Addressing Water Sustainability Challenges in North Africa with Artificial Intelligence

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ABSTRACT

The topic of water sustainability has been leading the priorities worldwide where Artificial Intelligence (AI) can position research institutions, public & private companies and governments towards evidence-based decision-making in regards to water resources. In this particular domain, the amount and heterogeneity of data generated allied to the rapid progress of scientific research and technological development have created vast amounts of data, but significant challenges to gathering, filtering, and making sense of this information. This paper presents the research outcomes of collaborative effort engaging a total 51 students mentored by 15 professors across 11 research institutions in North Africa, distributed by 14 selected projects focusing the appropriate application of machine learning methods to local and national water sustainability problems. These outcomes were motivated by a youth challenge co-organized during May 2024 between AI Africa and IRCAI with the support of GITEX.

KEYWORDS

Machine learning, text mining, large language models, community engagement, water sustainability, competition

1 Introduction

Building upon common interests, exciting initiatives and existing projects developed by IRCAI and AI in Africa (aiinafrica.org), focused on AI and Sustainability, this activity aimed to build capacity within African youth to advance the Sustainable Development Goals (SDGs) though AI on challenges within their own communities and in the region. The AI Youth Challenge originated in the context of discussions started in GITEX Dubai in 2023 and forwarded to a concrete event in the AI Everything section of the GITEX Africa in the end of May 2024. It was mostly directed to PhD/MsC students and young entrepreneurs working on AI to solve problems for the good of their communities, exploring a wide range of machine learning methodologies (from image recognition on satellite imagery, to text mining on social media, gamification strategies optimizing water consumption, and application of LLM frameworks for RAG and AI Agents in the context of water sustainability), engaging experts from global agencies like, e.g., UNESCO, AI Movement, and UNESCO's Water Education Institute, as well as national companies, research institutions and government. The global challenge of this action, "Water, AI and Sustainability" is one of the MENA priorities, takes into consideration the UN Water Program for 2024-25 [12], and follows the work done by IRCAI with the European Commission (EC) on the NAIADES Water Observatory [9], as well as the recently opened new IRCAI Committee on AI and Water Resource Management [4] focusing on the impact of AI in SDG 6 [11]. This work aligns with UNESCO's interests in taking action to capacitate the Youth towards AI, with focus on the recent activities based from Morocco but with a global scope, including the opening of the new UNESCO AI Centre, the AI Movement (aim.um6p.ma).

Figure 1: Winner of the AI4Water challenge, designed and developed by UM6P students, exposing a water map that pinpoints remote villages with assigned water scores based on satellite imagery and crowdsourced data.

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2 Finalist innovative ideas on water sustainability

Attracting the participation of more than 50 PhD and MsC students across 20 teams based in research institutions in Morocco, this initiative was designed to encourage a conversation between the communities, corporate thought leaders, the education visionaries, and the ecosystems builders to have constructive conversations around the shifts and needs of the changing future landscape. The discussions included researchers, start-up communities, technologists, and government representatives to unite and define the future of water sustainability as they see it. The selected AI technologies and methodologies ranged from the use of satellite imagery to the analysis of news and social media, or the input from water-related sensors and the application of Large Language Models (LLMs) to describe good practices. We shall proceed with describing the problems addressed by the finalists of the AI4Water challenge, their prototypes and the value of the innovation they brought with them.

AquaScore. The Rural communities in Morocco's High Atlas Mountains struggle with water management due to limited resources and visibility. Despite needing modest funds, these villages face significant hurdles in accessing support. The challenge lies in objectively quantifying water issues and connecting these communities with potential supporters. AquaScore creates a water map that pinpoints remote villages and assigns them water scores based on satellite imagery and crowdsourced data. This enables ranking villages by water criticality, helping funders and supporters identify where to direct their assistance effectively. The prototype (described in Figure 1) also offers a platform for discussing water solutions, fostering community engagement through gamification features. By increasing the visibility of rural Moroccan villages and providing objective water criticality assessments, AquaScore facilitates efficient resource allocation for donors and experts. This AI-driven approach ensures fair and unbiased assistance to communities in need, promoting water sustainability and improved water management in constrained environments.

AquaScore employs a hybrid approach combining Computer Vision (CV) and Natural Language Processing (NLP). CV algorithms segment satellite images to generate automated baseline water scores, while NLP algorithms extract insights from textual data to enhance score accuracy. This combination allows for objective assessment and continuous improvement of water criticality rankings. The team has already aggregated data on 1,322 High Atlas villages, extracted satellite images, and segmented them using Facebook's Segment Anything model. This process was completed on UM6P servers using 500GB of storage and 80 CPU cores. The system will incorporate user-submitted reports and internet-scraped data to further refine water scores. The uniqueness of AquaScore lies in its data generation and refinement approach. It creates datasets in areas with data scarcity, starting with an automated baseline from satellite imagery and then enriching it through user-generated content. This closed-loop system employs active learning, progressively enhancing accuracy and relevance of water scores.

AquaSense. Water management is a critical issue in many countries, including Morocco. Severe droughts, poor water distribution, and recent natural disasters raise the urgent need for better solutions to manage water resources effectively. AquaSense's prototype (see Figure 2) offers a smart way to handle water resources by predicting future water situations, visualizing key data, and engaging citizens and communities. This helps decision-makers plan better, save resources, and respond quickly to local water issues. AquaSense provides accurate forecasting of water parameters for informed management and answers water-related questions with detailed analysis using the latest data and news. It offers transparent data visualization through interactive charts, allowing users to view and upload data easily. The community & citizens' space features real-time news updates, a water levels map to locate and help regions in need of water, and a tool to easily report local water issues.

Figure 2: Screenshot of the prototype of Aquasense defining parameters, visualizing data and monitoring engagement.

AquaSense combines two distinct parts of AI: DL (LSTM) and Generative AI (RAG and AI Agents). AquaSense uses Multivariate and multistep LSTMs to accurately predict water parameters' levels for the coming years, and Retrieval-Augmented Generation and AI Agents to answer water-related queries with detailed analysis, using the latest data, news, predicted parameters, and documents from sources like UN, UNCCD, and EPA. AquaSense uses Tensorflow and Keras (LSTM model), Pandas and Numpy (data preparation & mgmt.), Langchain (LLM framework for RAG and AI Agents), Chroma (Vector DB), Nomic Embeddings (Open-Source embeddings), GPT3.5-TURBO (LLM model), Streamlit (Web app). Aquasense improves water management by helping stakeholders make informed decisions, enhancing resource allocation, and promoting sustainable practices. Through its innovative features, it bridges the gap between citizens and authorities, which fosters collaboration and reduces water crises over time. Also, AquaSense aligns with several UN Sustainable Development Goals (SDGs) such as SDG 6 (Clean Water and

Sanitation), SDG 13 (Climate Action), and SDG 11 (Sustainable Cities and Communities).

Water Consumption Tracker. This prototype is addressing the global problem of water optimization in the light of the already visible consequences of climate change. That is, the large amount of wasted water due to irresponsible water use by the households. The added value lies in the behavioral approach: the application is designed to make users more aware of their attitude toward water consumption, and to make water conservation a pleasure rather than a responsibility. Introducing a gamification approach as a new strategy should help make water conservation more appealing. It is based on an app that tracks real-time water usage, provides personalized recommendations, and motivates users over a gamification environment, fostering a community focused on sustainable water use.
The use of Machine Learning models such as Random Forest Regressor to find patterns between the households characteristics and their water usage behavior. We plan to add GenAI using LLM model as a chatbot to support our vision by providing custom tips to optimize water usage. The approach was fundamentally based on: (1) collecting data about the households using our application UI; (2) providing optimum water consumption level by the ML model based on the data collected; and (3) monitoring water usage through IoT sensors and the notification system of our App. The data collected is used to optimize the ML model performance. Our approach can potentially reduce household water waste by 20-50% by educating users about their consumption habits through notifications, ranking systems, and feedback mechanisms.

Figure 3: The pitch of one of the top 3 teams – Ghayt – presenting the Water Consumption Tracker at the AI stage of GITEX Africa.

Aquatic Biodiversity. The introduction of non-native species into marine ecosystems presents a significant threat to the fragile equilibrium of these vital environments. Invasive species, often aggressive, can outcompete native organisms, leading to disrupted food chains, altered habitats, and potentially irreversible ecological harm. From coastal areas to the open sea, the swift proliferation of invasive plants, animals, and microorganisms endangers the biodiversity, productivity, and resilience of our marine life. Addressing this escalating global issue requires immediate and decisive action. AI-powered early detection algorithms were prepared to constantly monitor for signs of invasive species, triggering immediate alerts to enable rapid response. Based on species-specific data, the system can precisely deploy the most effective eradication methods, from underwater drones to selective biocides. As invasive species evolve, the AI-driven platform continuously adapts strategies, ensuring that the interventions remain effective and environmentally responsible.

YAZ. High unemployment rates in North Africa often translate into many individuals employed in low-wage jobs, particularly youth from low-income households. Severe water scarcity leading is decreasing exports and rising prices of vegetables and fruits. Challenges meeting the needs of Morocco's population while being a major exporter of produce to global markets. This AI-based agricultural solution is based on Smart Hydroponic Towers designed to efficiently grow crops vertically indoors and outdoors, offering optimal use of available spaces. The adoption of hydroponics in Africa has the potential to create millions of new jobs in the coming years. Integrated with GPT architecture, the technology allows real-time monitoring, pest detection, and yield estimation. YAZ hydroponics are a shift towards a resilient and sustainable Moroccan agriculture.

The tools and technologies presented in this paper that are open source, are available at IRCAI's SDG Observatory GitHub repository (github.com/IRCAI-SDGobservatory).

3 From concept to prototype in a month

AI in Africa in collaboration with IRCAI conducted a gathering of minds which culminated in a 1-day summit around technologies and shifts of the future, hosted by GITEX in the AI Everything section of the GITEX Africa 2024. Between 26th April and 31st May, 55 PhD and MSc students from 11 research institutions took part of a complete program including expert sessions kicked-off at the AI movement, UNESCO's new center for AI in Africa, and engaging experts in water-related topics such as Matjaž Mikoš, UNESCO chair for landslide risk reduction, droughts and floods, discussing our recent research on news mining for extreme weather events [5, 6]; Gerald Corzo Perez, senior researcher at the UN Water Education IHE Delft, discussing our ongoing research on Water, AI and Twitter [7]; and Ignacio Casals, R&D Manager in Aguas de Alicante Spain, providing a industrial perspective on the use of AI to tackle the challenges of wastewater management [8].
The students were followed across 8 stages including: conceptualization; data collection, analysis and visualization; methodology and implementation, prototype building and pitch (see Figure 3). In order to maximize the impact of the programme, the content from the abovementioned opportunities will be organized across UNESCO's most related to the five areas: (1) capacity building; (2) developing

supportive policy; (3) effective, inclusive and equitable access to quality Education; (4) nurturing and creating sustainability models for Water Sustainability; and fostering and facilitating international cooperation.

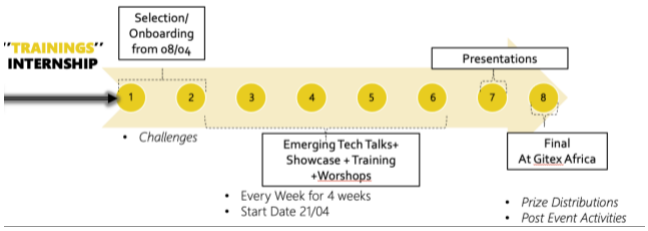

Figure 4: The phases of the training curriculum across 5 weeks.

The training curriculum included weekly seminars open to public, training workshop for participants, showcases and mentoring sessions (see Figure 4). The discussions forming the bae concepts of the participant projects were held in the light of IRCAI's research and research achievements (see Figure 5), aiming at building research collaboration bridges.

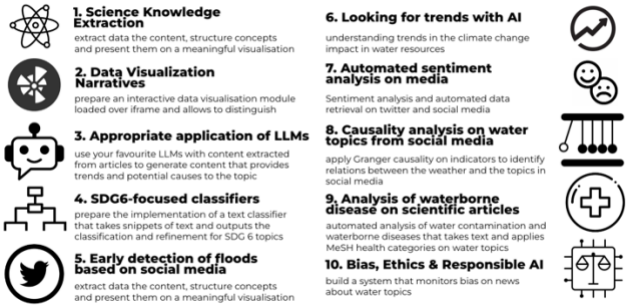

Figure 5: Selected topics from IRCAI's research to motivate challengers in AI and Water research

The data and methods generated by the participants programme can be used by companies, government and research institutions to aid in the resolution of problems related to Water Sustainability, by identifying trends and major areas of discussion, and to explore successful scenarios through similar challenges and cases. IRCAI's SDG 6 Observatory [10] is being built to properly address the challenges of decision makers, using AI. It is benefitting: (i) national governments providing access to a variety of perspectives (including trend and comparative) on a data driven dashboard with information on Water Sustainability trends for decision-making; access to local (e.g. country-level) progress on SDG 6; (ii) educational institutions, offering access to information on current trends on Water Sustainability research and development; (iii) research institutions, sourcing open data over interactive visualisation and research; (iv) the NGO community, easing access to information directly linked to community priorities including citizen science activities; and (v) general population, empowering water education for all.

4 Conclusions and further work

The capacity building to enhance opportunities can benefit from the engagement of the Youth in AI-driven challenges that start in research problems deriving from issues to address in their communities. Problems they know well and data that they often have privilege access to, with promising impact that can ensure the sustainability of the innovation offered. The initiative served us also to collaboratively discuss sustainable solutions that help large scale recovery and define a better and more hopeful inclusive Africa. The winning outcomes of this challenge will integrate a vibrant worldwide Community of researchers and entrepreneurs focusing on AI and SDGs, starting with SDG 6, and supported by initiatives such as IRCAI's Top 100 or the SDG Observatory. Ethical considerations are being addressed in the context of the EC project AI4GOV.

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