

UNVEILING ADVANCED TECHNOLOGIES AND COLLABORATIVE EFFORTS FOR SUSTAINABLE DEVELOPMENT

INTELLIGENT BREAKTHROUGHS IN ENVIRONMENTAL AND HYDROLOGICAL CHALLENGES



INNOVATIVE GEOSCIENCES

PUBLISHED BY

Laboratory of Geology Mineral Resources and
Energy (LGRME), Université Félix Houphouët-
Boigny

COLLABORATION

- In partnership with School of
Geosciences and Info-Physics, Central
South University

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FIRST EDITION



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Acknowledgments

We gratefully acknowledge the invaluable support of our
collaborators, institutions, and funding bodies, whose
contributions have been instrumental in advancing our research
initiatives. Thank you for your unwavering dedication and
cooperation.

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1. About Us: Pioneering Innovation in Geosciences with Artificial Intelligence

At the cutting edge of geosciences, our team at the Laboratory of Geology, Mineral Resources, and Energy (LGRME), in collaboration with the School of Geosciences and Info-Physics at Central South University, is driving forward the future of environmental and hydrogeological solutions through the innovative application of artificial intelligence (AI).

Our mission is to develop intelligent systems that not only predict and solve complex environmental issues but also enhance the sustainability and efficiency of natural resource management. By integrating AI with traditional geophysical methods, we are able to offer unprecedented insights and more accurate predictions, thereby minimizing risks and maximizing outcomes in water resource management, mining, and urban planning.

Innovative Projects for a Sustainable Future

Our portfolio of projects demonstrates our commitment to innovation and excellence. From the Predictive Water Sourcing System (PWSS) that utilizes ensemble machine learning to optimize drilling operations, to the WATex-Intelligent Explorer that advances water exploration capabilities, our initiatives are at the forefront of technological advancement. Our projects like the Proactive Urban Resilience model use AI to predict land subsidence, supporting urban development plans that account for environmental changes.

Global Collaboration and Impact

The success of our research has been made possible through the collaboration between top international institutions and the support of global funding agencies. Our work is not just about technological advancement but also about building a sustainable future through international cooperation and knowledge exchange.

Engage with Our Work

We invite industry professionals, researchers, and the public to explore our findings and join us in our journey towards transforming geosciences with AI. Through our detailed project catalogue, stakeholders can gain insights into the methodologies, outcomes, and impacts of our research, fostering opportunities for collaboration and innovation.

As we continue to push the boundaries of what is possible in geosciences, we remain dedicated to the pursuit of knowledge and the application of our research to real-world challenges. Join us in shaping the future of environmental science and resource management with AI-driven solutions.

"Access the French version of the catalogue by scanning the QR code."



2. Honors

Recognition for Excellence in Geophysics and Environmental Engineering

1. Best Report at ICEEG 2023



In the prestigious annual International Conference on Environmental and Engineering Geophysics, held in Beijing, the report presented by Kouao Laurent Kouadio stood out among 512 submissions to win the Best Report Award.

This acclaimed presentation introduced an innovative approach that synergizes machine learning, geological data, and historical drilling insights to intelligently locate water reservoirs. This methodology notably minimizes resource waste in drilling operations, providing a significant advancement in both hydrogeology and mining industries.



2. Session Chair at GEM 2024



At the esteemed GEM 2024 International Workshop on Gravity, Electrical & Magnetic Methods and Their Applications, Kouao Laurent Kouadio was honored as the session chair due to his significant contributions to the

field of geophysics. His pioneering work, integrating artificial intelligence with geophysical methods, has pushed forward the boundaries of environmental solutions and sustainability. Leading a technical session, he facilitated discussions that explored how artificial intelligence can dramatically enhance research sustainability and development within the realm of Gravity, Electrical, and Magnetic methods.

These accolades reflect Kouao Laurent Kouadio's profound impact on advancing geophysical research and his ongoing commitment to developing innovative, sustainable solutions for environmental challenges.



3. Introduction

Welcome to our comprehensive project catalogue, which showcases a series of groundbreaking research initiatives undertaken at the intersection of geosciences, environmental management, and advanced computational technologies, in the last two years. My name is Kouao Laurent Kouadio, and I am a leading researcher at the School of Geosciences and Info-physics, Central South University. This catalogue is designed to highlight the innovative approaches and significant achievements of our projects, each developed to address some of the most pressing challenges in water resource management, environmental sustainability, and urban planning.

Our projects, conducted in collaboration with various international institutions, leverage a blend of cutting-edge machine learning techniques and traditional geophysical methods. These initiatives aim not only to advance scientific understanding but also to provide practical solutions that enhance community resilience and sustainability across the globe. Whether you are a technical expert in the field, a potential investor looking to support impactful research, or a general reader interested in the latest developments in environmental science, this catalogue will provide you with detailed insights into the scope, methods, outcomes, and broader impacts of our work.

Purpose and Audience

The primary purpose of this catalogue is to inform stakeholders, including academic peers, industry professionals, policymakers, and the broader public, about the outcomes and benefits of our diverse research projects. By presenting our findings and methodologies, we aim to foster collaboration, inspire innovation, and encourage the application of our research in practical, real-world environments.

We invite you to explore these pages to understand better how our research is making a measurable difference in tackling environmental challenges through technological innovation and collaborative effort. Thank you for your interest in our work, and we look forward to engaging with you to explore these exciting developments further.

Completion and Publication of Projects

We are pleased to announce that all the projects featured in this catalogue have been successfully completed and their findings rigorously validated through publication in esteemed scientific journals. Each project has contributed significantly to the advancement of knowledge within their respective fields, adhering to the highest standards of research excellence.

For those interested in a deeper exploration of the methodologies, mathematical expressions, and detailed results, comprehensive articles and reports on each project can be accessed in these journals. These publications provide extensive insights into the scientific processes and innovations developed during the research, offering valuable resources for academic and professional reference.

To further facilitate your exploration and understanding, we have included specific references and links to the journals where these studies are published at the end. Incubating robust research, these publications serve as a testament to the collaborative efforts and scholarly commitment of our research teams and partners worldwide.

We encourage scholars, practitioners, and enthusiasts from various sectors to delve into these publications for detailed theoretical and practical insights, which could serve as a foundation for further research or practical application in related areas.

Collaborative Efforts

The success of the projects detailed in this catalogue is a testament to the power of collaboration between diverse institutions and experts from around the globe. These partnerships have been crucial in combining traditional knowledge with innovative approaches to address complex environmental and geophysical challenges.

Each project has thrived on the synergies created by the collaborative efforts of academic institutions, government agencies, and industry stakeholders. We are grateful for the participation of renowned entities such as the School of Earth Sciences at Zhejiang University, the Laboratory of Geology Mineral Resources and Energy (LGRME), Félix Houphouët-Boigny University, and many others who have contributed their expertise and resources.

This cooperative approach not only enriched the research but also ensured the practical applicability and impact of our findings. The collective input and interdisciplinary dialogue have led to the development of robust methodologies and breakthrough technologies that have been acknowledged in high-impact scientific journals.

We remember and appreciate every contribution from our collaborators, whose diverse perspectives and dedicated efforts have been fundamental to our achievements. These successful partnerships underscore our ongoing commitment to fostering international cooperation and knowledge exchange to advance scientific research and sustainable practices.

Catalogue structure

Structure is designed to guide you through the extensive details provided in our project catalogue, ensuring easy access to the specific information you need about our innovative research initiatives.

1. Introduction

- Welcome and Overview
- Purpose and Audience

2. Project Summaries

- Predictive Water Sourcing System (PWSS)
- WATex-Intelligent Explorer: Advancing Water Exploration with Machine Learning
- Proactive Urban Resilience: Machine Learning for Land Subsidence Prediction in Nansha District
- Advanced Hydrogeophysical Management System (AHMS)
- Leachate Leakage Detection and Management System (LLDMS)
- Hydrogeological Parameter Prediction System (HPPS) using Featurizer Strategy in Niming Coal Mine

3. Technologies and Methods

- Description of Innovative Techniques and Methodologies Used Across Projects

4. Challenges and Solutions

- Overview of Major Challenges and Strategic Solutions Implemented

5. Project Outcomes and Impact

- Detailed Review of the Results and Impacts of Each Project

6. Benefits

- Comprehensive Analysis of the Benefits Delivered by Each Project

7. Completion and Publications

- Information on Project Completions and Journal Publications

8. Visuals and Additional Information

- Links to Additional Resources, Graphs, and Published Findings

9. Acknowledgments

- Expression of Gratitude to Collaborative Partnerships and Institutional Contribution

4. Engineering Projects

4.1. *Predictive Water Sourcing System (PWSS)*

Duration: July 2018- October 2023

Affiliation

- Laboratory of Geology Mineral Resources and Energy (LGRME), Félix Houphouët-Boigny University, Abidjan, Cote d'Ivoire
- School of Geosciences and Info-physics, Central South University, Changsha, PR China
- Institut National Polytechnique Félix Houphouët-Boigny, Yamoussoukro, Cote d'Ivoire



Overview

The Predictive Water Sourcing System (PWSS) aims to address the challenge of locating viable groundwater sources for drinking water supply, especially in regions facing water scarcity like the Bagoue region in Cote d'Ivoire (Fig.1). Leveraging an ensemble machine learning (EML) approach, PWSS integrates data from electrical resistivity profiling (ERP) and vertical electrical sounding (VES), along with geological information, to predict the flow rate (FR) of potential boreholes before drilling operations commence. By accurately estimating FRs in advance, PWSS assists geophysical engineers and drilling ventures in selecting optimal drilling locations, thereby minimizing the risk of unsuccessful boreholes and maximizing water supply efficacy. The system categorizes observed FRs into productive and unproductive boreholes, trains base learners (BLs) using binary datasets, and aggregates them with a pre-trained Support Vector Machine (pSVM) to form the EML base estimator. PWSS is designed to achieve at least an 80% correct FR

prediction rate on validation sets, offering a reliable tool for future Campaigns for Drinking Water Supply (CDWS) initiatives.

The project was implemented in the Bagoue region of Cote d'Ivoire, situated in southern West Africa. This region was selected due to its water scarcity challenges and the availability of comprehensive survey data collected during governmental drinking water supply programs conducted in 2012–2014. The area's geological diversity, including volcano-sedimentary schists, migmatite-gneiss, geosynclinal-granites, and granites, provides a rich dataset for the development and validation of the PWSS model.



Objectives

- Develop a predictive model that uses EML to forecast flow rates from geoelectrical features with high accuracy.
- Enhance the decision-making process for drilling locations to meet the required flow rates (RFR) and reduce unsuccessful drillings.

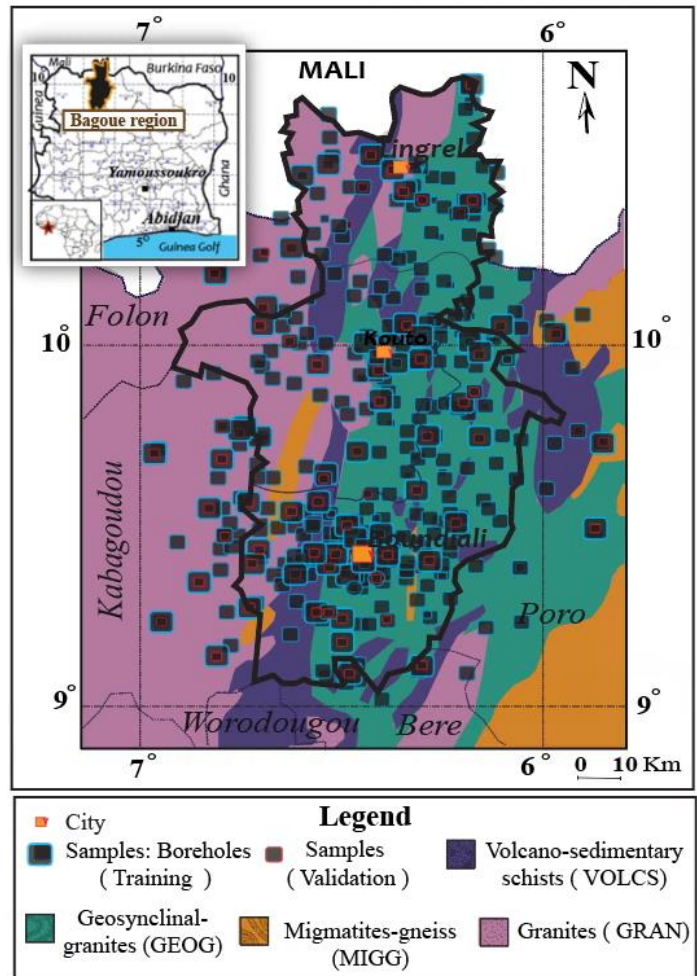


Figure 1: Bagoue region geographical location and simplified geological structures.

-Evaluate the effectiveness of EML methods in predicting flow rates and identifying optimal drilling sites (Fig,2).



Technologies and Methods

- ✓ Geophysical Techniques: ERP and VES to gather subsurface data.
- ✓ Ensemble Machine Learning Models: Including Logistic Regression, K-nearest Neighbors, Decision Trees, and Support Vector Machines combined to enhance predictive accuracy.
- ✓ Evaluation Metrics: Utilizing Matthews correlation, accuracy measures, confusion matrix, precision-recall, and cumulative gain plots to assess model performance.



Challenges and Solutions:

Challenge: High financial losses due to numerous unsuccessful drillings.

Solution: The introduction of EML paradigms to provide a robust predictive framework capable of achieving flow rate prediction scores between 90 ~ 96%, thus minimizing the risk of unsuccessful drillings.

Outcomes

- Successful development of a model capable of predicting flow rates with high accuracy, demonstrated by prediction scores between 90% and 96%.
- Significant reduction in financial losses by pinpointing more accurate drilling locations, thereby increasing the success rate of water boreholes.
- Valuable insights into the interplay of subsurface geoelectrical features and flow rates, informing future drilling and exploration projects.

Benefits



By integrating these cutting-edge methods, our project significantly reduces the financial and resource losses associated with unproductive boreholes, which historically amount to nearly 49.65% in certain regions.

Cost Savings: Traditionally, each unsuccessful drilling operation, inclusive of the necessary pumping tests, costs approximately \$24,810, and each survey costs around \$1,654. Given the prevalence of these unsuccessful operations in projects covering over 2,000 villages, the financial implications are substantial. Through the predictive accuracy of EML, specifically achieving greater than 90% accuracy in flow rate predictions, our approach drastically reduces these costs. By effectively predicting viable drilling locations, the project cuts down on the number of unproductive boreholes, leading to direct cost savings.

Economic Impact: By minimizing drilling failures, the project not only saves funds but also allows for the reallocation of saved resources to extend the project's reach. This means more villages can have access to clean drinking water without the need for additional funding. For instance, with a 90% predictive score from our EML model, the improved accuracy in FR predictions has the potential to enhance the lives of approximately 2,000 villages. The savings accrued from reduced unsuccessful drillings, estimated at \$6,880,640, can be reinvested into expanding the project to other areas, demonstrating a significant return on investment.

Support for Sustainable Development: Accurate FR predictions contribute to more effective water resource management, crucial for areas facing severe water scarcity. This proactive approach supports sustainable development by ensuring that water resources are developed and managed efficiently, reducing environmental impact and supporting the welfare of local communities.

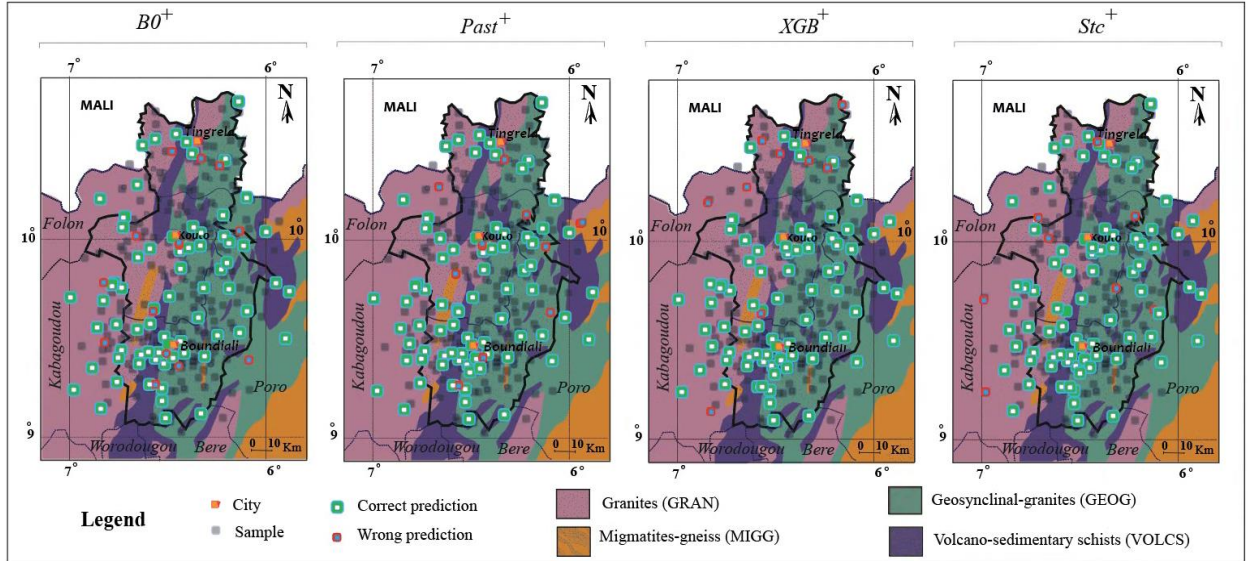


Figure 2: Relationship between FR prediction and geological structures of the experiment area. All predictions were performed on the test data in the experiment area and were projected based on the real geographical coordinates



Summary

The Predictive Water Sourcing System (PWSS), developed between July 2018 and October 2022, revolutionizes the identification of viable groundwater sources in water-scarce regions like the Bagoue area in Côte d'Ivoire. This innovative system combines ensemble machine learning with geophysical techniques such as electrical resistivity profiling and vertical electrical sounding, alongside geological data, to predict the flow rates of potential boreholes before drilling.

By predicting flow rates with an accuracy between 90% and 96%, PWSS significantly reduces the risk and financial costs associated with unsuccessful drillings.

The use of EML in predicting flow rates before drilling provides a robust solution to one of the most pressing issues in water resource management for developing countries. This method offers a way to optimize resource use and also serves as a critical tool in the strategic planning and execution of water supply initiatives, thereby enhancing community resilience and sustainability.

The project has markedly reduced resource losses, traditionally costing up to \$24,810 per unsuccessful operation. Moreover, the accuracy of the PWSS allows for the expansion of drinking water supplies to more villages without additional funding, enhancing the lives of about 2,000 villages and achieving substantial cost savings. This approach supports sustainable water resource management and aids in strategic planning for future water supply initiatives, emphasizing community resilience and sustainability.

The success and methodologies of PWSS are detailed in reputable journals and are accessible through a dedicated data repository, showcasing the project's contribution to both local communities and the broader field of water resource management.

Additional Information

Graphical representations of data flows, model accuracies, and methodological frameworks.

The full text and findings of the study have been published in the journal [Water Resources Management](#) and [Water Resources Research](#).

Data repository: <https://zenodo.org/records/5571534>.

Water Resources Research

RESEARCH ARTICLE

10.1029/2021WR031623

Key Points:

- The support vector machines (SVMs) are used to predict groundwater flow rate (FR) before the drilling operations
- Prediction data are gathered from electrical profiling, vertical electrical sounding, and boreholes
- The SVM models correctly perform 77% and 83% of FR predictions for multiclass and binary data sets respectively

Groundwater Flow Rate Prediction From Geo-Electrical Features Using Support Vector Machines

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Water Resources Management (2023) 37:4413–4431

<https://doi.org/10.1007/s11269-023-03562-5>



Ensemble Learning Paradigms for Flow Rate Prediction Boosting

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Received: 29 January 2023 / Accepted: 17 July 2023 / Published online: 25 July 2023

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4.2. WATex – Intelligent Explorer: Advancing Water Exploration with Machine Learning

Duration : Sep 2020 - Mar 2023

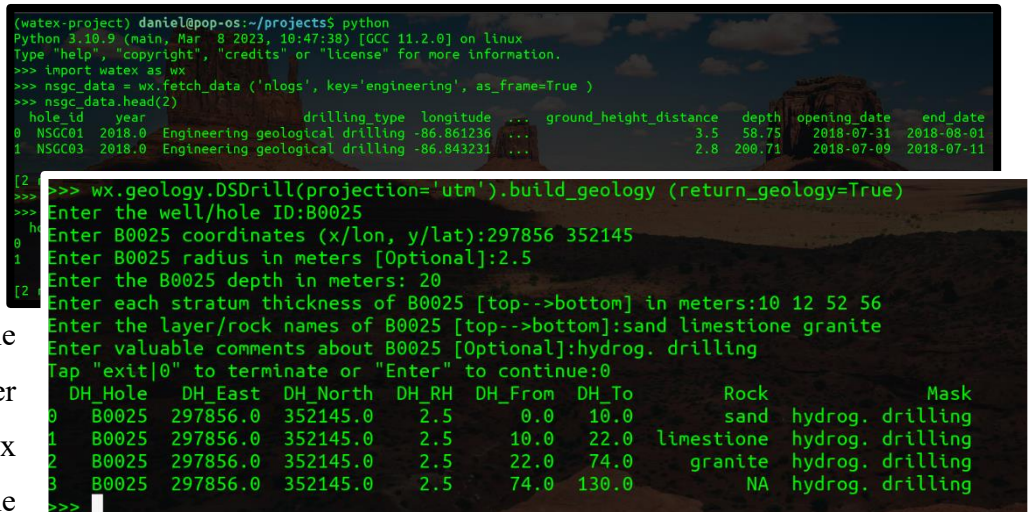
Affiliation

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- School of Geosciences and Info-physics, Central South University, Changsha, PR China

Overview

Overview

WATex is an innovative project aimed at revolutionizing water exploration and access using advanced machine learning techniques. Originating from the challenges posed by climate change and the scarcity of water resources, WATex seeks to address the



```
(watex-project) daniel@pop-os:~/projects$ python
Python 3.10.9 (main, Mar 8 2023, 10:47:38) [GCC 11.2.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> import watex as wx
>>> nsgc_data = wx.fetch_data('nlogs', key='engineering', as_frame=True)
>>> nsgc_data.head(2)
  hole_id  year  drilling_type  longitude  ...  ground_height_distance  depth  opening_date  end_date
0  NSGC01  2018.0  Engineering geological drilling  -86.861236  ...          3.5    58.75    2018-07-31    2018-08-01
1  NSGC03  2018.0  Engineering geological drilling  -86.843231  ...          2.8   200.71    2018-07-09    2018-07-11

[2] >>> wx.geology.DSDrill(projection='utm').build_geology(return_geology=True)
>>> Enter the well/hole ID:B0025
>>> Enter B0025 coordinates (x/lon, y/lat):297856 352145
0 Enter B0025 radius in meters [Optional]:2.5
1 Enter the B0025 depth in meters: 20
[2] Enter each stratum thickness of B0025 [top-->bottom] in meters:10 12 52 56
Enter the layer/rock names of B0025 [top-->bottom]:sand limestone granite
Enter valuable comments about B0025 [Optional]:hydrog. drilling
Tap "exit|0" to terminate or "Enter" to continue:0
  DH_Hole  DH_East  DH_North  DH_RH  DH_From  DH_To      Rock      Mask
0  B0025    297856.0  352145.0    2.5      0.0   10.0      sand  hydrog. drilling
1  B0025    297856.0  352145.0    2.5     10.0   22.0  limestone  hydrog. drilling
2  B0025    297856.0  352145.0    2.5     22.0   74.0    granite  hydrog. drilling
3  B0025    297856.0  352145.0    2.5     74.0  130.0        NA  hydrog. drilling
>>>
```

Figure 3: WATex software interface for processing borehole data in open-source manner

critical need for efficient and reliable methods to locate groundwater reservoirs, particularly in developing countries.

Drawing inspiration from successful initiatives like the Community Drinking Water Supply (CDWS) projects in Cote d'Ivoire, WATex was conceived to democratize access to advanced geophysical data analysis. By harnessing the power of machine learning, WATex aims to significantly improve the accuracy of groundwater detection, thereby reducing the risk of unsuccessful drillings and maximizing the impact of available resources.

The genesis of WATex can be traced back to the [Diacohou-Nord project](#), Cote d'Ivoire, West Africa, where the acute water shortage and the dangerous quest for water highlighted the urgent need for innovative solutions. Motivated by this experience, the project founder embarked on a journey to develop a machine capable of detecting underground water reservoirs and estimating flow rates, even during dry seasons.

Through collaborative efforts, WATex has evolved into a functional tool with practical applications. By integrating machine learning algorithms with traditional geophysical methods, WATex offers a novel approach that enhances the prediction and analysis capabilities of researchers and practitioners in the field of hydrogeological exploration.

With a commitment to continuous improvement and expansion, WATex aims to foster a community of users and contributors who can collectively address the pressing environmental challenges of water scarcity and sustainable water management.

Through WATex, we envision a future where access to clean and reliable water is no longer a privilege but a fundamental right for all.



Objectives

- Develop an efficient tool to enhance the accuracy of groundwater detection and the assessment of hydrogeological parameters.
- Reduce the economic losses associated with unsuccessful boreholes by improving prediction capabilities.
- Provide a user-friendly and accessible tool for the geophysical and hydrogeological community to leverage in both academic and field settings (Fig.3).

Technologies and Methods

- *Geophysical Methods*: Utilizes direct-current (DC), electromagnetic (EM), and logging data for subsurface exploration.
- *Machine Learning Algorithms*: Includes models like Support Vector Machines (SVM) and eXtreme Gradient Boosting (XGB) within a comprehensive Python framework.
- *Software Environment*: Compatible with multiple operating systems including Windows, Linux, and MacOS, ensuring wide accessibility and integration.



Figure 4: Successful test performed in Tankesse, Eastern part of Cote d'Ivoire. See Test Video [here](#).



Challenges and Solutions

- *Challenge:* High rates of unproductive drilling operations and the intricate task of accurate hydrogeological parameter prediction.
- *Solution:* The WATex library employs a mixture learning strategy (MXS) that utilizes both supervised and unsupervised machine learning methods to enhance prediction accuracy, thereby reducing the number of unsuccessful drillings.

Outcomes

- Successfully developed a robust platform for predicting groundwater availability and hydrogeological parameters, significantly reducing the frequency of unproductive boreholes.
- Facilitated more efficient and cost-effective groundwater management practices.



Benefits

WATex delivers multiple benefits that significantly enhance the efficiency and effectiveness of groundwater exploration:

- **Enhanced Accuracy:** Integrates advanced machine learning with traditional geophysical methods to improve the accuracy of hydrogeological parameter predictions, such as flow rates and permeability coefficients.
- **Reduced Costs:** Decreases financial and resource losses by minimizing unsuccessful drilling operations, making groundwater exploration more cost-effective.
- **Informed Decision-Making:** Provides reliable data that enable better decision-making in groundwater management, supporting more effective strategies and interventions.

- User-Friendly Platform: Offers a robust and accessible platform that is easy to use for both academic researchers and field practitioners, enhancing user engagement and productivity (Fig.4).
- Sustainability Support: Aids organizations in aligning with global sustainability goals by optimizing water resource management and reducing environmental impact.



Summary

WATex initiative, led by the Laboratory of Geology Mineral Resources and Energy at Université Félix Houphouët-Boigny and the School of Geosciences and Info-physics at Central South University, utilizes advanced machine learning techniques to enhance the detection and management of groundwater resources, particularly in areas facing acute water scarcity due to climate change.

WATex was inspired by the dire need for reliable water sources in Cote d'Ivoire, as highlighted by the challenges encountered during the Diacohou-Nord project. By integrating machine learning with traditional geophysical methods, such as direct-current, electromagnetic, and logging data, WATex significantly improves the accuracy of groundwater detection. This integration reduces the prevalence of unsuccessful drilling attempts, thereby optimizing resource use and reducing associated costs.

Key objectives of WATex include enhancing the precision of hydrogeological parameter assessments, minimizing economic losses from failed boreholes, and providing a user-friendly tool accessible to both the academic and field-based geophysical communities. The project has successfully developed a robust platform that has not only reduced the frequency of unproductive

boreholes but has also facilitated more cost-effective groundwater management practices. The benefits are manifold:

- **Enhanced Accuracy:** By combining machine learning with geophysical methods, WATex offers improved predictions of hydrogeological parameters like flow rates and permeability.
- **Cost Efficiency:** It reduces financial and resource losses by decreasing the number of unsuccessful drilling operations.
- **Informed Decision-Making:** The platform provides reliable data that improve strategic planning and implementation in groundwater management.
- **User-Friendly Interface:** WATex is designed to be accessible and easy to use, promoting greater productivity and engagement among users.
- **Support for Sustainability:** The project aligns with global sustainability goals by enhancing the efficiency of water resource management.

In conclusion, WATex addresses the technical aspects of water exploration and also contributes to the broader goal of making clean and reliable water access a universal right. Through continuous improvement and community engagement, WATex aims to meet the ongoing challenges of water scarcity and environmental sustainability.

Visuals and Additional Information

Links: [GitHub Repository](#) & [Documentation](#)

The full text and findings of the study have been published in the journal [SoftwareX](#) contributing to academic and practical advancements in geosciences (Fig. 5)

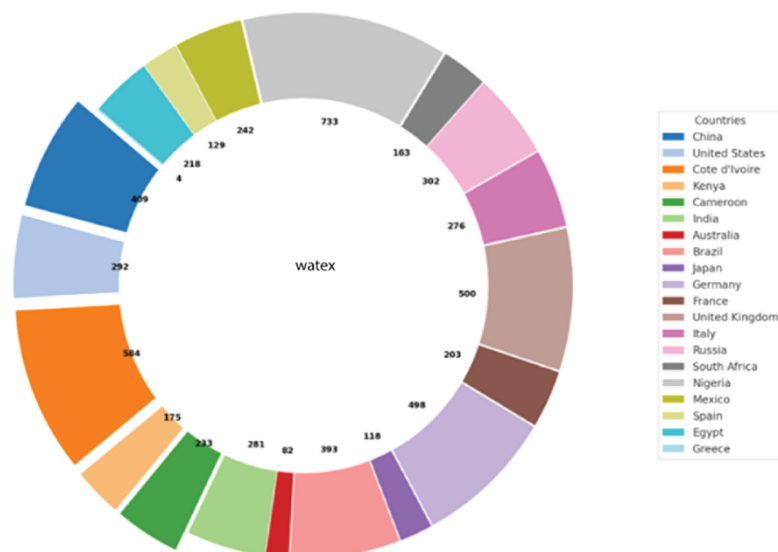


Figure 5: Global download of watex in [Anaconda distribution platform](#)



Contents lists available at [ScienceDirect](#)

SoftwareX

journal homepage: www.elsevier.com/locate/softx



Original Software Publication

watex: machine learning research in water exploration

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4.3. Proactive Urban Resilience (PUR): Machine Learning for Land Subsidence Prediction

Duration: Jan 2023 – Dec 2023

Affiliation

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- Laboratory of Geology Mineral Resources and Energy (LGRME), Félix Houphouët-Boigny University, Abidjan, Cote d'Ivoire



Overview

In an era of rapid urbanization and climate change, managing land subsidence (LS) has become increasingly vital for sustainable urban development. Our project aims to develop innovative machine learning-based techniques to forecast LS in urban areas, thereby empowering policymakers with proactive strategies for resilience and adaptation.

In China, such as the Nansha district in Guangzhou, the rapidly urbanizing regions, have caught the attention of researchers, urban planners, and policymakers (Fig.6). Initial studies into LS in the Guangdong province primarily revolved around natural causes, such as tectonic activities and sediment compaction. However, as urbanization increased, anthropogenic factors became more prevalent in discussions about subsidence. Urban construction, especially the development of skyscrapers and underground infrastructure (Fig.7), has also been noted to contribute to the pressure on the land, leading to subsidence.

Utilizing advanced models such as the eXtreme Gradient Boosting Regressor (XGBR) and Long Short-Term Memory (LSTM), we seek to analyze the complex interplay of factors influencing LS,

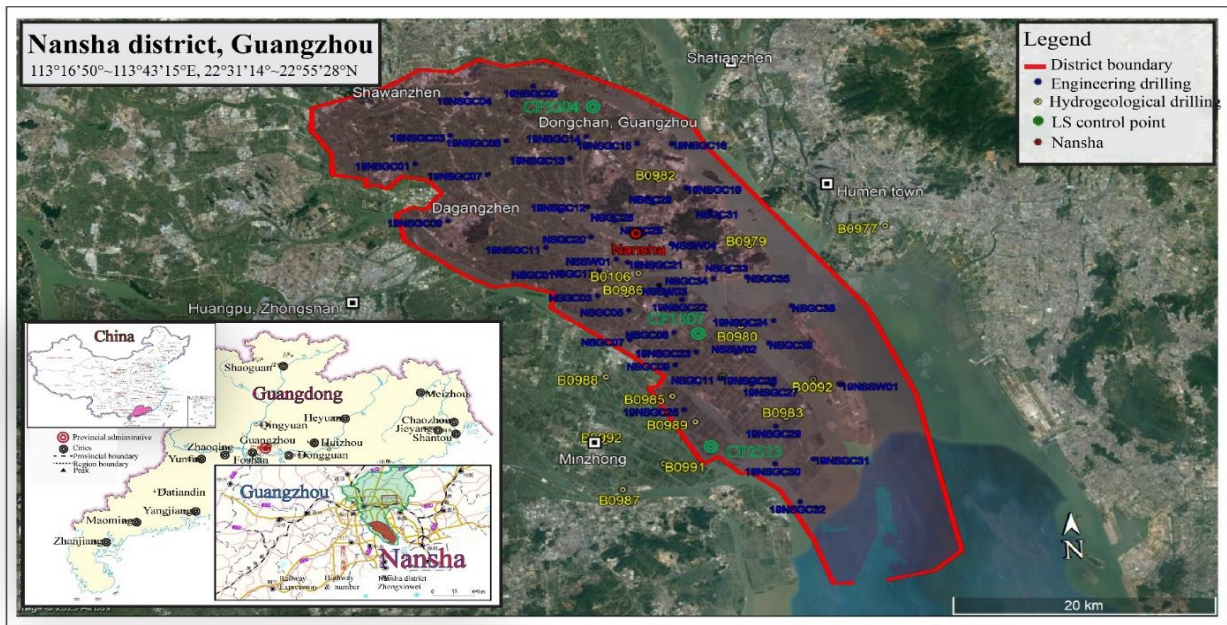


Figure 6:Nansha district geographical location. The satellite map includes hydrogeological, engineering drillings with the location of three control points (CP1507, CP 2513, CP3204).

including groundwater levels and building concentration. By integrating these dynamic environmental variables into our predictive models, we aim to provide accurate and timely forecasts of future subsidence trends.

Through the application of delta-rate calculus, we will simulate various scenarios to assess the potential impact of policy interventions, such as reductions in groundwater extraction and urban development density. By quantifying the effectiveness of these strategies, our project will inform

evidence-based decision-making processes and guide the implementation of sustainable urban policies.

By pioneering the integration of real-time data adaptation and dynamic environmental factors in LS management, our project sets a new standard for urban resilience initiatives. Through collaboration with stakeholders and policymakers, we aim to create a blueprint for proactive LS management, ensuring the long-term sustainability and resilience of urban environments.



Objectives

- To develop a robust predictive framework for land subsidence using cutting-edge ML models.
- To enhance urban planning and infrastructure resilience by accurately simulating subsidence risks.
- To provide actionable insights for policymakers through scenario-based LS simulations, helping mitigate the adverse effects of urban land subsidence.



Figure 7: Examples of LS consequences. Top, the stairs broken in Nansha district



Technologies and Methods

- Machine Learning Models: Utilizes XGBR and LSTM for high-accuracy predictions of land subsidence based on environmental and urban factors.
- Geophysical Data Analysis: Incorporates groundwater impact modeling and building concentration data to assess subsidence risks.
- Simulation Techniques: Employs delta-rate calculus to project future subsidence under various urban development scenarios.

Data

Land Subsidence Simulation in Urban Areas project utilizes a range of critical data to inform its models and simulations:

- *Groundwater Levels*: Data on the depth and variation of groundwater levels over time to assess their impact on subsidence.
- *Building Concentration Data*: Information on the density and distribution of buildings within the urban area to understand how structural loading affects subsidence.
- *Geophysical Data*: Includes subsurface imaging and resistivity measurements that help map the geological features influencing land subsidence.
- *Environmental Variables*: Additional data such as soil composition, land use patterns, and previous subsidence incidents to enrich the model's context.
- *Historical Subsidence Data*: Past records of subsidence in the area to train the machine learning models with real-world outcomes.

- Real-time Monitoring Data: Continuous data acquisition from sensors monitoring subsidence-related parameters to enable dynamic model updating.
- Policy and Infrastructure Data: Information regarding existing policies on land use and infrastructure development to simulate the impact of potential policy changes.
- Demographic and Economic Data: Details on population density and economic activities that might influence or be impacted by land subsidence.

These data points are integral to developing accurate and reliable predictive models for land subsidence, facilitating effective urban planning and management.



Challenges and Solutions

- Challenge: The high complexity and variability of land subsidence are influenced by a mix of natural and anthropogenic factors, making accurate prediction and management difficult.
- Solution: Implementing advanced machine learning (ML) models that can process and analyze complex datasets to deliver reliable predictions. These models are further enhanced by the capability for real-time data adaptation, allowing them to remain effective as environmental conditions change.

Outcomes

- Predictive Accuracy: The project has demonstrated high predictive accuracy in simulating land subsidence, with machine learning models such as XGBR (eXtreme Gradient Boosting Regressor)

and LSTM (Long Short-Term Memory) achieving significant correlations with observed data (Fig.8).

- Scalable and Adaptable Framework: A scalable and adaptable framework has been developed for land subsidence risk assessment. This framework is versatile enough to be applied across various urban contexts globally, providing a reliable tool for urban planning and risk management.

- Informed Policy-Making: The insights derived from data-driven analyses have informed urban development policies, contributing to a reduction in the economic and environmental impacts of land subsidence. This proactive approach aids policymakers in making informed decisions that enhance urban resilience and sustainability.



Benefits

- Enhanced Predictive Accuracy: Utilizes advanced machine learning models such as XGBR and LSTM to accurately predict land subsidence, providing reliable forecasts that help in proactive urban planning and risk management.

- Cost-Effective Urban Management: Reduces the economic impacts of land subsidence by enabling better planning and mitigation strategies, thus decreasing the need for costly repairs and retrofits in infrastructure affected by subsidence.

- **Data-Driven Decision Making:** Supports policymakers and urban planners with actionable insights derived from detailed simulations of land subsidence under various scenarios, facilitating informed decisions that enhance urban resilience.

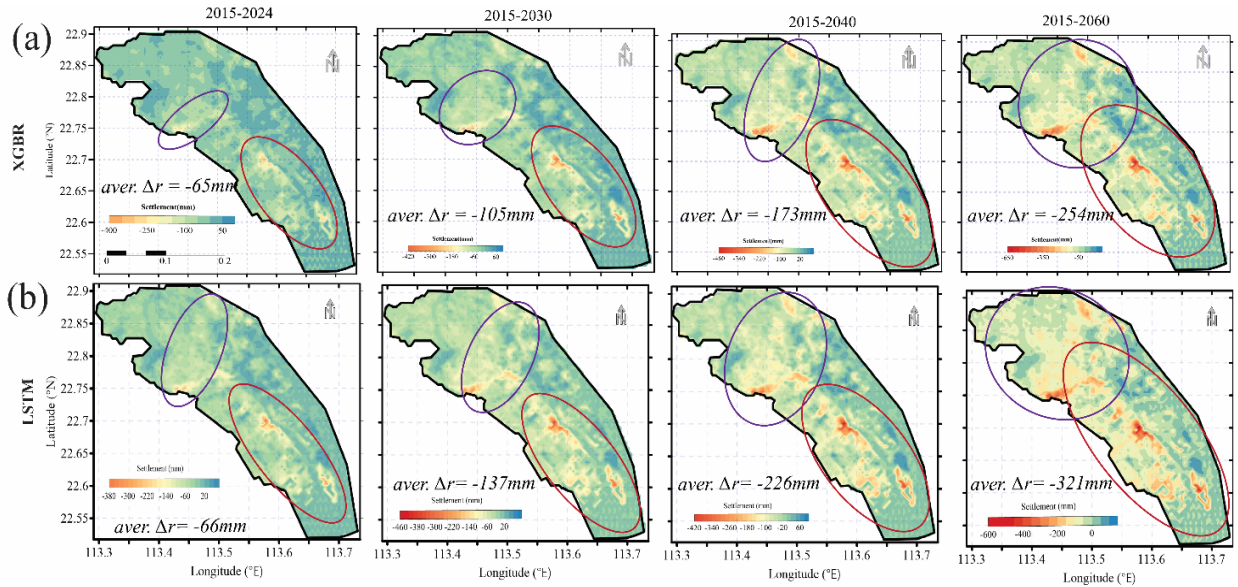


Figure 8: LS simulation of 2024, 2030, 2040, and 2060 using Δr : a) Simulation with XGBR. b) Simulation with LSTM. LSTM predicts severe subsidence compared to XGBR to 2060.

- **Adaptability and Scalability:** Offers a scalable solution that can be adapted to different urban environments, making it a versatile tool for cities worldwide facing subsidence challenges.
- **Environmental Sustainability:** Helps in the sustainable management of urban environments by predicting and mitigating the effects of land subsidence, thus contributing to the long-term health and stability of urban landscapes.

Summary



In summary, the project effectively captures the essence and impact of integrating machine learning with geophysical data analysis to advance urban environmental management. It enhances our understanding of land subsidence (LS) by examining the interplay between critical factors such as groundwater levels and building densities. By incorporating these dynamic environmental variables into predictive models, the project provides accurate and timely forecasts of future subsidence trends. Through the use of delta-rate calculus, it simulates various scenarios to assess the potential impacts of policy interventions, such as reducing groundwater extraction and moderating urban development densities. This quantitative analysis supports evidence-based decision-making, guiding the implementation of sustainable urban policies. The project sets new standards for urban resilience by pioneering real-time data adaptation and the integration of dynamic environmental factors into LS management. Collaborating with stakeholders and policymakers, it aims to establish a blueprint for proactive LS management, ensuring the long-term sustainability and resilience of urban environments.

Visuals and Additional Information

- Visual representations of model predictions and their validations against observed data.
- Published research article in the Journal of Environmental Management, detailing methodologies, results, and implications for urban planning (<https://doi.org/10.1016/j.jenvman.2024.120078>)

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Contents lists available at [ScienceDirect](#)

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman



Research article

Machine learning-based techniques for land subsidence simulation in an urban area

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4.4. Advanced Hydrogeophysical Management System (AHMS)

Duration: Aug 2023 - Jan 2024

Affiliation

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Overview

The Advanced Hydrogeophysical Management System (AHMS) addresses the environmental challenges associated with unregulated mineral extraction, focusing on groundwater contamination in the Huayuan mining area in Hunan Province, China (Fig.8). AHMS integrates hydrogeologic surveys with geophysical prospecting, specifically utilizing audio-frequency magnetotellurics (AMT), to characterize aquifers, fault zones, and subsurface resistivity distributions. By employing the nonlinear conjugate gradient (NLCG) algorithm for data inversion, AHMS generates 2D models highlighting structural fracture zones and electric resistivity structures, providing insights into groundwater flow patterns and potential pollution sources. The

system identifies areas at risk of contamination from mining-related pollutants, guiding the placement of infrastructure for sewage diversion and water treatment. By leveraging AMT's capability to probe deep into the subsurface and map geologic features, AHMS facilitates informed decision-making for proactive environmental management, ensuring the preservation of groundwater quality and safeguarding against future pollution incidents.

The project was implemented in the Huayuan mining area in Hunan Province, China. This region is rich in manganese and lead-zinc ores, with extensive mining activities dating back to the late 1980s. The unregulated

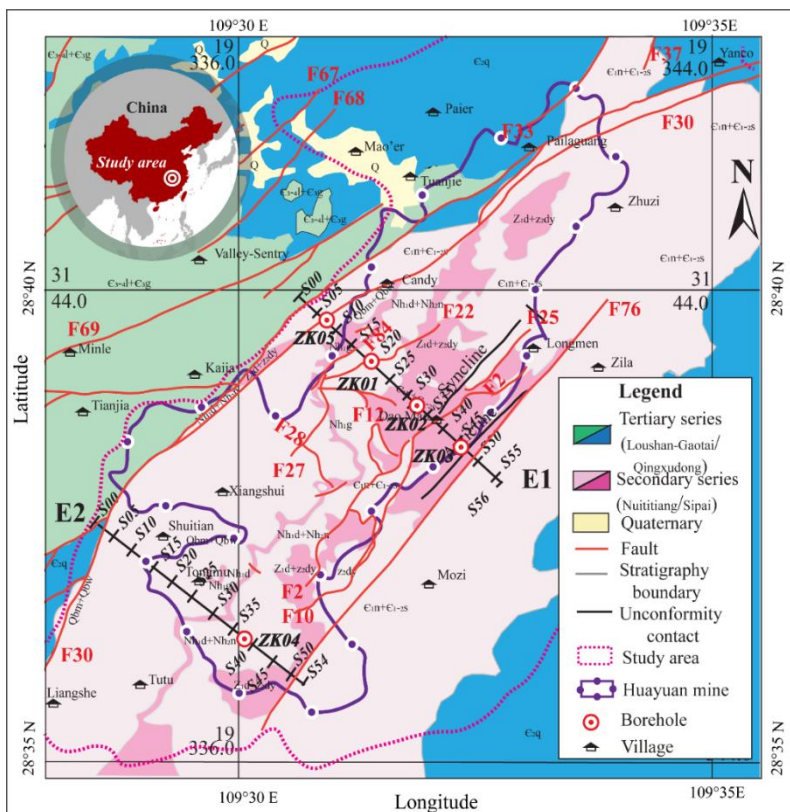


Figure 9: Geological settings showing the fault structures and geophysical prospecting lines as well as the inspected drilling of the Huayuan mining area.

extraction of manganese has led to significant environmental challenges, particularly groundwater contamination, posing risks to local communities and ecosystems. The integration of hydrogeologic surveys with geophysical prospecting in this area aims to mitigate pollution risks and protect valuable groundwater resources. The comprehensive subsurface information provided

by AHMS will support the design and implementation of sewage diversion systems, ensuring the long-term availability of clean and safe drinking water for the surrounding population.



Objectives

- To identify and map the lateral resistivity distribution underground using AMT to locate new stations for effective water treatment and sewage diversion.
- To integrate geological, drilling, and geophysical data to comprehensively understand the subsurface conditions and guide environmental mitigation strategies.
- To establish proactive measures for preserving the quality of groundwater and preventing future pollution.

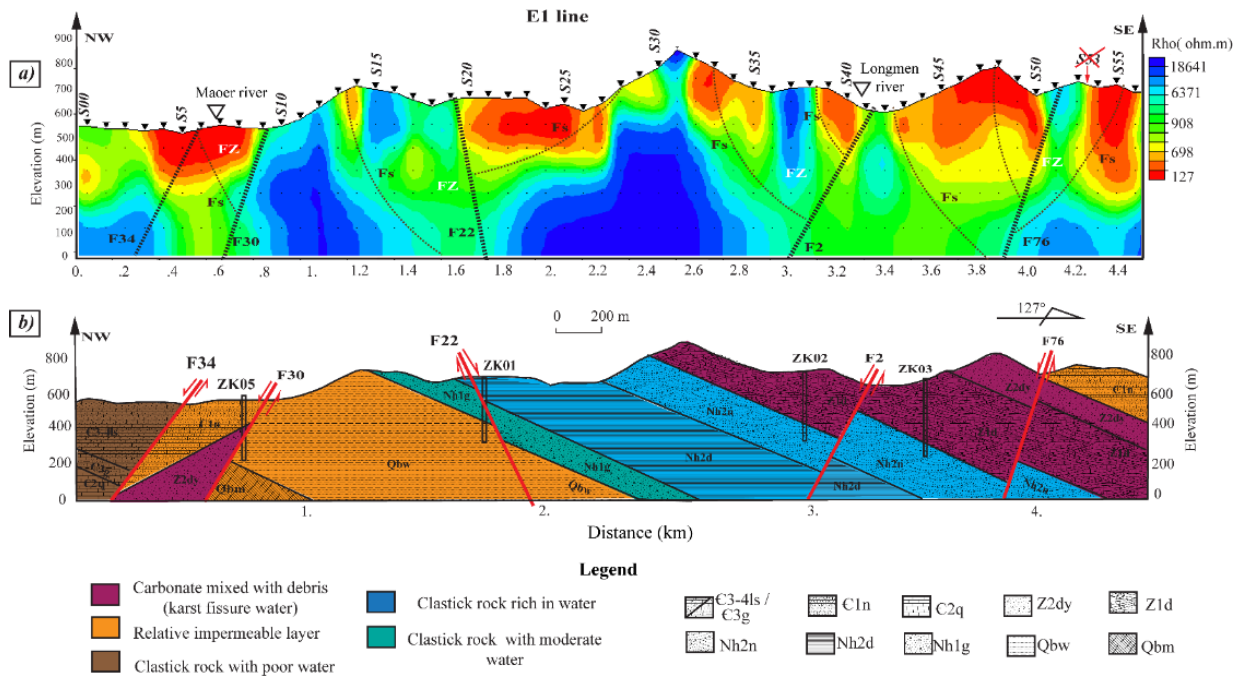


Figure 10: The selected 2D inverted model of AMT data. b) Geo-stratigraphic-map. Sketch of the geologic section based on credible drilling log and geological data of Huayuan mine.



Technologies and Methods

- Audio-frequency Magnetotellurics (AMT): Utilized for deep subsurface profiling to understand the distribution of resistivity and identify impermeable layers for optimal sewage diversion.
- Data Integration: Combining resistivity models with geological mapping and water quality analysis to delineate safe from unsafe zones.

- Environmental Geophysics: Employing AMT surveys across strategic lines that cross the mining area to capture comprehensive data on underground structures (Fig,11) influencing water flow and quality.



Challenges and Solutions

- Challenge: The complex subsurface environment influenced by intense mining activities complicates the identification of safe zones for water treatment infrastructure. (Fig.12)
- Solution: Advanced geophysical methods (AMT) coupled with robust data processing techniques to accurately map and interpret subsurface resistivity variations, enabling precise placement of sewage diversion infrastructures (Fig.13).

Outcomes

- Developed a detailed subsurface resistivity model that delineates areas suitable for placing new water treatment facilities, effectively diverting sewage away from critical water reservoirs.
- Provided a framework for integrating geophysical data with environmental planning to enhance decision-making in mining operations.
- Contributed to sustainable mining practices by ensuring the protection of groundwater resources through scientifically informed diversion strategies.

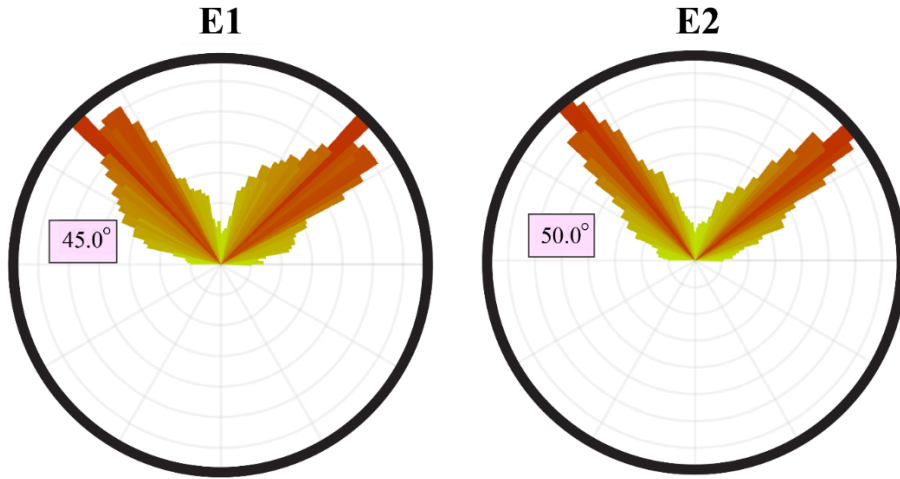


Figure 11: Rose diagram showing the strike analysis. NW-SE and NE-SW are the two directions that dominated the Huayuan mine by resolving the ambiguity. We retained NE45°SW instead of NW305°SE and NE50°SW over NW306°SE as the main direction of geological structures and validated by the direction of many faults observed in Fig.9



The project offers numerous benefits, particularly in enhancing environmental management and sustainability within mining operations:

- Environmental Protection: Effectively prevents groundwater contamination by identifying optimal locations for sewage diversion infrastructure through detailed subsurface resistivity modeling.
- Resource Sustainability: Ensures the protection and sustainable management of water resources crucial to the local ecosystem and the community dependent on these water sources.

- **Cost Efficiency:** Reduces potential costs related to water treatment and environmental clean-up by preventing pollution rather than managing its consequences.

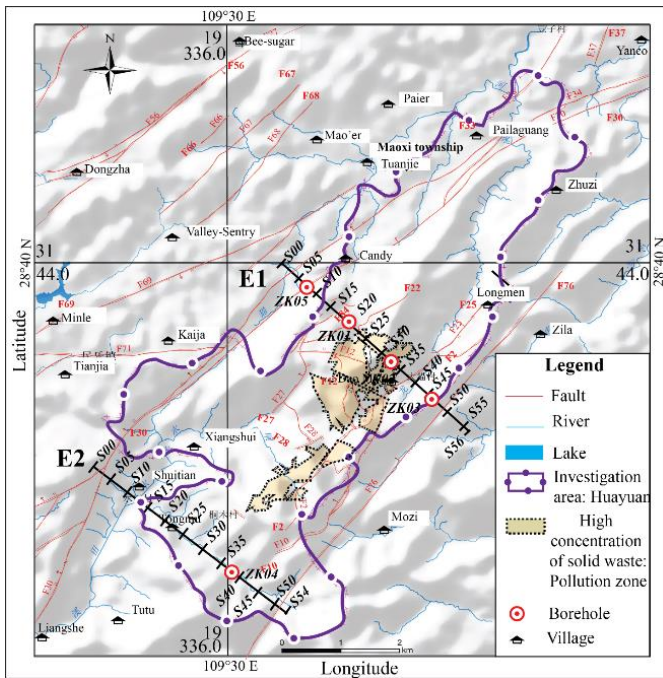


Figure 12: Huayuan solid waste concentration map. The map is generated from sampling points of chemical analysis of the whole area.

environmental management practices.

- **Stakeholder Engagement:** Facilitates better communication and collaboration between mining companies, environmental agencies, and local communities by providing transparent and scientifically backed data and methodologies.

- **Enhanced Decision-Making:** Provides mining managers and environmental planners with detailed geophysical data and analysis, improving decision-making processes regarding where and how to implement sewage diversion and water treatment strategies.

- **Technical Innovation:** Demonstrates the application of audio-frequency magnetotellurics (AMT) in environmental geophysics, advancing the field by integrating this technology with traditional

- Regulatory Compliance: Assists in meeting environmental regulations and standards by providing effective strategies to manage waste and protect water quality, ensuring the long-term viability of mining operations.

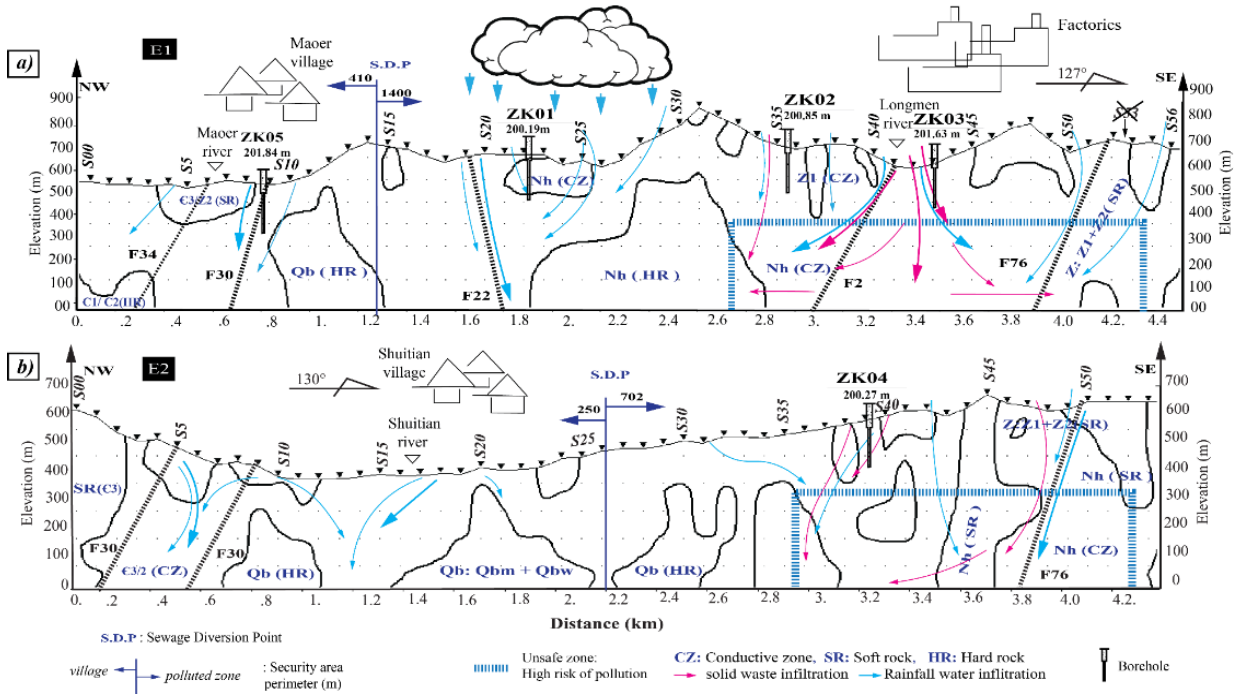


Figure 13: Integrated map for sewage infrastructure positioning. The thickness of the arrows shows how intensely water or solid waste is migrating underground. a) Line E1. b) Line E2.

Summary



In summary, the project employs an integrated geophysical approach to enhance sewage diversion and environmental management in mining operations. Utilizing audio-frequency AMT, this initiative focuses on optimizing sewage diversion strategies to prevent groundwater contamination from mining activities. By mapping the subsurface resistivity, the project identifies

optimal locations for water treatment facilities, ensuring sustainable management of local water resources. This innovative application of AMT not only aids in protecting the environment but also supports sustainable mining practices by providing crucial data for effective decision-making and compliance with environmental regulations. The outcomes of this project contribute significantly to the field of environmental geophysics, demonstrating how advanced technologies can be applied to address ecological challenges in the mining industry.

Visuals and Additional Information: - Published findings in [Geophysics](#) journal, providing a valuable reference for similar environmental geophysics applications in the mining industry.

GEOPHYSICS, VOL. 89, NO. 4 (JULY-AUGUST 2024); P. B241–B256, 15 FIGS., 3 TABLES.
10.1190/GEO2023-0332.1



Case History

An integrated approach for sewage diversion: Case of the Huayuan mine, Hunan Province, China

Kouao Laurent Kouadio¹, Jianxin Liu², Wenxiang Liu³, Rong Liu², and Zakaria Boukhalfa⁴

4.5. Leachate Leakage Detection and Management System (LLDMS)

Duration: Jun 2023 - Apr 2024

Affiliation

- School of Geosciences and Info-physics, Central South University, Changsha, PR China
- Laboratory of Geology Mineral Resources and Energy (LGRME), Félix Houphouët-Boigny University, Abidjan, Cote d'Ivoire



Overview

The Leachate Leakage Detection and Management System (LLDMS) is a cutting-edge solution designed to combat the environmental threat posed by leachate leakage from landfill sites worldwide. Located in Chaling County, China (Fig.14), LLDMS combines advanced



Figure 14: Overview of the Chaling Landfill Site and Study Area. The main map highlights the study area boundary (red outline), showing the distribution of Electrical Resistivity Tomography (ERT) lines (G1020, G1040, G2010, G2030, G3010, G3032, G3040) and stations (S1, S55, S60, S35) used in the study.

machine learning algorithms with geophysical methods like Electrical Resistivity Tomography (ERT) to revolutionize leachate detection and management. Key features include a hybrid machine

learning approach, real-time monitoring, and customization for individual landfill sites. LLDMS enables early detection and mitigation of leachate contamination, optimizes waste management practices, and provides valuable insights for policymakers to safeguard groundwater resources and public health.

The project focuses on the Chaling County Domestic Waste Sanitary Landfill in Huishan Village, Sicong Township, Chaling County, located approximately 8.6 kilometers from the county seat in Zhuzhou City, Hunan Province, China. The landfill site, covering an area of approximately 186,000 m², has been in operation since 2012 and serves a population exceeding 130,000 in rural areas (Fig,14). The Leachate Leakage Detection and Management System (LLDMS) is a cutting-edge solution designed to combat the environmental threat posed by leachate leakage from landfill sites worldwide. Located in Chaling County, China, LLDMS combines advanced machine learning algorithms with geophysical methods like Electrical Resistivity Tomography (ERT) to revolutionize leachate detection and management. Key features include a hybrid machine learning approach, real-time monitoring, and customization for individual landfill sites. LLDMS enables early detection and mitigation of leachate contamination, optimizes waste management practices, and provides valuable insights for policymakers to safeguard groundwater resources and public health. The project focuses on the Chaling County Domestic Waste Sanitary Landfill in Huishan Village, Sicong Township, Chaling County, located approximately 8.6 kilometers from the county seat in Zhuzhou City, Hunan Province, China. The landfill site, covering an area of approximately 186,000 m², has been in operation since 2012 and serves a population exceeding 130,000 in rural areas.



Figure 15: Field Operations at Chaling County Landfill. This series of images showcases various stages of landfill management and ERT exploration at Chaling County. From left to right: the accumulation of waste materials at the landfill site, a worker conducting ERT data collection amidst the debris, and the setup of an extensive ERT exploration grid over a covered section of the landfill. These scenes depict the practical challenges and efforts involved in environmental monitoring and management.

Objectives

- To enhance the detection of leachate leakages and tears in anti-seepage membranes using innovative machine learning algorithms integrated with ERT data.
- To improve the accuracy and efficiency of environmental monitoring practices at landfill sites, safeguarding groundwater from contamination.
- To offer a scalable and adaptable framework that can be applied to diverse landfill environments for broader environmental protection.



Technologies and Methods

- Electrical Resistivity Tomography (ERT): Used for mapping subsurface resistivity variations to detect potential leachate leakages.

- Machine Learning Algorithms (IF, OC-SVM, LOF): Employed to analyze complex ERT data sets, identifying anomalies that signify potential leakages.
- Integration of Geophysical and Machine Learning Data: Combines traditional geophysical data with modern analytical techniques to increase detection sensitivity and specificity.



Challenges and Solutions

- Challenge: Traditional ERT methods alone often lack the precision to identify specific leachate leakages.
- Solution: By integrating ERT with machine learning algorithms, LLDMS significantly enhances the capability to detect specific anomalies, reducing the risk of groundwater contamination.

Outcomes

- Demonstrated superior performance in detecting leachate leakage points, with significantly higher sensitivity and specificity compared to traditional methods (Fig.15).
- Established a robust, adaptable framework capable of being tailored to the specific conditions of various landfill sites.
- Enhanced environmental protection by providing more reliable data for decision-making in landfill management and groundwater preservation.



Benefits

LLDMS offers numerous benefits for landfill management and environmental protection:

- *Enhanced Detection Accuracy*: Integrates Electrical Resistivity Tomography (ERT) with advanced machine learning algorithms such as Isolation Forest, One-Class SVM, and Local Outlier Factor, significantly improving the accuracy in identifying leachate leakages.
- *Environmental Protection*: By effectively detecting and managing leachate leakages, LLDMS helps prevent groundwater contamination, thereby protecting the surrounding environment and public health.
- *Cost Efficiency*: Reduces the costs associated with traditional leachate management techniques by pinpointing exact leakage locations, thus minimizing the area that needs remediation.

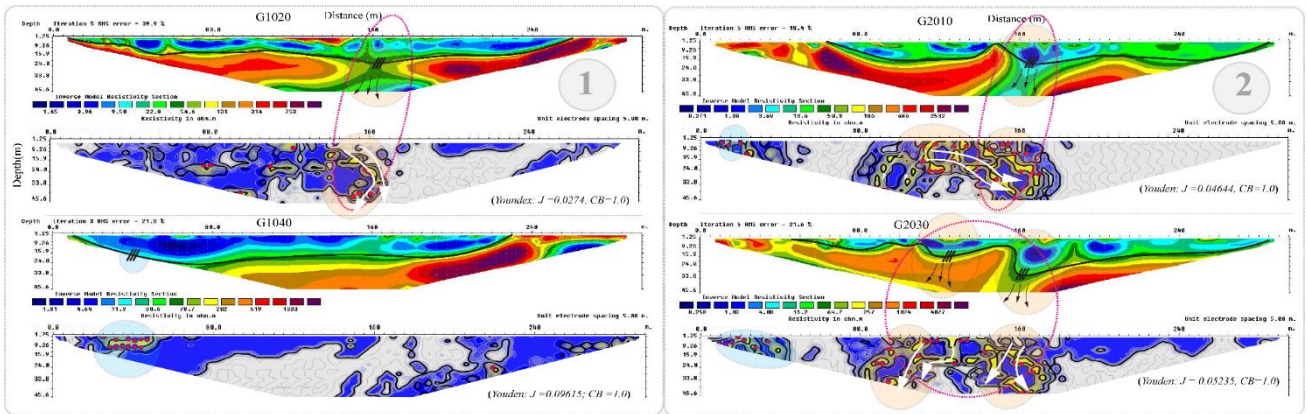


Figure 16: Comparative Analysis of ERT Inversion and LLDMS Results for Leachate Leakage Detection at Chaling Landfill Site: Section 1 (Lines G1020, G1040), and Section 2 (Lines G2010, G2030). The upper panels display the ERT inversion models, revealing general resistivity variations and structural features. The lower panels show LLDMS results, with detected anomalies marked by purple circles, highlighting potential leakage zones and membrane anti-seepage tears. Youden's Index values and cost-based (CB) performance metrics are provided for each line, indicating the detection efficacy of LLDMS. The results illustrate LLDMS's superior capability in pinpointing precise leakage points, ensuring reliable environmental monitoring, and targeted remediation efforts.

- *Adaptability*: The framework can be customized for different landfill environments, making it a versatile tool for global application in various geological settings.
- *Data-Driven Insights*: Provides landfill operators with reliable and actionable data, enabling informed decision-making for effective management and remediation strategies.

- **Technological Advancement:** Demonstrates the utility of combining geophysical methods with machine learning for environmental applications, paving the way for further technological innovations in the field.
- **Regulatory Compliance:** Assists landfill operators in meeting environmental regulations by providing a more robust monitoring and detection system for leachate management (Fig.16).

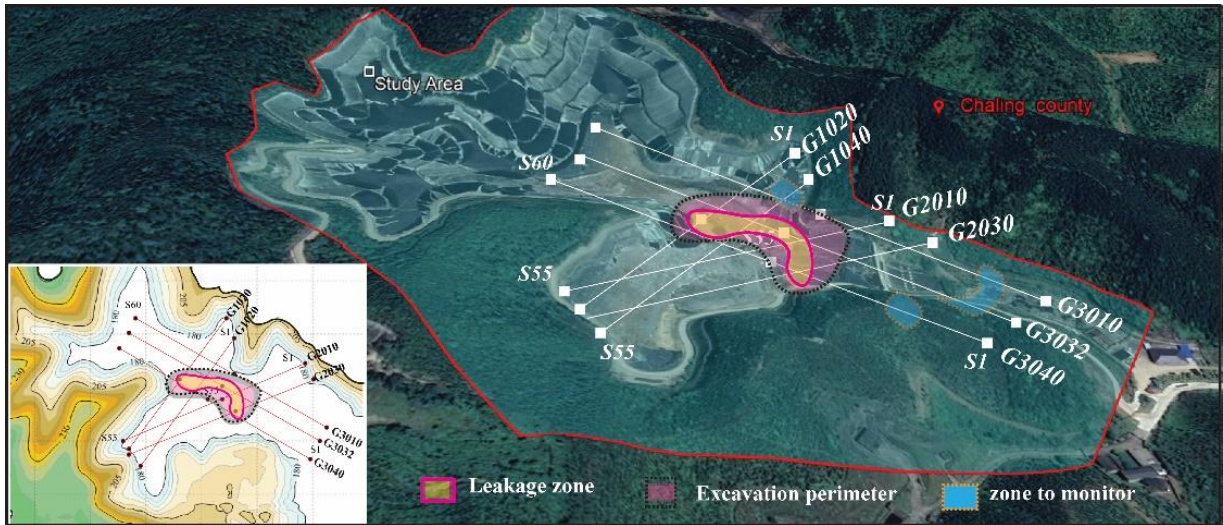


Figure 17: Leakage Detection and Monitoring Plan for Chaling Landfill Site and the positions of Electrical Resistivity Tomography (ERT) lines (G1020, G1040, G2010, G2030, G3010, G3032, G3040) and ERT stations (S1, S55, S60, S35). The identified leakage zones indicate areas where leachate leakage has been detected. The recommended excavation perimeter focuses on areas that require remediation to prevent further leachate migration. The zones to monitor are areas identified for ongoing observation to ensure early detection of potential future leaks. This comprehensive layout underscores the strategic approach to environmental assessment and remediation planning facilitated by LLDMS.

Visuals and Additional Information

- Detailed maps and diagrams illustrating the effectiveness of LLDMS in identifying leakage points.

At the time of publishing this catalogue, the results of our research are currently under review in the "Journal of Environmental Management," specifically for the special issue titled "***ML/AI-Assisted Modelling and Management of Environmental Systems: Methods, Applications, and Challenges***." This review process highlights the significant contributions our project has made to the fields of environmental science and landfill management.

4.6. *Hydrogeological Parameter Prediction System (HPPS) using K-Means Featurizer Strategy*

Duration: August 2023 – Janvier 2024

Affiliation

- School of Geosciences and Info-physics, Central South University, Changsha, PR China
- Laboratory of Geology Mineral Resources and Energy (LGRME), Félix Houphouët-Boigny University, Abidjan, Cote d'Ivoire



Overview

The Hydrogeological Parameter Prediction System (HPPS) addresses the challenge of predicting permeability coefficient (K) values in geoscience engineering projects, particularly in aquifer characterization and groundwater resource management. HPPS leverages machine learning (ML) methodologies to predict K values using logging and borehole data, reducing the reliance on costly and often unsuccessful pumping tests. The system employs a mixture learning strategy (MXS) that combines unsupervised and supervised ML algorithms to handle missing K values and enhance prediction accuracy.

The project employs the K-Means Featurizer (KMF) strategy which introduces a novel approach to handle complex and limited datasets, particularly in geoscience engineering. By integrating machine learning with geophysical data analysis, KMF uses K-Means clustering to enhance the predictive performance of models like Random Forest, K-Neighbors, Support Vector Machines, Extreme Gradient Boosting, and Multiple Layers Neural Networks (Fig.18). This project aims to improve hydraulic conductivity predictions essential for effective water resource management and infrastructure planning.

The project focuses on the Niming coal mine in China, where accurate estimation of K values is crucial for successful drilling technology construction and groundwater management. The Hongliu coal mine, being one of the super-large mines in China, has extensive drilling and geophysical logging exploration works, providing ample data for analysis and prediction (Fig.19).

Objectives



- To advance the accuracy of predictive models in geosciences using the K-Means Featurizer.
- To reduce operational costs and data loss in hydraulic conductivity measurements traditionally requiring extensive field tests.
- To provide a robust framework that can be adapted to various domains facing complex data challenges.

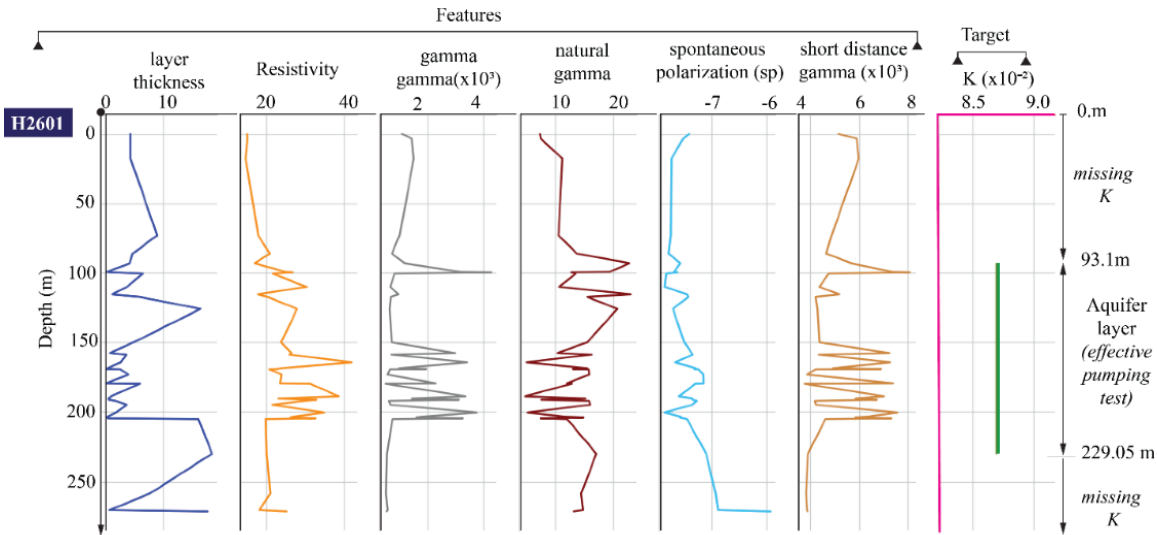


Figure 18: Example of borehole H2061. The strata as a categorical feature are excluded for visualization



Technologies and Methods

- *K-Means Clustering for Feature Engineering*: Utilizes an innovative approach where K-Means clustering is adapted to include target variables, creating new features that enhance the alignment between data structures and predictive models.
- *Advanced Machine Learning Integration*: Applies a suite of sophisticated machine learning algorithms, including Random Forest, K-Neighbors, Support Vector Machines, Extreme Gradient Boosting, and Multiple Layers Neural Networks, to assess and enhance the effectiveness of the K-Means Featurizer.
- *Comprehensive Data Analysis*: Integrates and analyzes geological and hydrological data sets with machine-generated features to optimize the accuracy and efficiency of predictive models.

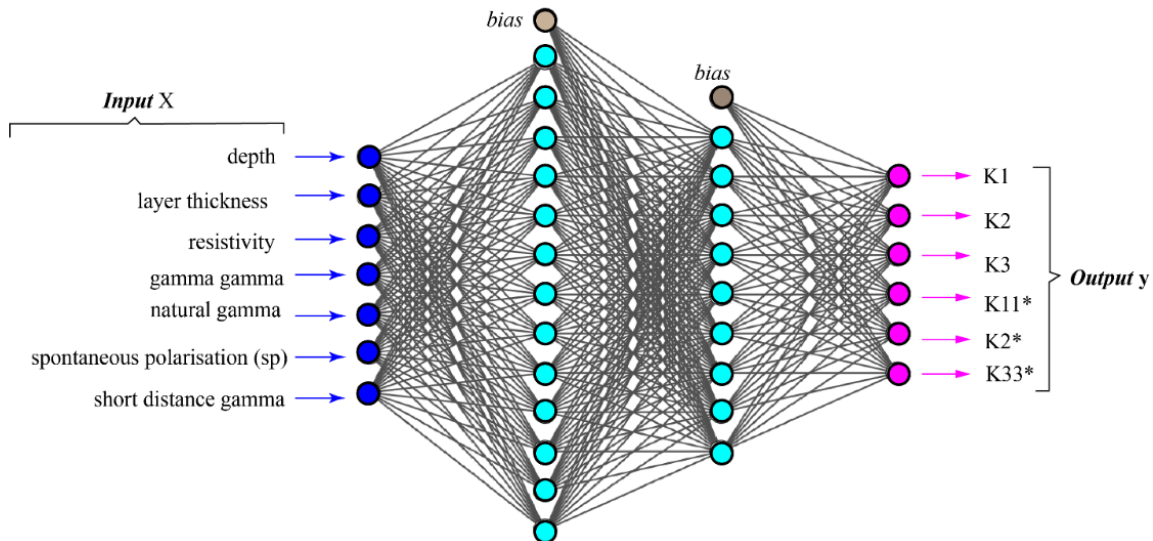


Figure 19: Proposed architecture of Multilayer Neural Network for classifying K

Challenges and Solutions



- Challenge: Complex geological datasets often feature intricate patterns that are difficult to model with standard machine learning techniques due to their high dimensionality and limited sample sizes.
- Solution: The K-Means Featurizer addresses these issues by transforming the data space into a more structured format that enhances the predictive models' ability to learn effectively. This transformation results in significantly improved model accuracy and generalization across various datasets.
- Challenge: Traditional hydraulic conductivity measurements are costly and time-consuming, involving extensive physical sampling and testing.
- Solution: By enhancing the predictive accuracy of models through K-Means Featurizer, the project reduces the reliance on physical samples, thereby decreasing operational costs and expediting data processing.

Outcomes

- Enhanced Model Performance: The integration of K-Means Featurizer has shown to boost the accuracy of predictive models significantly, with K-scores increasing by up to 90%, demonstrating a marked improvement in model reliability and efficiency.
- Cost Reduction in Field Operations: The application of KMF has led to a decrease in the need for expensive and labor-intensive field tests traditionally used to measure hydraulic conductivity, resulting in considerable cost savings.
- Broad Applicability: The successful application of the K-Means Featurizer across various algorithms underscores its versatility. Its adaptability has been further validated through extended

applications in other scientific and engineering fields, illustrating the potential for widespread use in handling complex datasets.



Benefits

The HPPS project brings a multitude of benefits to geoscience and other fields requiring complex data analysis:

- Improved Prediction Accuracy: By enriching feature engineering with K-Means clustering, the project significantly enhances the accuracy of machine learning models, facilitating better predictions of hydraulic conductivity and other critical parameters (Fig.20).
- Cost Efficiency: Reduces the financial and time costs associated with extensive field data collection and testing by providing accurate predictions using computational methods.
- Operational Efficiency: Speeds up the data processing and analysis phase, allowing for faster decision-making and implementation of practical solutions in water resource management and infrastructure planning.
- Enhanced Model Robustness: Increases the robustness and reliability of predictive models, ensuring they perform well across various conditions and datasets, which is crucial for geoscientific applications.
- Versatility and Scalability: Demonstrates the framework's adaptability, proving that the method can be applied to various domains beyond geosciences, such as environmental science, engineering, and even business analytics.

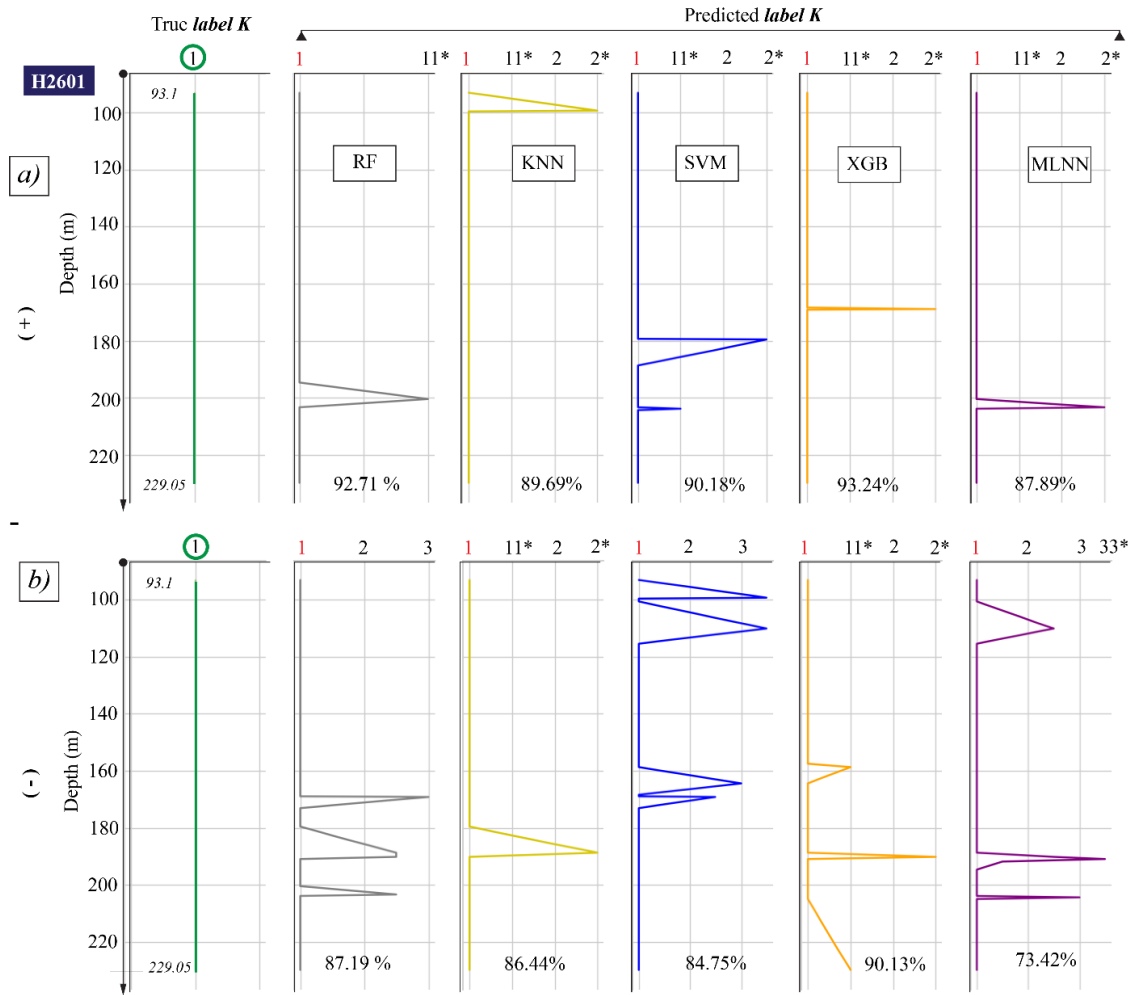


Figure 20: Comparative analysis of hydraulic conductivity prediction in borehole H2601. (a) illustrates the enhanced accuracy of predictions across various machine learning algorithms when KMF is applied, with a notable performance by XGB; (b) demonstrates the predictive outcomes without KMF, highlighting the challenges in accurate aquifer group classification.

- Environmental Impact: Supports sustainable environmental practices by improving the management of natural resources, thus minimizing potential environmental damage from inaccurate resource allocation.
- Innovative Approach: Pioneers the integration of cluster analysis with target-oriented feature creation, setting a new standard in the field of machine learning and data science for complex datasets.

Visuals and Additional Information

- Visualizations of improved clustering and predictive performance.
- Graphs showing model accuracy and the impact of KMF on various machine learning algorithms.
- Published findings in [Earth Sciences Informatics](#) journal, providing a valuable reference for similar environmental geophysics applications in the mining industry.

Earth Science Informatics
<https://doi.org/10.1007/s12145-024-01236-3>

RESEARCH



K-Means Featurizer: A booster for intricate datasets

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Received: 30 October 2023 / Accepted: 18 January 2024

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5. Some Project Images participated from 2015 to 2016 in Cote d'Ivoire

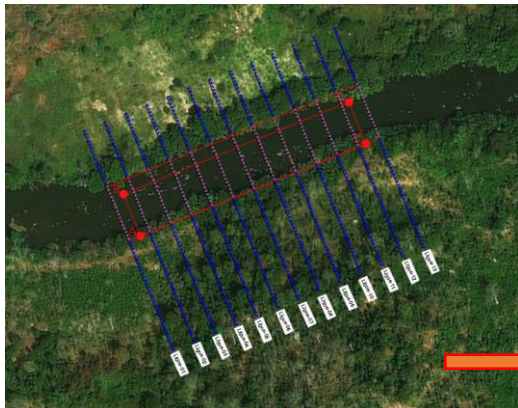


Figure 21: Sangbe, Gao ERT map, Biankouma



Figure 22: Blue points indicate locations where populations have benefited from improved access to drinking water supplies.



Figure 23: Borotoukoro, Biankouma



Figure 24: Niangorovogo, Nielle



Figure 25: Sama, Bondoukou, CIV



Figure 26: Koro, Boundiali department, CIV



Figure 28: Gao, Biankouma



Figure 27: Sekonkaha, Ferkessedougou



Figure 29: Diacohu Nord, Bouafle, CIV

6. Acknowledgments

The authors acknowledge their sincere gratitude to the governments of Côte d'Ivoire and China for their fruitful cooperation, which has been instrumental in the successful accomplishment of these projects. This collaboration between institutions from both countries has facilitated significant exchange and advancement in our initiatives.

They extend their heartfelt gratitude to a wide array of collaborators, institutions, and supporters who have contributed significantly to the various projects detailed in this catalogue. We are deeply thankful to the Laboratory of Geology Mineral Resources and Energy (LGRME) of the School of Earth Science and Mineral Resources (STRM) at Felix Houphouet Boigny University and the Hunan Key Laboratory of Nonferrous Resources and Geological Hazards Exploration of the School of Geosciences and Info-physics for their leadership and dedication.

Special thanks go to Ibrahim Berthe and Diarassouba Mada from the Cote d'Ivoire National Office for Drinking Water (ONEP), as well as Boffoue Moro Olivier from the Polytechnical University of Man, for their substantial involvement and support, which have been crucial for the welfare of the populations served. Our appreciation also extends to Jiawen Wang from the Coal Geology Bureau of Ningxia Hui Autonomous Region, China, for providing essential datasets, and to the Guangdong Provincial Geological Bureau for their valuable hydrogeology and engineering geology data.

We acknowledge the significant financial support from the National Natural Science Foundation of China under grant nos. 42130810, 42004065, 42074165, 41774149, and 42374093, which enabled much of the research discussed, particularly at the Huayuan mine and Chaling County.

Further thanks are due to contributors like Soro Nanin, Sombo Boko Celestin, and others from STRM, as well as Denis Simonin of FORACO-CI, Irie Bi Goli of IBS+, and Alexis Kouame Kouakou of GEOTRAP SARL for their roles in data collection and analysis. The project also benefited from the editorial and methodological guidance of Guillaume Saint-Cirgue and the polishing efforts by Ndeutala Selma Iita, Chaoqiang Xi, Sakinatu Issaka, Marie-Berthe Kadja, Elodie Kossonou, Albert Okrah Malory, and Dalal Ezzedine.

Finally, our profound thanks to the anonymous reviewers and editors whose insightful feedback has immensely enhanced the quality and accessibility of our project publications, making them more informative and effective in reaching the wider public. Your contributions have been invaluable in refining our work and extending its impact within and beyond the academic community.

7. Key Researchers and Contributors



Kouadio Laurent

Kouadio Laurent is an visitor researcher at Felix Houphouët Boigny and postdoctoral fellow at Central South University with a robust background in computational geophysics,

specializing in the integration of artificial intelligence and machine learning into hydro-geophysics and environmental solutions. His work predominantly revolves around developing innovative strategies and intelligent tools to enhance the detection and management of natural resources. Kouadio has been instrumental in leading various groundbreaking projects and has contributed extensively to the academic and practical advancements in geosciences.



Kouamelan Serge

Serge is a lecturer and researcher at the Félix Houphouët-Boigny University, specializing in mining geology and environmental management. His expertise spans across teaching and coordinating complex projects in both academic and industrial settings, enhancing the training of students and professionals in the application of geophysics to environmental stewardship and resource management.



Jianxin Liu

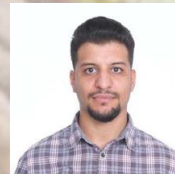
Jianxin Liu serves as the Director of the Hunan Provincial Key Laboratory for Non-ferrous Resources and Geological Disaster Exploration. With an extensive background in project management and supervision, Liu has been crucial in overseeing the successful execution of

numerous geophysical projects. His leadership ensures the alignment of project goals with scientific rigor and operational excellence, contributing significantly to the field of geophysical research.



Liu Rong

Associate Professor Liu Rong is a distinguished member of the academic community, known for his exemplary contributions to education and research in geophysics. With multiple provincial awards and patents to his name, Liu's work focuses on the application of sophisticated geophysical data analysis techniques and machine learning models to solve complex environmental and engineering problems.



Zakaria Boukhalfa

A seasoned geoscientist, Zakaria Boukhalfa brings a wealth of experience from his studies and research in resource exploration and geophysics. With a PhD from Zhejiang University, Boukhalfa has worked both in academia and the field, focusing on geodynamic processes and magnetotelluric surveying. His research has significantly advanced the understanding of geological structures through innovative geophysical methods.

These professionals have advanced their respective fields through innovative research and dedicated teaching and have also played pivotal roles in fostering collaboration across institutions, contributing to a richer, more comprehensive understanding of geosciences. Their collective efforts have significantly propelled the projects discussed in this catalogue, demonstrating the powerful synergy of collaborative scientific research.