environment naturally by volcanoes or rock weathering, as well as by human activity, such as mining and the creation, use, and disposal of products that contain cadmium.

It can linger in the environment for a very long period once it is there. Particles that are either transported by the wind or washed away by water might carry it from one place to another.

Many cadmiums usage have been drastically reduced in industrialized nations as awareness of the toxic effects of cadmium has increased. Waste management systems have also been implemented to reduce the amount of cadmium that is released into the environment.

The purpose of this study was to look into the impact of cadmium on fenugreek seed germination parameters.

According to preliminary findings, the germination index is lower than it would be in a control.

**Keywords:** cadmium, fenugreek & germination.





## Porous ceramic from phosphogypsum and natural phosphate for wastewater treatment.

*S. Bouk<sup>1\*</sup>, L. Bennani<sup>1</sup>, M. Elkouali<sup>1</sup> & A. Abourich<sup>2</sup>*

<sup>1</sup> Laboratory of analytical and molecular chemistry (LCAM), faculty of science ben m'sik, Casablanca, Morocco, Benguerir 43150, Morocco.

<sup>2</sup> Laboratory Materials, Processes, Environment and Quality, National School of Applied Sciences, Safi, Morocco

\* Email: [sara.bouq@gmail.com](mailto:sara.bouq@gmail.com) / [lailaben91@hotmail.com](mailto:lailaben91@hotmail.com)

### Abstract:

Membrane technology has long been considered one of the most effective methods for the filtration of industrial effluents and the treatment of wastewater, in fact, there are known varieties of membranes according to their nature, in particular the organic membranes, which are the most used because of the low cost compared to inorganic membranes (metal oxides: Alumina, Zirconia, titanium, silicon carbide, etc.). On the other hand, organic membrane technology is often limited due to its poor physical and chemical properties. To overcome these obstacles associated with ceramic membranes, several researchers are focusing on the preparation of ceramic membranes from affordable precursors such as natural earth clays and industrial waste materials, mostly attending to the economic advantages.

In this study, we focused on manufacturing flat ceramic membranes (membrane support) based on phosphogypsum industrial waste with different pore-forming agents. To improve their porosities. The ceramics were prepared by a uniaxial pressing process using a mixture of phosphogypsum and 20 wt% of natural phosphate. They were then fired at different temperatures (900, 1000, 1100, and 1150 °C). The research involved the characterization of the raw materials and resulting ceramic supports using various analytical techniques such as X-ray diffraction, EDX, GTA, porosity, and indirect tensile strength.

**Keywords:** Phosphogypsum; Porous ceramics; Mechanical strength; water treatment.



## Impact of Nitrogen Fertilization on Soil Nitrate Concentrations in an Onion Field in the Saiss Basin.

*C. Nessah<sup>1,2\*</sup>, A. El Hmaid<sup>1</sup>, A. Lahjouj<sup>1,3</sup>, El. M. El Faleh<sup>2</sup> & K. Bouhafa<sup>1</sup>*

<sup>1</sup> Soil, Plant, and Water Laboratory, National Institute of Agronomic Research, km 10, Road Haj Kaddour, P O Box 578 VN, Meknes, Morocco,

<sup>2</sup> Department of Geology Faculty of Sciences, Moulay Ismail, University, P O Box 11202, Zitoune, Meknes, Morocco,

<sup>3</sup> Laboratory of Geo-engineering and Environment, Department of Geology, Faculty of Sciences, Moulay Ismail University, P O Box 11202, Zitoune, Meknes, Morocco.

\* Email: [nessah.chaimae@gmail.com](mailto:nessah.chaimae@gmail.com)

### Abstract:

High nitrogen (N) fertilizer rates can result in excessive nitrate (NO<sub>3</sub>-N) in soils and groundwater. The Saiss basin is an agricultural area in Morocco, where substantial increases in nonpoint source pollution from excessive N fertilization is commonly observed. The purpose of this study was to determine the short-term effect of N fertilizer application rates on soil NO<sub>3</sub>-N and soil water contents (SWC) in an onion (*Allium cepa* L.) field over two consecutive years (2021 and 2022). The field experiment was conducted in a randomized complete block design. Six N rates, namely 0, 90, 135, 180, 225, and 270 Kg N/ha were considered in drip-irrigated onion crops. Soil samples were collected from five consecutive soil layers, namely 0-20, 20-40, 40-60, 60-80, and 80-100 cm, and analyzed for NO<sub>3</sub>-N contents and SWC. SWC were lower before irrigation and increased significantly after irrigation for both seasons. There was no significant effect of N rates on SWC. Soil NO<sub>3</sub>-N decreased significantly with time. In the first season, lowest NO<sub>3</sub>-N levels was observed after harvest for all N rates. Visually, a marked accumulation of nitrate in soil was observed in the three highest N rates after harvest. Statistically, N rates did not show significant effect on soil NO<sub>3</sub>-N ( $p > 0,05$ ) in 2021 and 2022. This finding may be explained by the predominance of the denitrification process at Douyet station.

**Keywords:** Saiss Basin, Soil Nitrate, high nitrogen & soil water contents.





## The aquifers of the Western Anti-Atlas: geological and hydrogeological features.

*M. Benssaou*<sup>1\*</sup>, *M. Hssaisoune*<sup>1,2,3</sup>, *H. Boudhair*<sup>1,4</sup>, *M. Abioui*<sup>5</sup>, *M. Benssaou*<sup>5</sup> & *L. Bouchaou*<sup>2,3</sup>.

<sup>1</sup> LAGAGE, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco

<sup>2</sup> Mohammed VI Polytechnic University, IWRI, Benguerir, Morocco

<sup>3</sup> Faculty of Applied Sciences, Ibn Zohr University, Agadir, Morocco

<sup>4</sup> SOMATEP, Agadir, Morocco

<sup>5</sup> GEGL, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco

\* Email: [mouadbensaou79@gmail.com](mailto:mouadbensaou79@gmail.com)

### Abstract:

In the Anti-Atlas, surface water resources are scarce, and they are becoming more and more so as the aridity inherent in climate change accelerates. Therefore, underground reservoirs, even the deepest ones, are actively sought.

In particular, the Western Anti-Atlas is a very large hydrogeological basin where the Proterozoic basement and its Cambrian cover constitute two different aquifers. To contribute to a better determination of areas suitable for the exploitation of these aquifers, the approach adopted in this work is based, on the one hand, on outcrop and subsurface data through boreholes, and on the other hand, on the use of geographic information system (GIS) tools.

The geological approach made it possible to reconstruct the litho-stratigraphic successions of more than 350 boreholes. The interpretation of these sections shows that inside the inliers, the aquifer is mainly housed in permeable conglomeratic and volcano-detrital deposits, which generally rely on metamorphic quartzites with low porosity. In the cover, on the other hand, it is the dolomites and limestones of the Adoudou Formation that play the role of aquifer. The major interest of this formation lies in its carbonated lithological nature.

The GIS has made it possible to carry out a geospatial mapping of hydrogeological parameters (piezometric level/soil, flow rate and electrical conductivity), the values of which are acquired from the technical data sheets provided by the Souss-Massa Hydraulic Basin Agency.

Regarding flow, it seems that the high values are found in intensely fractured areas, such as the vicinity of the Lakhssas plateau and the valleys of Ait Mansour and Talat n'Issi between Kerdous and Tagragra of Akka. The electrical conductivity parameter, which reflects the quality of groundwater, reveals the existence of high anomalies at the level of the buttonhole of Ifni, in particular Ait Baha north of Kerdous. The common feature of these three zones is that the geological bedrock is formed of volcano-sedimentary materials, the alteration of which enriches the circulating water with dissolved chemical elements, causing the high electrical conductivity in these three zones.

**Keywords:** Anti-Atlas, Adoudounian Aquifer, Hydrogeological Sections, Discontinuous environment, GIS.



## Evaluation of precipitation datasets for drought monitoring in the Tensift basin (Morocco).

*K. Oukaddour*<sup>1\*</sup>, *M. Le Page*<sup>2</sup> & *Y. Fakir*<sup>1,3</sup>

<sup>1</sup> GEOSCIENCES Laboratory, Faculty of Sciences Semlalia, Cadi Ayyad University, 40000 Marrakech, Morocco.

<sup>2</sup> Centre d'Etudes Spatiales de la Biosphère (CESBIO), Université de Toulouse, CNES/CNRS/INRAE/IRD/UPS, 31400 Toulouse, France.

<sup>3</sup> Center for Remote Sensing Applications (CRSA), Mohammed VI Polytechnic University (UM6P), Ben Guerir 43150, Morocco..

\* Email: [kaoutaroukaddour@gmail.com](mailto:kaoutaroukaddour@gmail.com)

### Abstract:

Global precipitation estimates based on reanalysis data are of paramount importance to compensate for the scarcity of data from hydrometeorological networks. However, there are several restrictions on gridded data evaluation regarding observed data deficiency, evaluation techniques, and time frame selection. The objective of this paper is to evaluate the accuracy of CHIRPS, ERA5, ERA5Land, and MERRA-2 concerning their monthly precipitation estimates products, compared to observations from six rain gauges in the Tensift basin in Morocco. These high-resolution datasets are obtained by combining models with observations and are currently in operational production. They are known for being state-of-the-art precipitation datasets. Data evaluation was carried out over 40 years (1981-2021), and over each decade of that period using a set of statistical metrics. Our findings consistently demonstrate that the products exhibit reduced performance for high-altitude stations. Another noteworthy finding is the occurrence of some shifts across decades, in particular, the one from 2001 to 2010 had a much worse performance for CHIRPS. ERA5 data generally outperforms the other products and showed their relevance in the simulation of precipitation over the entire study period. However, with a coefficient of correlation of 0.68, NSE of 0.44, and RMSE of 20.6 mm/month, ERA5 only achieved a medium accuracy which could impact surface and groundwater storage assessments. Afterwards, the Standardized Precipitation Index (SPI) is computed to determine the main drought periods of the basin, showing different situations in terms of duration, severity, and affected area.

**Keywords:** Precipitation estimates, Drought, CHIRPS, ERA5, ERA5Land, MERRA-2.



## Assessment of the effect of drought and anthropogenic liquid pollution on the physico-chemical quality of the waters of Oued Inaouène (Taza, Morocco).

*F.E. Sghiouer<sup>1,2,\*</sup>, A. Nahli<sup>1</sup>, H. Bouka<sup>2</sup> & M. Chlaida<sup>1</sup>*

<sup>1</sup> Ecology and Environment Laboratory, Université Hassan II de Casablanca, Faculté des Sciences Ben M'sik, PB 7955 – Sidi Othman, Casablanca, Morocco.

<sup>2</sup> Natural Resources and the Environment Laboratory, Université Sidi Mohamed Ben Abdallah, Faculté Polydisciplinaire de Taza, PB 1223, Taza, Morocco.

\* Email: [fatysghiouer@gmail.com](mailto:fatysghiouer@gmail.com)

### Abstract:

The Inaouene river, a tributary of the Oued Sebou, is subject to the effects of drought in the Mediterranean climate and pollution from raw wastewater. Assessment of water quality in this hydrosystem using the water quality index (WQI) calculated from 19 physico-chemical parameters (pH, T°, EC, DO, MES, NH<sub>4</sub><sup>+</sup>, NTK, NO<sub>3</sub>, SO<sub>4</sub><sup>--</sup>, PO<sub>4</sub><sup>--</sup>, PT, COD, BOD<sub>5</sub>, Cl<sup>-</sup>, Cr, Zn, Pb, Cu and Fe) over 3 hydrological cycles (May 2019 to June 2022) showed that upstream, water quality remains very poor, with no significant inter-annual variations, except for stations located on Oued Lahdar (WQI=35.11) and those downstream of Inaouène (WQI=43.71), where quality is good during the 2nd hydrological cycle. During the 1st and 3rd hydrological cycles, water quality deteriorated in the Inaouene (WQI>100), reflecting water quality unfit for consumption. Overall, the WQI values recorded are very high during the 3rd dry hydrological cycle. Moreover, the WQI varied significantly between the 3 cycles (p = 0.0006).

**Keywords:** Oued Inaouene, water, physico-chemistry, WQI, pollution, drought.



## Hydrogeological characterization of Settât-Ben Ahmed plateau aquifer (Central Morocco).

*A. Elfirdoussi<sup>1</sup>, N. El Amrani Paaza<sup>1</sup> & A. Soulaïmani<sup>2</sup>.*

<sup>1</sup> Laboratory of Applied Chemistry and Environment, Faculty of Science and Techniques, Hassan First University, 50 Rue Ibnou Lhaytham, B.P. 577, Settât 26002, Morocco,

<sup>2</sup> Agricultural Innovation and Technology Transfer Center, Mohammed VI Polytechnic University, Benguerir 43150, Morocco

\* Email: [youssef.arjidal@uit.ac.ma](mailto:youssef.arjidal@uit.ac.ma)

### **Abstract:**

This study aims to determine groundwater dynamic and hydrochemistry for a better understanding of a hydrogeological unity of sedimentary rock to learn about chemical processes and water quality of Settât Ben Ahmed plateau aquifer. The findings reveal the chemical facies change according to the depth and geological nature of the aquifer captured. Samples of deeper point captured upstream and from Cenomano-Turonien limestones are HCO<sub>3</sub>-Ca-Mg type and account for lowest electric conductivity (EC) values..

**Keywords:** Groundwater, Piezometry, Hydrochemistry, GIS, Settât Ben Ahmed plateau & aquifer (Morocco).



## Drâa complex aquifers: groundwater quality overview toward sustainability.

A. Khettouch<sup>1\*</sup>, M. Hssaisoune<sup>1, 2, 3</sup>, Y. Ez-zaouy<sup>3</sup>, L. Bouchaou<sup>1, 3</sup>.

<sup>1</sup> Applied Geology and Geo-Environment Laboratory, Faculty of Sciences, Ibn Zohr University, Agadir, 80035, Morocco.

<sup>2</sup> Faculty of Applied Sciences, Ibn Zohr University, B.O. 6146 Azrou District, 86153, Ait Melloul, Morocco

<sup>3</sup> Mohammed VI Polytechnic University, International Water Research Institute, Ben Guerir, 43150, Morocco.

\* Email: [dimane.fouad@gmail.com](mailto:dimane.fouad@gmail.com)

### Abstract:

The Drâa River Basin (DRB) is a vast arid region that encompasses the most important oases in the south of Morocco. Climate change, population growth, and recent intensive agricultural activities have led to the overexploitation of limited groundwater resources and the degradation of their quality. This study aims to provide a comprehensive overview of groundwater quality within the DRB. A hydrochemical database was compiled from various research projects and work conducted on the major aquifers. Major and trace geochemical concentrations were compared to the guideline values recommended by the World Health Organization (WHO) and Moroccan standards for drinking water. Furthermore, water quality assessment parameters, including the water quality index (WQI) and total hardness (TH), were also included. The results indicate that groundwater quality in the DRB can be described as a transition from relatively fresh to saline water along a hydraulic gradient. Salinity increases from the Upper Drâa to the Middle Drâa basin and has reached alarming levels (12634 mg/l). About 40% of samples in the DRB fell below the permissible limit of hardness, while 100% of the samples were classified as very hard. The WQI values in the DRB ranged from 77.41 to 207.4, with a mean value of 109.27. Most waters suitable for drinking are primarily located in the upstream part of the DRB and the first oases downstream of the Mansour Eddahabi dam. Conversely, groundwater of poor quality is primarily found in the Ketaoua and M'hamid aquifers, located in the last oases adjacent to Saharan lands. Indeed, many groundwater sites do not meet the requirements defined by the WHO and Moroccan standards for drinking purposes. In some areas, nitrate contents imply anthropogenic contamination, especially from traditional septic tanks and agricultural activities. Natural geogenic sources and the context of overexploitation contribute accordingly to the degradation of water quality, but heavy metals do not contribute to the deterioration of water quality. This evidence could enhance knowledge and provide stakeholders with insights into sites that require more attention in the Draa area. Ultimately, management strategies towards sustainability were proposed to protect and valorize water resources in Drâa area.

**Keywords:** Hydro-geochemistry, Drâa river basin, arid environment, water quality assessment.





## Optimizing water productivity for Menara olive cultivar: exploring the impact of regulated and sustained deficit irrigation strategies in Morocco.

*K. Ibba<sup>1\*</sup>, S. Er-Raki<sup>1,3</sup>, J. Kassout, A. Bouizgaren & R. Hadria.*

<sup>1</sup> ProcEDE/AgroBiotech Center, Faculty of Sciences and Technologies, Cadi Ayyad University, Marrakech, Morocco

<sup>3</sup> Center for Remote Sensing Applications, Mohammed VI Polytechnic University, Ben Guerir, Morocco.

\* Email : [s.erraki@gmail.com](mailto:s.erraki@gmail.com)

### Abstract :

The main objective of this study is to evaluate water productivity (WP) in terms of fruit yield and to identify the most appropriate deficit irrigation strategy for high water productivity in 'Menara' olive cultivar. In this regard, an irrigation experiment was conducted over two years 2021 and 2022 in the field on 12 years old trees of 'Menara' cultivar planted with 156 trees/ha density in research station of Saada at INRA Marrakech. The impact of seven irrigation treatments with regard to water productivity was evaluated. In addition to a control regime (FI) fully irrigated: T0 (100% ETc), four water regimes were tested for RDI: T1 (SP 100- NP 70% ETc), T2 (SP 100- NP 60% ETc), T3 (SP 80- NP 70% ETc), T4 (SP 80- NP 60% ETc). We designed the RDI strategy based on knowledge of the sensitivity of the olive tree to water stress during various phenological periods. The irrigation regimes were studied according to the sensitivity of phenological phases to water stress with (SP) 'Sensitive period' and (NP) 'Normal period'. For SDI, two water regimes were evaluated: T5 (70% ETc) and T6 (60% ETc). The results obtained indicate that the applied irrigation treatments significantly influenced water productivity (WP) of Menara olive trees. In 2021, the WP showed higher values in the T3 and T4 treatments following the RDI strategy. These treatments demonstrated a notable improvement in WP, ranging from 4% to 18%. Similarly, the T5 and T6 treatments within the SDI strategy demonstrated a remarkable increase in WP, reaching an increase of approximately 25%. In 2022, the treatments following the RDI strategy demonstrated notably higher fruit yield and water productivity. Among these treatments, the RDI strategy exhibited the greatest increase in WP, ranging from 7% to 22% compared to the control T0. However, the SDI strategy with T5 and T6 treatments, which reduced total water application by 30% and 40% throughout the entire season compared to the control T0, recorded the lowest fruit yield and water productivity. Among these treatments, the SDI strategy resulted in the most significant drop in WP, ranging from 19% to 33% T0. These results provide valuable insights into the nature of plant responses to water stress. Over time the SDI strategy, with its limited water availability, leads to a decline in the fruit yield of Menara olive trees. However, the RDI strategy, particularly in the T4 treatment, makes it feasible to conserve a substantial amount of irrigation water, approximately 40% during the phase when pit hardening occurs, and 20% during sensitive periods, all without compromising fruit yield. These findings highlight the potential of RDI strategy in enhancing water efficiency and water productivity, offering promising insights for sustainable agricultural practices.

**Keywords:** Menara olive cultivar, deficit irrigation, SDI strategy, RDI strategy & Morocco.

