Under the Patronage of His Excellency **Eng. Abdulrahman bin Abdulmohsen AlFadley**
Minister of Environment, Water & Agriculture

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A Holistic approach for a Smart Groundwater Management System: ILMA Solution

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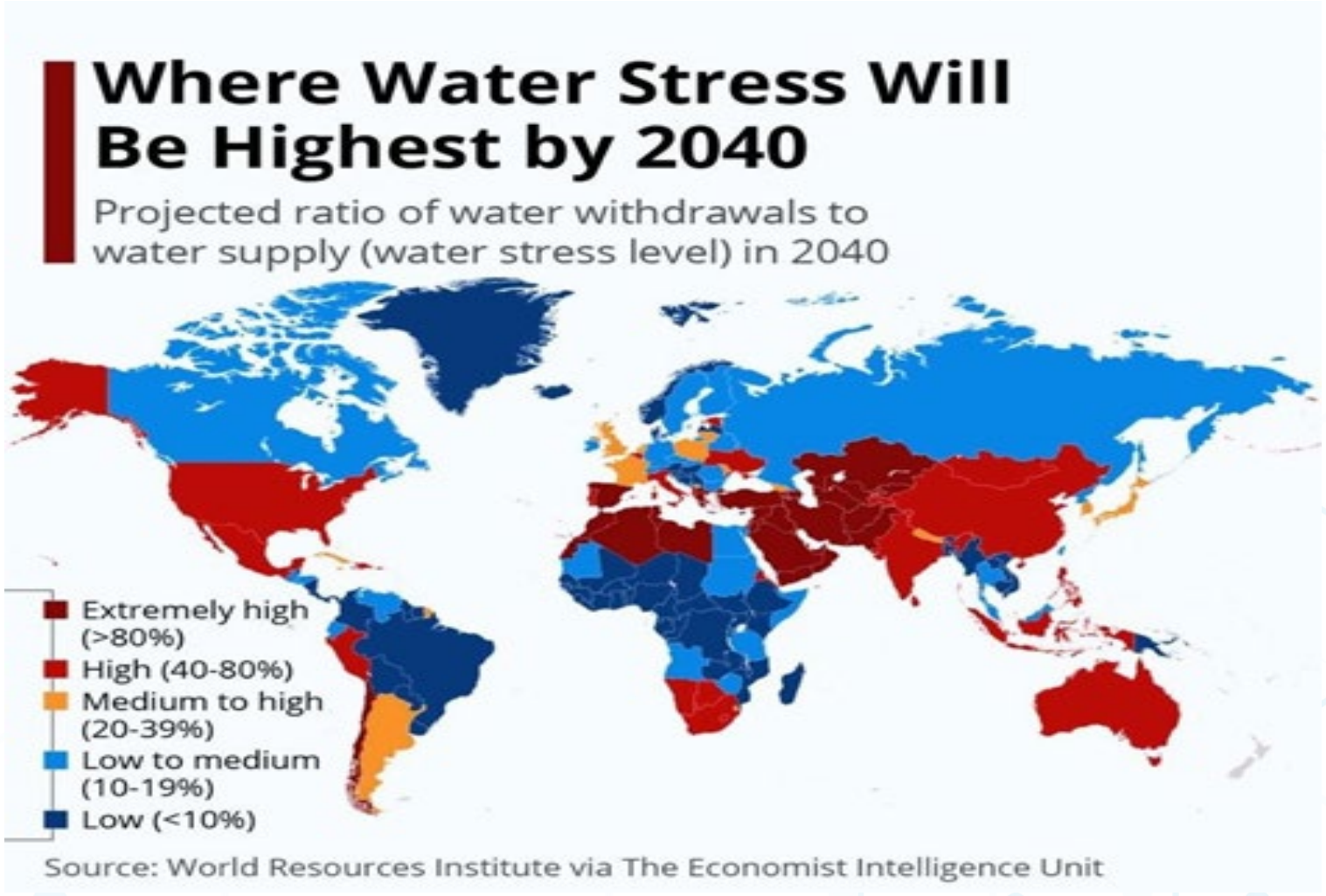
MAEE

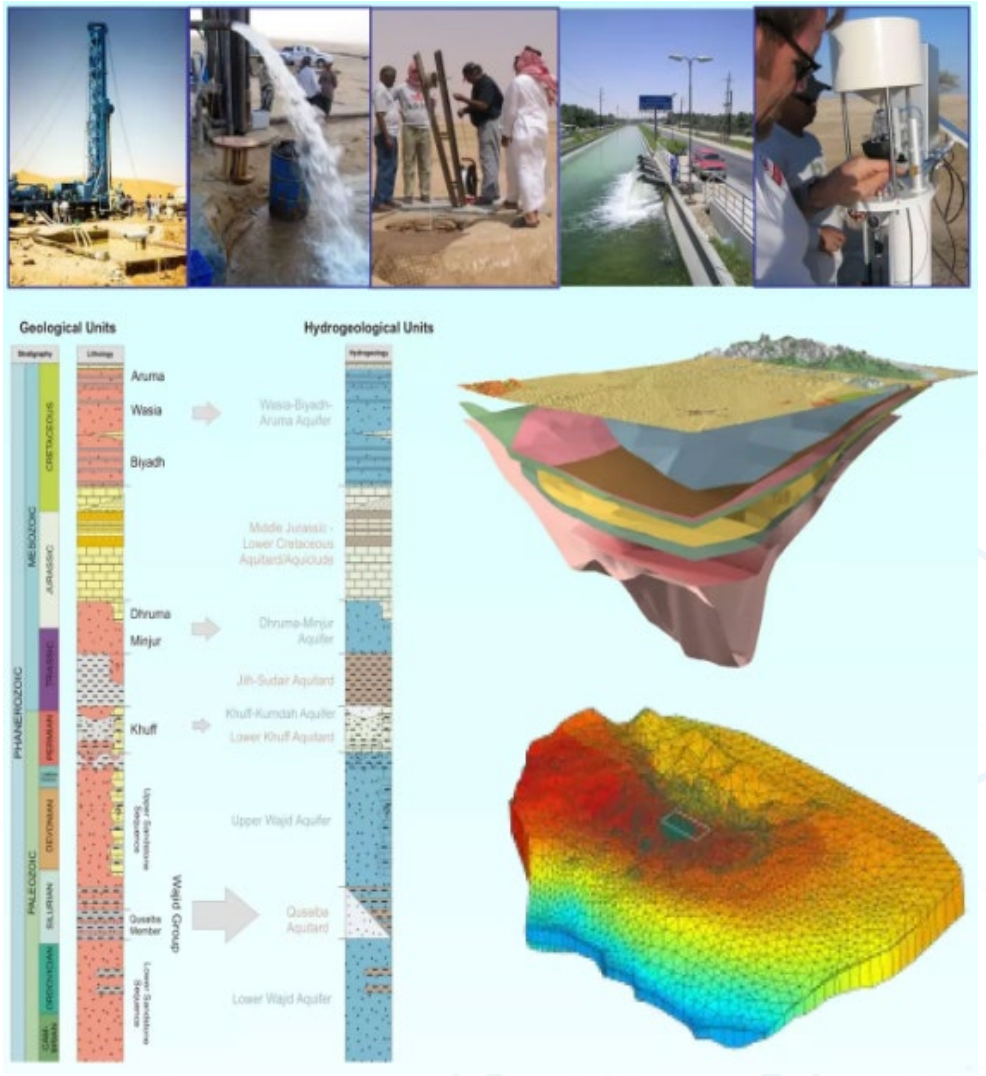
Current Situation – Arid and Semi Arid regions



- Economic, environmental and political impact

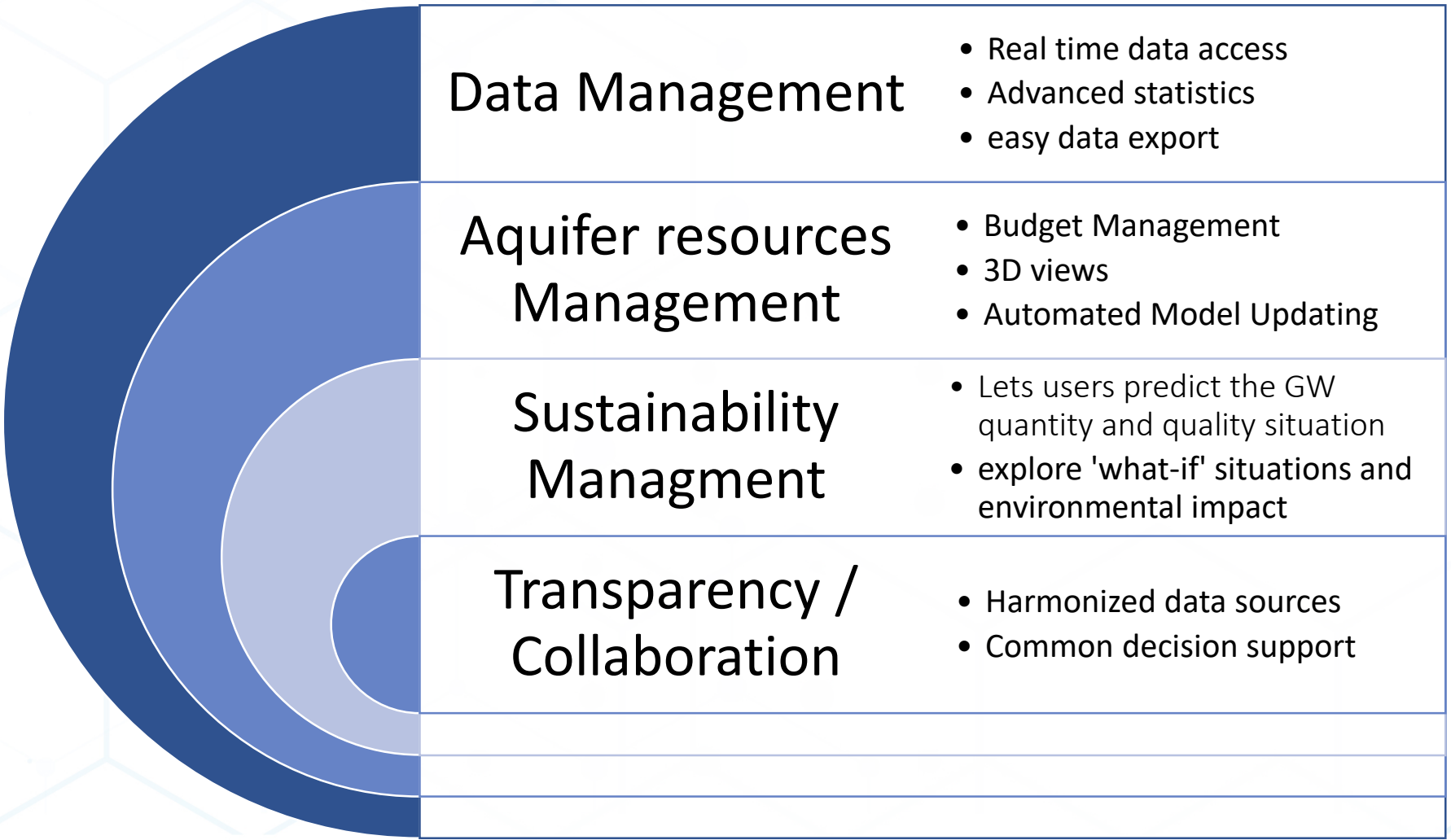
Current Situation – technology

- Right now, the technology we have isn’t keeping up with the demands for smart planning and management of groundwater resources. We need tools that are proactive, real-time, and allow collaboration, but what's available doesn’t match these needs.
- While groundwater models are essential, keeping them updated is challenging, leading to them quickly becoming outdated and too complex for non-experts to use
- There’s a serious lack of visibility and predictability in how we deal with this
- This directly affects how long our groundwater can stick around sustainably



ILMA solution goals

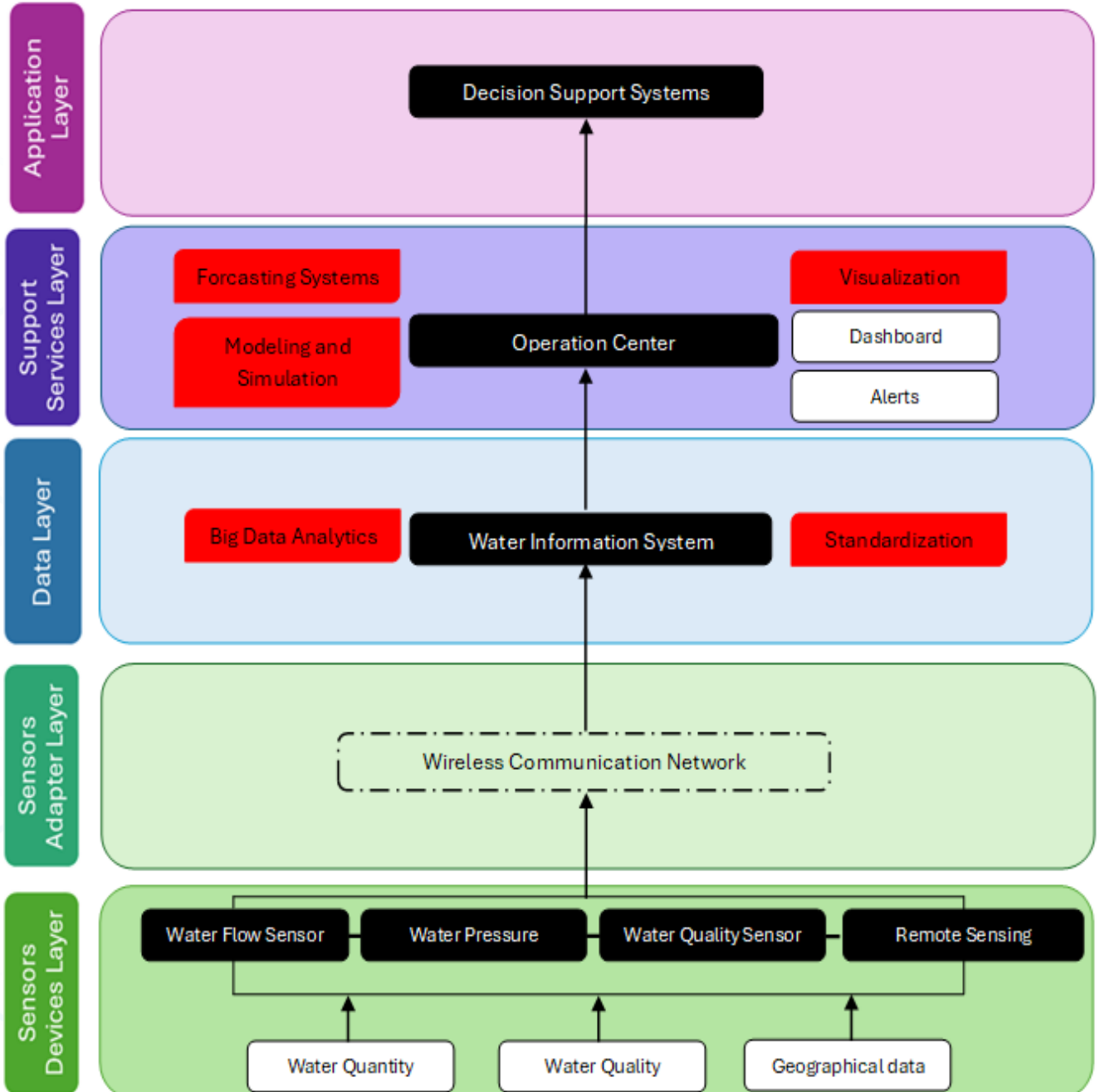
To tackle **water scarcity** and **the smart technologies use**, our creation, ILMA, serves as a strong solution for real-time monitoring, prediction, and decision-making about groundwater. This innovative system has four main goals:



Data Management	• Real time data access • Advanced statistics • easy data export
Aquifer resources Management	• Budget Management • 3D views • Automated Model Updating
Sustainability Managment	• Lets users predict the GW quantity and quality situation • explore 'what-if' situations and environmental impact
Transparency / Collaboration	• Harmonized data sources • Common decision support

These parts make ILMA stronger, giving a complete way to deal with water scarcity and handle lake-related technology

ILMA solution concept



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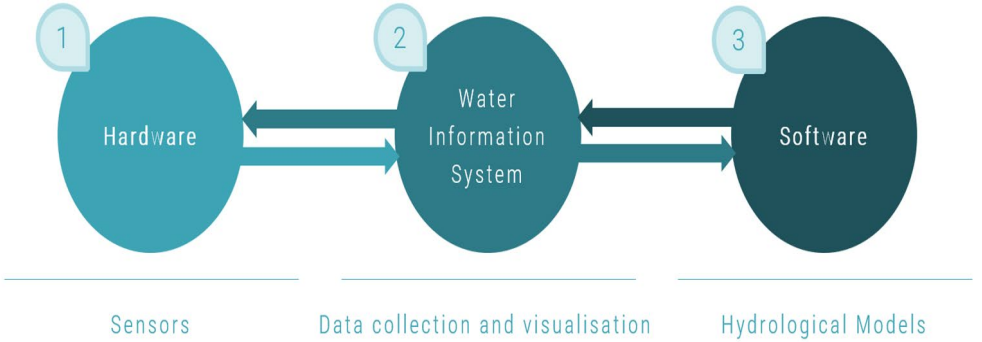
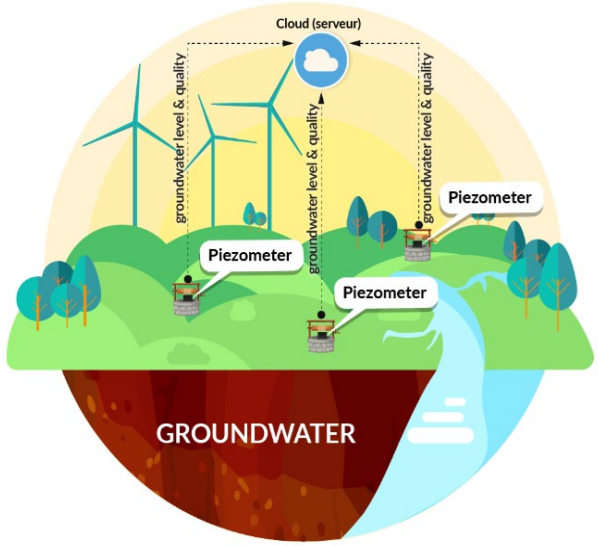
IoT_based Smart Groundwater management system

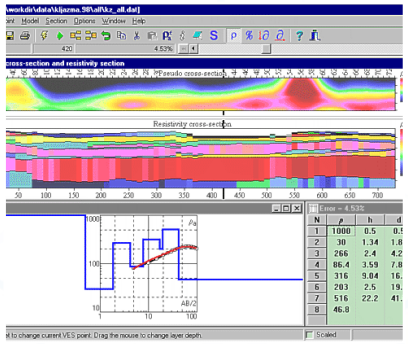


Source : Manel ENNAHEDH, Mohamed RAJHI, Fakhreddine MRABET, Hamza ESSAYAH, Ahmed AOUITI , 'A concept for the application of integrated digital technologies to enhance intelligent groundwater management systems: ILMA solution' , The 3rd Mediterranean Geosciences Union , Istanbul ,Turkey

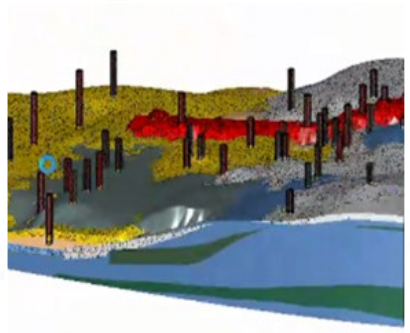
ILMA solution concept : Hardware



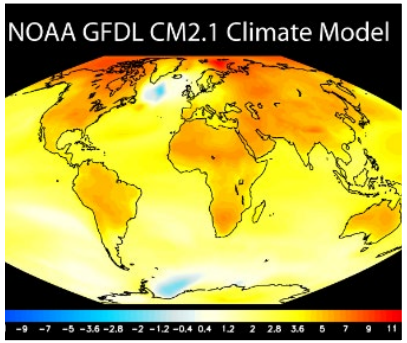
This includes sensors for data monitoring (GWL, GW quality, Climate data) and sensors adapters for collection, conversion and transmition of data



Sensors data



Hydrological data



Climate change data

In this step, we integrate IOT Sensors, Geo data and climate change scenarios to create an AI algorithm to monitor and predict water resources using mobile application

ILMA solution concept : Water information system

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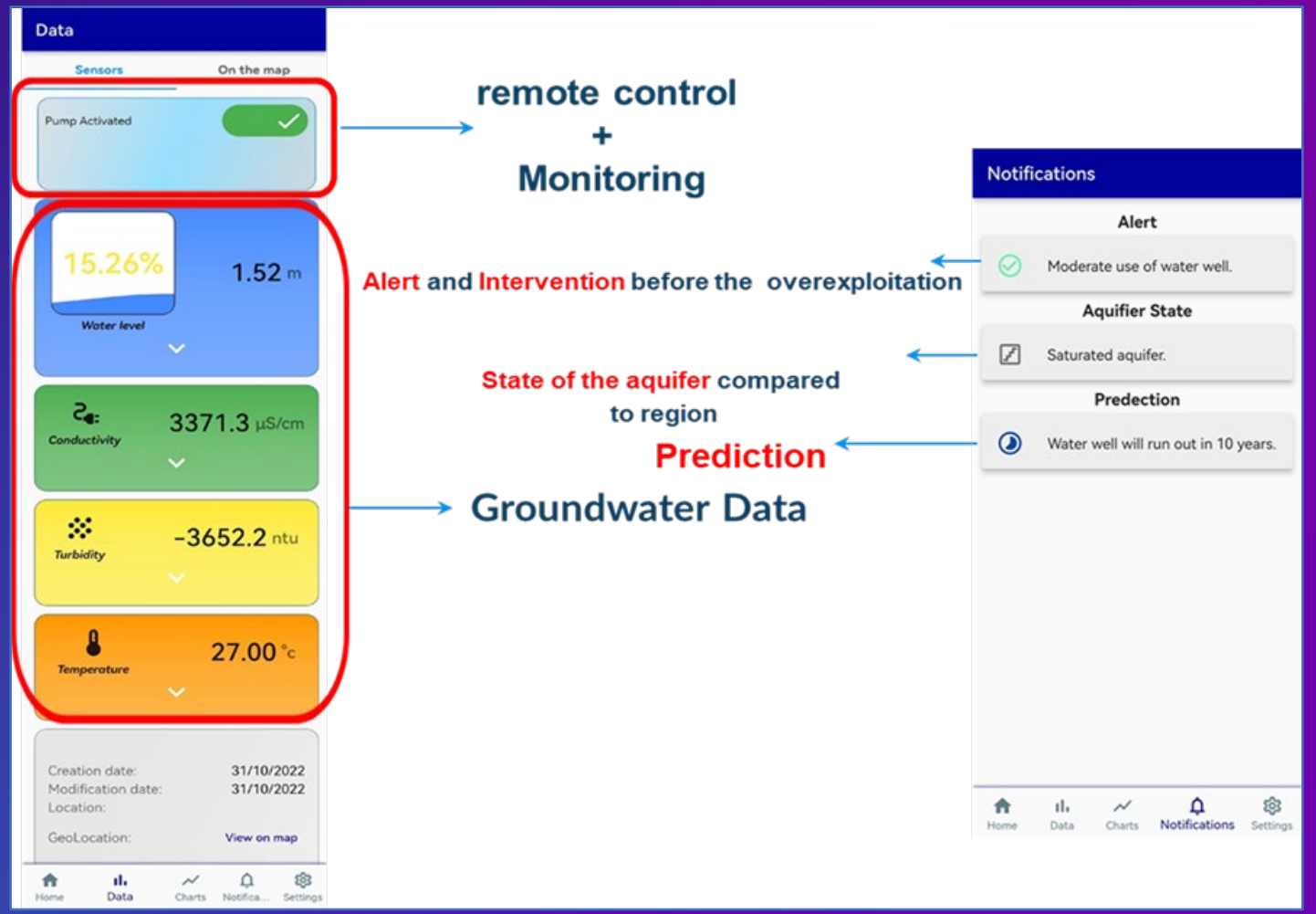
Data collection , traitement and visualisation : This is a data integration architecture that hosts all data, including sensors data (real time data) and data from models simulation (prediction), This setup allows for the real-time visualization of various parameters and the issuance of alerts.

Mobile application's interface



ILMA solution concept : Water information system

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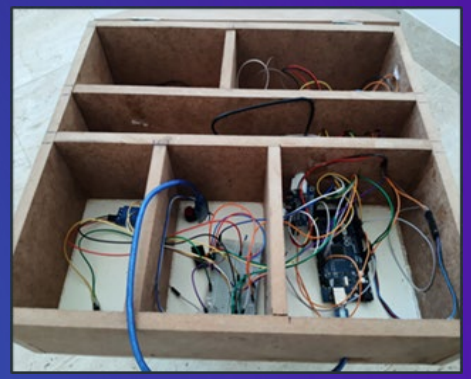
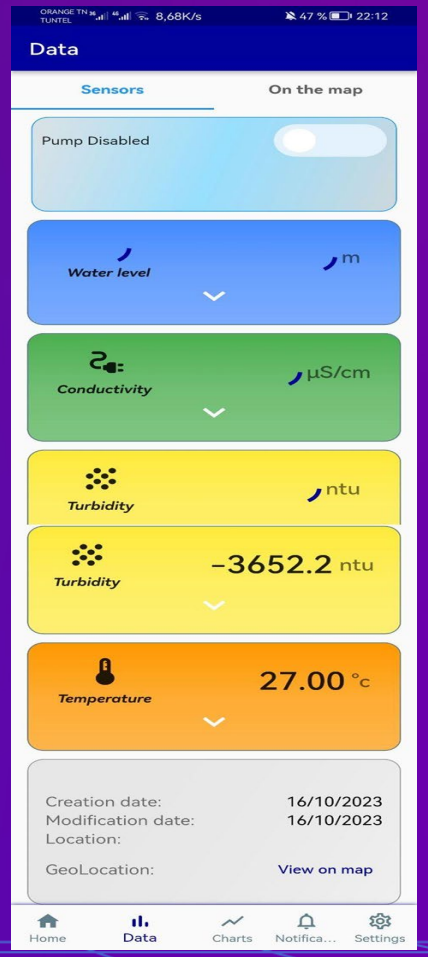
1.Installation of **the mobile application** by the customers

2. Installation of **sensors** in the wells of our customers
Installation of the **Box**

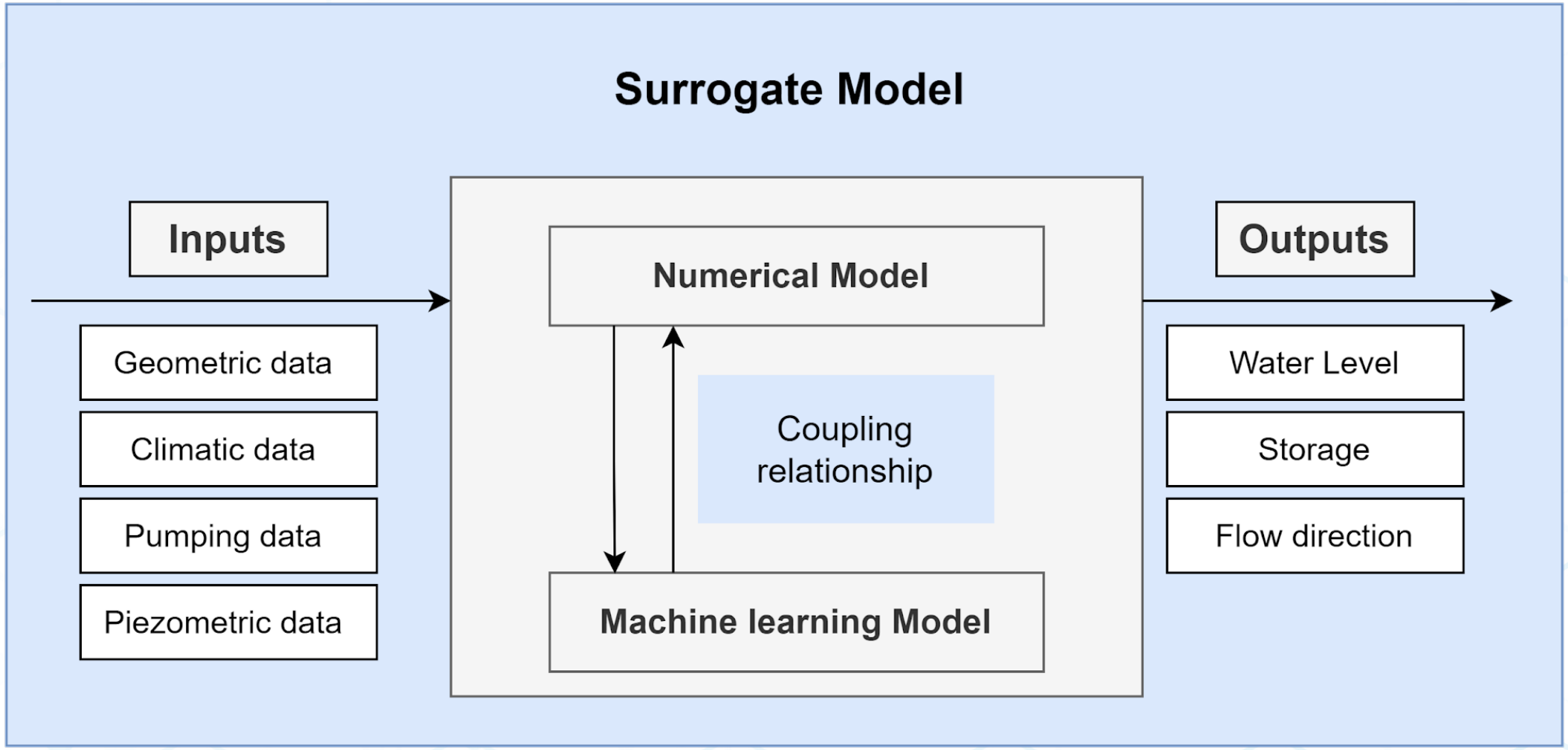


3. ILMA **monitoring** tools

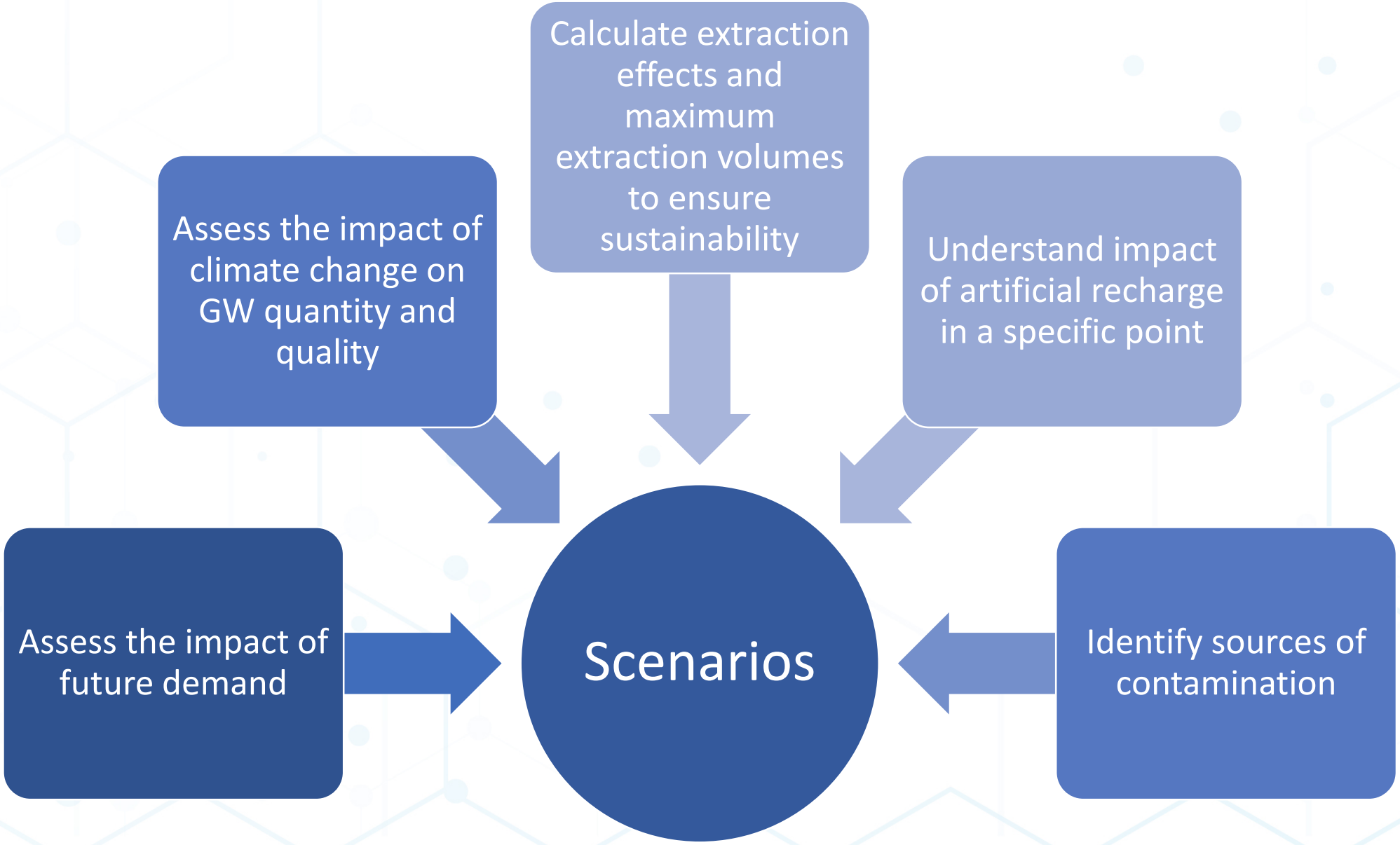


ILMA solution concept : Software

This includes modelling and analytics (forcasts) for support services and decision support system : Surrogate model



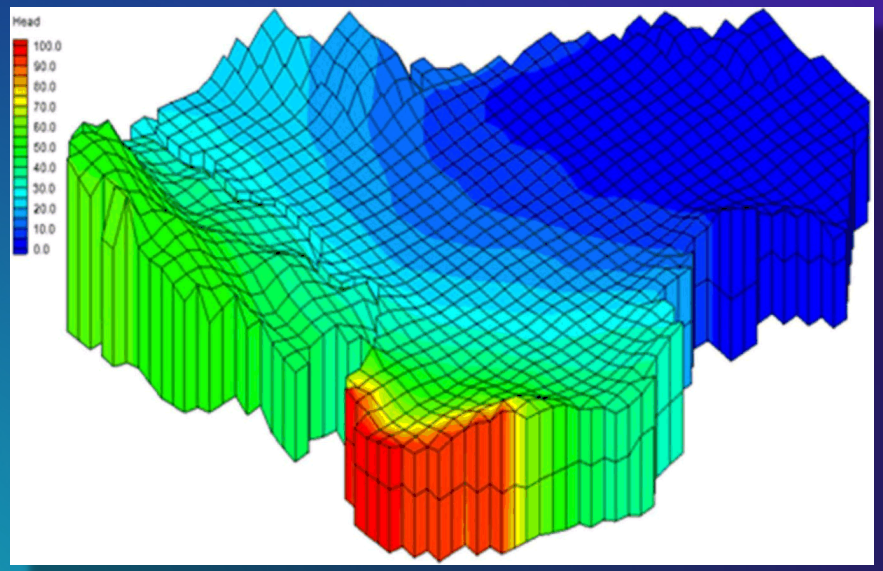
ILMA solution concept : Scenarios



Use Case 1 : Surrogate Modeling ,Mornag Plain Aquifer , Tunisia

General location map of the study area (Geographic Information System)

3D shape of the Mornag aquifer model calibrated (Groundwater Modeling System)



Inputs: recharge rate and pumping wells

Outputs: flow front face, flow lower face, flow right face, hydraulic head level, and storage

Source : M. G. C. A. Cimino; Manel Ennahedh; Federico A. Galatolo; Nejla Hariga-Tlatli; Issam Nouiri; Nicola Perilli; Jamila Tarhouni., "A machine learning approach for groundwater modeling," 2022 IEEE 9th International Conference on Sciences of Electronics, Technologies of Information and Telecommunications (SETIT), Hammamet, Tunisia, 2022, pp. 299-304, doi: 10.1109/SETIT54465.2022.9875601.

Use Case 1 : Surrogate Modeling ,Mornag Plain Aquifer , Tunisia

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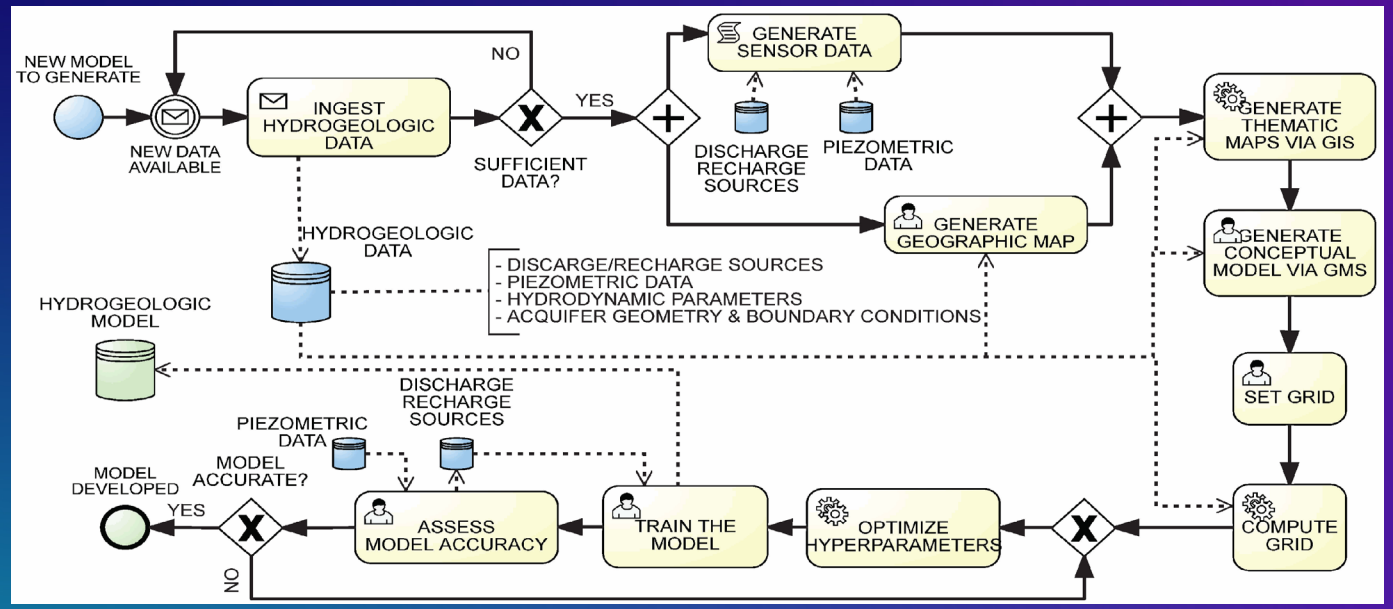
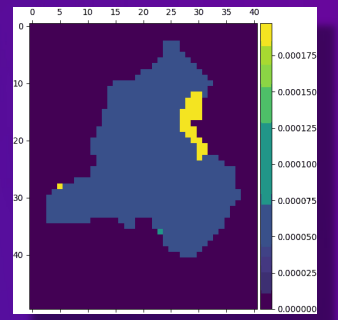
Workflow of groundwater Surrogate Modeling : Modflow + CCN

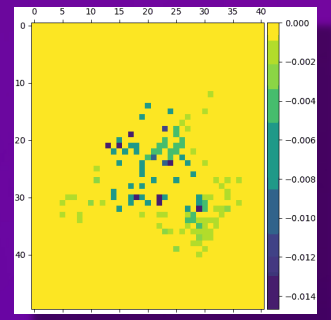


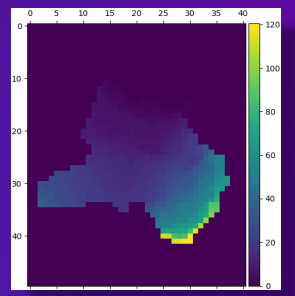
PERFORMANCE OF THE DATA-DRIVEN MODEL

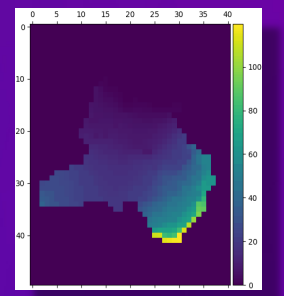
Output	Training MAE (mt.)	Validation MAE (mt.)	Testing MAE (mt.)
Flow front face	0.000287	0.000320	0.000305
Flow lower face	1.626	2.365	1.794
Flow right face	0.000242	0.000255	0.000248
Hydraulic head level	0.319	0.320	0.329
Storage	0.000160	0.000185	0.000163
Average	**0.0639**	**0.0641**	**0.0659**

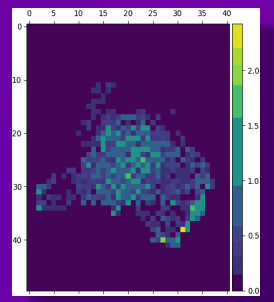
Input: recharge rate , pumping wells











hydraulic head level (output, target, abs error)

Source : M. G. C. A. Cimino; Manel Ennahedh; Federico A. Galatolo; Nejla Hariga-Tlatli; Issam Nouiri; Nicola Perilli; Jamila Tarhouni., "A machine learning approach for groundwater modeling," 2022 IEEE 9th International Conference on Sciences of Electronics, Technologies of Information and Telecommunications (SETIT), Hammamet, Tunisia, 2022, pp. 299-304, doi: 10.1109/SETIT54465.2022.9875601.

Use Case 2: LSTM model , the Mornag Plain Aquifer , Tunisia

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General location map of the study area (Geographic Information System)

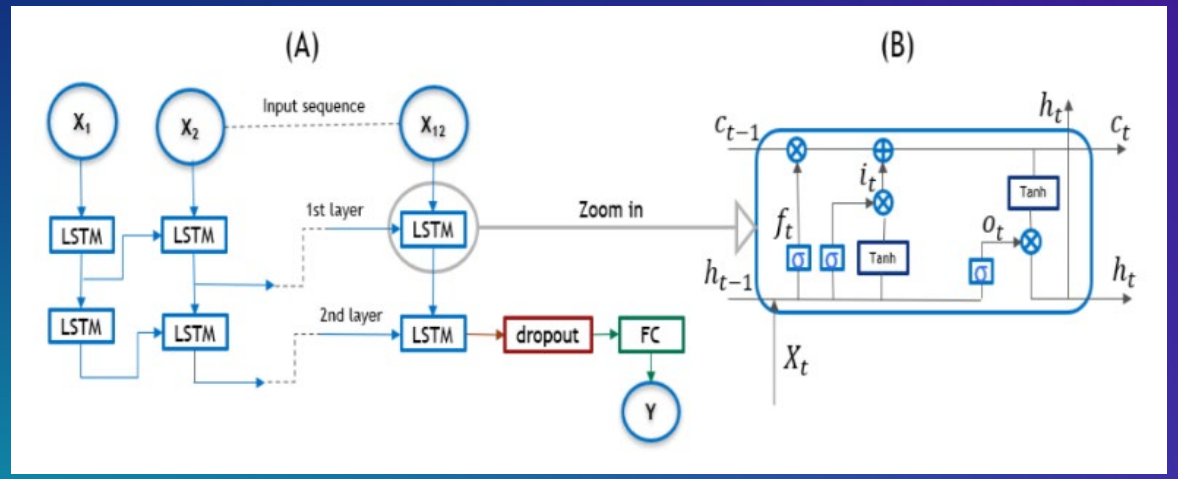
Dataset Sample Overview

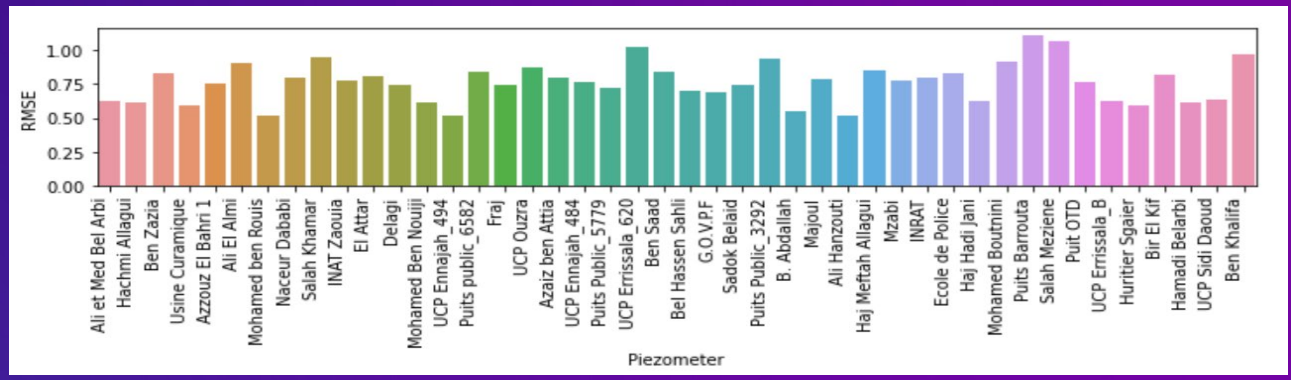
Time	PZ	RG	Zone	Year	Month	SPI	SPI_Category	RFd	RFm	RFt	RFs	RFy	GWL
2013-04-01	Ben Khalifa	MORNEG FERME ESSADIR	3	2013	4	-0.236898	Moderately dry	0.0	51.8	54.3	191.0	384.5	10.741000
2010-04-01	Salah Khamar	OUDHNA FERME CHIBOUB	1	2010	4	-0.236898	Moderately dry	0.0	49.0	123.0	251.0	388.0	20.763000
2007-09-01	Ben Saad	OUDHNA FERME CHIBOUB	1	2007	9	-0.236898	Moderately dry	0.0	78.0	81.0	241.0	453.0	16.795667
2008-09-01	Hamadi Belarbi	MORNEG FERME ESSADIR	3	2008	9	0.337611	Moderately Wet	3.0	34.0	34.0	90.5	221.0	11.625000
2015-04-01	El Attar	MEGRINE PARC CRDA	4	2015	4	-0.236898	Moderately dry	0.0	1.5	10.5	269.5	319.5	2.318846
2008-04-01	Azaiz ben Attia	OUZRA AGRI FLORA	1	2008	4	-0.236898	Moderately dry	0.0	21.0	42.0	107.5	181.5	9.019000
2014-09-01	Puits Public_5779	MEGRINE PARC CRDA	4	2014	9	-0.236898	Moderately dry	0.0	3.0	4.5	178.0	333.6	32.364663
2008-09-01	INAT Zaouia	MORNEG FERME ESSADIR	3	2008	9	-0.236898	Moderately dry	0.0	34.0	34.0	90.5	221.0	-2.976000
2015-04-01	Puit OTD	FOUCHANA FERME GAMOU	3	2015	4	-0.236898	Moderately dry	0.0	2.0	18.5	253.0	291.5	23.213000
2012-09-01	Puits Public_5779	RADES PF	4	2012	9	2.252640	Extremely wet	13.0	21.7	36.6	165.0	303.5	33.474208

Source : Tfifha, Y., Ennahedh, M., Debbabi, N. (2024). Artificial Intelligence-Based Decision Support System for Groundwater Management Under Climate Change: Application to Mornag Plain in Tunisia. In: Chenchouni, H., et al. Recent Advancements from Aquifers to Skies in Hydrogeology, Geoecology, and Atmospheric Sciences. MedGU 2022. Advances in Science, Technology & Innovation. Springer, Cham. https://doi.org/10.1007/978-3-031-47079-0_4.

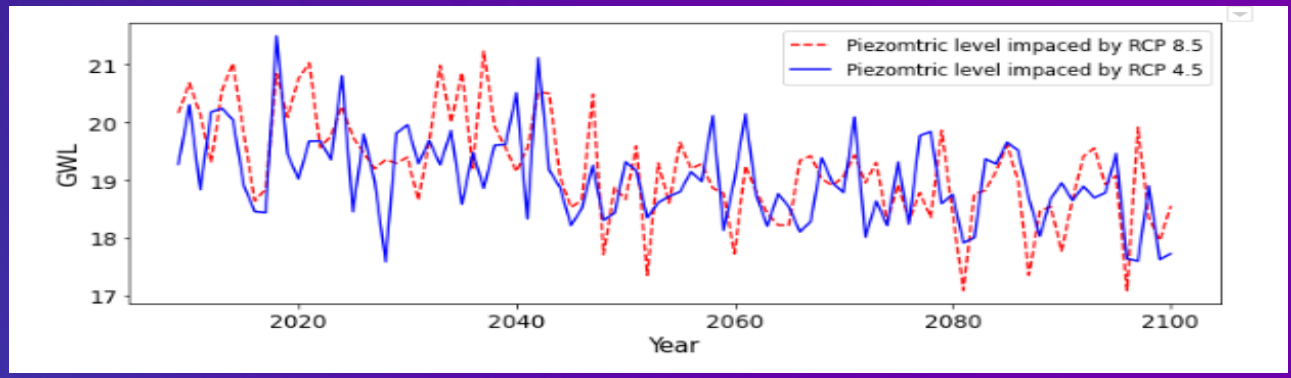
Use Case 2: LSTM model , the Mornag Plain Aquifer , Tunisia

LSTM Neural Network architecture for GWL forecasting





RMSE of all piezometric stations using data from 2013 to 2015.



A sample of the forecasting results under RCP 4.5 and 8.5 of “Ben Saad” piezometric station

Source : Tfifha, Y., Ennahedh, M., Debbabi, N. (2024). Artificial Intelligence-Based Decision Support System for Groundwater Management Under Climate Change: Application to Mornag Plain in Tunisia. In: Chenchouni, H., et al. Recent Advancements from Aquifers to Skies in Hydrogeology, Geoecology, and Atmospheric Sciences. MedGU 2022. Advances in Science, Technology & Innovation. Springer, Cham. https://doi.org/10.1007/978-3-031-47079-0_4.

Conclusion

Real time visibility and **predictability** over groundwater resources

Single "source of truth" for groundwater regulators, planners, managers and users

Groundwater **models**

- Are **updated automatically real time**
- Become **management tools**
- **Outdated** models become an asset again

Planners, managers and users can **easily** assess quantitative and qualitative **impact of decisions** – run "what-if" scenarios

Cost savings – between 5X-10X over traditional groundwater management processes

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