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HydroLearn Framework: Water Sense Knowledge Grid for Expert-Led Community Conservation Education

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Abstract

Water scarcity has become a major environmental and social challenge worldwide, particularly in drought-prone regions where inefficient water usage and limited awareness contribute to increasing pressure on water resources. Although digital technologies have created new opportunities for sharing information, users still face difficulties in accessing structured, reliable, and actionable knowledge related to water conservation. Information about water-saving techniques is often scattered across multiple sources, making it difficult for individuals and communities to find organized guidance and practical solutions. Earlier approaches to promoting water conservation mainly relied on offline awareness programs, printed materials, and community campaigns. While these methods helped spread general awareness, they lacked scalability, real-time accessibility, and interactive participation. Users were unable to easily contribute knowledge, access updated resources, or visualize region-specific water challenges through integrated tools. To overcome these challenges, the proposed system introduces a web-based platform developed using the Django framework with a MySQL database for efficient data storage and management. The system provides secure user authentication, expert-driven knowledge sharing, file upload and download functionality, and integrated map visualization to highlight drought-prone areas. Users can share water-saving techniques along with supporting materials, while others can access organized resources through a structured interface. The proposed platform improves accessibility, collaboration, and awareness by providing a unified environment for knowledge exchange. By combining centralized data management, interactive participation, and geographic visualization, the system supports informed decision-making and encourages sustainable water conservation practices, ultimately contributing to improved environmental sustainability and community engagement.

Keywords: Water Conservation, Django Web Framework, Drought Awareness, MySQL, Geographic Visualization.

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1. Introduction

Water is the most essential resource for the production of agricultural and industrial goods and services. It is while only 2.7% of the world's water is available as freshwater, and only 30% of freshwater can be consumed for meeting human needs. In line with these facts, arid and semi-arid countries are not well-endowed with freshwater, and water shortage is a major limitation for their socio-economic development. Also, rapid population growth, economic development, urbanization, industrialization, and land use change have exerted extra pressure on their freshwater resources. Meantime, the frequent and intensive droughts, which are predominantly driven by climate change dynamics, have significantly decreased the stock of freshwater resources while the demand for water consumption has increased in many arid and semi-arid regions of the world [1]. Moreover, climate change is expected to decrease freshwater supplies and increase the frequency and intensity of droughts in arid and semi-arid areas. As a result, water scarcity would turn out to be a great concern soon.

Fig. 1: How water supports human body's healing and function

Particularly, global water scarcity would affect the agricultural sector since agriculture accounts for approximately 90% of water withdrawals in developing countries that their rural economy relies on agriculture heavily. Furthermore, owing to the traditional methods of irrigation and water conveying systems, the efficiency of their irrigation systems is far lower than most developed countries, and a large fraction of scarce water is lost due to evaporation and percolation. Therefore, with the high levels of water stress, affordable use of water resources, improved productivity of farms in a sustainable way, and resilience building are imperative to mitigate the problem of water shortage in the arid and semi-arid regions of developing countries. However, resilience and adaptation are location-specific and depend on various climatic, socio-economic, and agro-ecological factors [2].

2. Literature Survey

Dai, et al. [3] proposed the two representative cases: Singapore's Smart Water Grid and selected pilot programs in Chinese cities (Shenzhen, Hangzhou, Beijing). These cases are analyzed for their level of digital integration, policy alignment, and performance outcomes, offering insights into both mature and emerging smart water implementations. Findings indicated that the transition from manual to intelligent governance significantly enhances system performance and robustness, particularly in response to climate-induced disruptions. Despite benefits such as reduced non-revenue water and improved pollution control, challenges including high initial investment, data interoperability issues, and cybersecurity risks remain critical barriers to widespread adoption. Policy recommendations focus on establishing national standards, promoting cross-sectoral data sharing, encouraging public–private partnerships, and investing in workforce development to support the long-term sustainability and scalability of smart water initiatives.

Shemer, et al. [4] proposed the Climate change, global population growth, and rising standards of living have put immense strain on natural resources, resulting in the unsecured availability of water as an existential resource. Access to high-quality drinking water is crucial for daily life, food production, industry, and nature. However, the demand for freshwater resources exceeds the available supply, making it essential to utilize all alternative water resources such as the desalination of brackish water, seawater, and wastewater. Reverse osmosis desalination is a highly efficient method to increase water supplies and make clean, affordable water accessible to millions of people.

Ssekyanzi, et al. [5] highlighted how social, environmental, economic, and policy factors affect the success of IRSS compared to traditional systems common in developing nations. IRSSs can outperform traditional methods in sustainability, encouraging their adoption. However, there is a significant gap in policy integration that needs to be addressed for successful implementation.

Oremo, et al. [6] analyzed farmers' engagement in water resources management and explored how this can inform water resource planning. Seasonal water scarcity and user conflicts were the major challenges experienced by the farmers. Ordinal and logistic regression models show that knowledge, attitude, and practices were culture-dependent, being impacted by educational attainment, level of income, access to extension, and membership to local networks. Attitude and practice were further influenced by land tenure and farm distance to water sources. Since knowledge of water management issues informed attitudes and practices, improved awareness and targeted extension support are necessary in the development and implementation of policy decisions on water resources management.

Bakar, et al. [7] proposed a subject in need of further theoretical and conceptual investigation. The research reviewed various approaches to effective communication and through a synthesis of the concepts, aimed to present a new, socio-psychological water conservation conceptual framework. The conceptual framework integrated emotional appeal, for use on social media platforms and in order to foster more water resilient communities.

Aboelnga, et al. [8] proposed a new urban water security assessment framework with application to the water-scarce city of Madaba, Jordan. The study applied the new assessment framework on the study area and measures urban water security using the integrated urban water security index (IUWSI) and the analytic hierarchy process (AHP) as a decision management tool to prioritise and distinguish indicators that affect the four dimensions of urban water security: drinking water, ecosystems, climate change and water-related hazards, and socioeconomic aspects (DECS).

Bouramdane, et al. [9] addressed the urban water resource management complexity, offered a multi-criteria approach to enhance traditional single-focused methods, evaluated water strategies in smart cities comprehensively, and provided a criteria-weight-based resource allocation framework for sustainable decisions, boosting smart city resilience.

Megdal, et al. [10] proposed the inspiration for the Special Issue came from their desired to provide a platform for sharing results and informing the global water governance community about the wealth of excellent interdisciplinary and transdisciplinary research and projects being carried out around the world.

3. Proposed Methodology

The Water Conservation Knowledge Sharing and Awareness Platform is a web-based system designed to promote sustainable water management practices by creating a centralized hub for knowledge sharing, collaboration, and resource distribution. The platform provides a space for users to share, access, and download water-saving techniques, tools, and educational videos, aiming to increase awareness and community participation in addressing the growing water crisis. The system allows users to register, log in, and contribute their own ideas or methods for conserving water. Uploaded content, such as documents and videos, is stored securely on the server and made available for others to download and learn from.

Expert Knowledge Sharing Technique

The Expert Knowledge Sharing Technique is one of the most vital operations in the system, enabling domain experts, educators, or environmentalists to contribute their ideas,

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research insights, and practical solutions related to water conservation. This feature acts as the foundation for community education, as it allows experts to upload their techniques, tools, or awareness videos into a centralized digital repository. The system ensures that every contribution is securely stored, properly categorized, and made accessible to all registered users through an interactive and user-friendly interface. This continuous sharing and collaboration promote sustainable learning and knowledge dissemination within the community.

Accessing the Knowledge Sharing Interface: When an expert logs into the platform, they can navigate to the “Share Knowledge” section from their user dashboard. This interface provides an input form where experts can enter their ideas, methods, or innovative techniques related to water saving. It serves as the starting point for knowledge contribution within the platform.

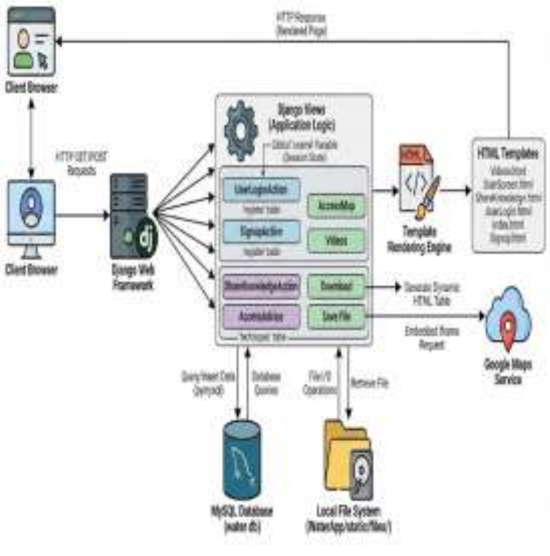

Fig. 2: Proposed system architecture.

Entering Descriptive Content: In this step, the expert writes a short explanation or description of their technique in the text box provided. The description may include details about the method, materials used, and how it helps in conserving water. The system captures this text data and prepares it for database storage once the expert submits the form.

Uploading Supporting Files or Videos: Along with the written content, experts can attach additional educational resources such as PDF documents, images, or awareness videos. The uploaded file is handled by Django’s FileSystemStorage, which temporarily stores the file in memory before writing it to the project’s local directory. This ensures that both textual and multimedia content are preserved for community access.

Data Transmission and Processing: After submission, the system processes the entered data and the uploaded file together. Django’s backend reads the file’s binary content and captures its filename for reference. The collected data is then prepared for insertion into the centralized MySQL database under the techniques table.

Database Insertion and Metadata Storage: The system connects to the MySQL database using the PyMySQL library and executes an insert query. It stores the expert’s username, the description of their idea, the filename, and the current date as metadata. This ensures that every technique is permanently recorded and traceable to its contributor.

File Storage in Centralized Repository: Before saving, the system checks whether a file with the same name already exists in the storage directory (WaterApp/static/files/). If it does, the old version is replaced with the new one to maintain an updated repository. The uploaded file is then written to the server’s storage, completing the upload process.

Confirmation of Successful Upload: Once the database and file storage processes are successfully completed, the system generates a confirmation message. This message informs the expert that their technique has been successfully uploaded and shared on the

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centralized platform. It serves as a feedback mechanism, assuring users that their contribution is now accessible to others.

Public Accessibility and Knowledge Dissemination: The uploaded ideas and materials become visible to all registered users through the "Access Advice" section. Community members can view expert names, read the shared ideas, and download attached resources for personal learning or local implementation. This continuous sharing cycle transforms the platform into an evolving knowledge hub for sustainable water management.

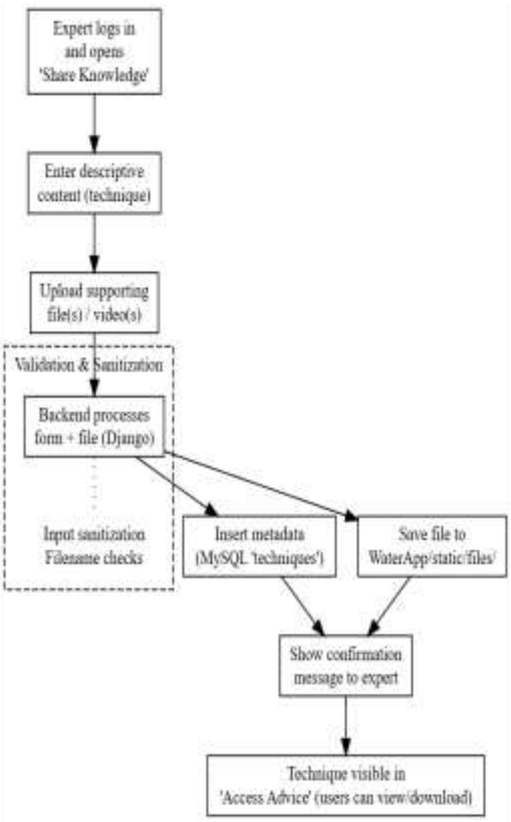

Fig. 3: Internal operation for expert knowledge sharing technique

Centralized Data Storage and Retrieval Technique

The Centralized Data Storage and Retrieval Technique play a crucial role in ensuring that all user activities, expert uploads, and shared knowledge are stored securely and can be accessed efficiently when required. This technique is responsible for managing the storage of data related to user registrations, expert-contributed water conservation techniques, and associated files. It uses a centralized MySQL database that allows structured storage, easy retrieval, and consistency of data across the entire system. By linking Django's backend logic with the MySQL database through PyMySQL connectivity, the platform ensures seamless communication between the web interface and the data repository.

Database Connection Initialization: When the user interacts with the system, Django first establishes a connection with the MySQL database using the PyMySQL connector. The connection parameters such as host address, username, password, and database name are defined to create a secure communication channel. This step ensures that all subsequent operations like data insertion or retrieval take place on a valid and authenticated connection.

Data Insertion During Knowledge Sharing: Whenever an expert uploads a new water-saving idea or educational material, the details are captured from the web form. The backend script extracts information such as the expert's name, the technique description, file name, and upload date. These values are then inserted into the techniques table of the database, ensuring that every contribution is stored in a structured and retrievable format.

Data Retrieval for User Access: When any user visits the "Access Advice" page, the system executes a SQL query to fetch all the stored records from the techniques table. This includes expert names, water conservation ideas, and uploaded file details. The retrieved data is processed in the backend and converted into a tabular HTML format before being sent to the user interface for display.

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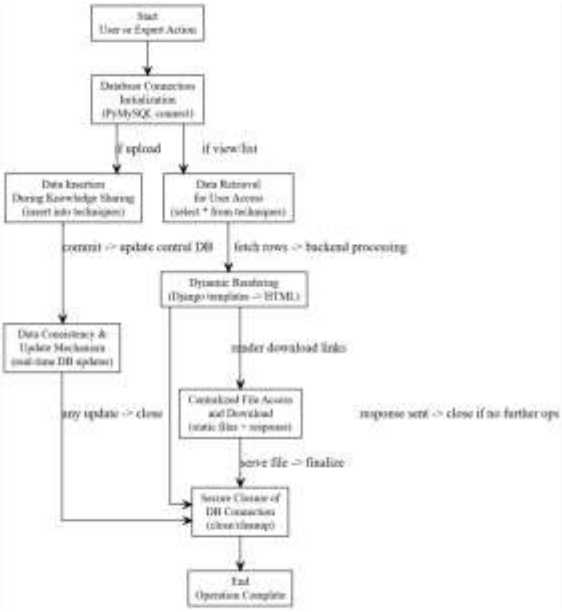

Fig. 4: Internal operation for centralized data storage and retrieval technique

Dynamic Rendering of Retrieved Data: The fetched data from the database is dynamically rendered through Django's template engine. Each record is displayed in a well-structured table with relevant columns such as Expert Name, Description, Upload Date, and a Download option. This makes the data presentation interactive and easy to understand for community members.

Centralized File Access and Download: Each technique record includes a reference to an uploaded file stored in the static file's directory. When users click on the download link, Django locates the corresponding file using the filename retrieved from the database. The system then provides the file as a downloadable HTTP response, ensuring smooth access to shared educational materials.

Data Consistency and Update Mechanism: The centralized structure ensures that all user and expert data is maintained consistently across the system. Any modification or new entry instantly updates the central database, allowing real-time reflection of information on all user interfaces. This prevents redundancy and ensures that all community members access the latest and verified content.

Secure Closure of Database Connection: After every data operation whether it is insertion, retrieval, or update the system securely closes the database connection. This helps maintain the integrity of stored data and prevents potential issues like unauthorized access or memory leaks. By managing the database connection lifecycle efficiently, the platform ensures reliable and stable performance.

4. Results description

Fig. 5 depicts the knowledge sharing confirmation screen for water conservation, representing the successful submission and storage of user-contributed techniques or ideas. It illustrates how shared knowledge becomes part of a centralized repository accessible to other community members. The figure reflects collaborative participation where users contribute practical conservation methods. It demonstrates the system's capability to support collective learning and information exchange.

Fig. 5: Knowledge sharing confirmation for water conservation.

Fig. 6 illustrates the access expert advice screen for water conservation, representing how users retrieve professional insights and recommended practices from experts. It depicts structured information that supports informed decision-making related to water-saving techniques. The figure reflects the connection between community users and domain experts within the learning platform. It

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highlights the availability of curated knowledge aimed at improving conservation awareness.

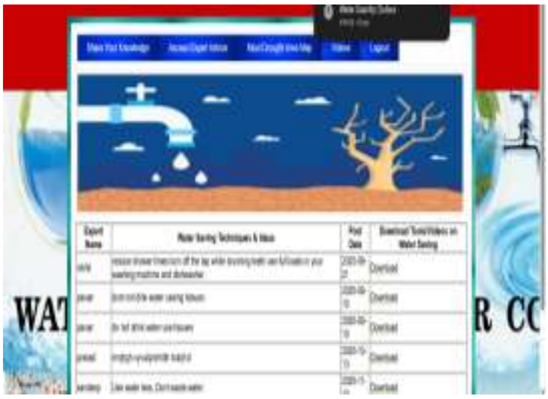

Fig. 6: Access expert advice screen for water conservation.

Fig. 7 depicts the most drought area map for water conservation, representing the visualization of geographical regions affected by water scarcity. It illustrates how spatial data is integrated to provide awareness about drought-prone locations. The figure reflects the system’s capability to combine mapping tools with educational resources for better understanding of environmental challenges. It demonstrates how users can explore location-based insights to support conservation planning.

Fig. 7: Most drought area map for water conservation.

Fig. 8 illustrates the videos section for water scarcity, representing the multimedia learning component within the Hydro Learn platform. It depicts the availability of educational video resources focused on water conservation techniques and awareness topics. The figure reflects the use of visual content to enhance knowledge dissemination and improve user engagement. It highlights how curated learning materials support awareness about sustainable water management practices.

Fig. 8: Videos section for water scarcity.

5. Conclusion

The research successfully demonstrates a robust, web-based system that centralizes expert knowledge and makes it accessible to the broader community. By integrating features such as expert-verified techniques, downloadable resources, and interactive maps of drought-prone areas, the platform effectively bridges the gap between water conservation experts and community users. Performance improvements, such as optimized database queries, secure session management, and efficient file handling, have enhanced the system’s responsiveness and scalability, ensuring smooth user experience even as the volume of shared knowledge grows. Moreover, the inclusion of real-time knowledge sharing fosters collaborative learning, empowering users to not only access information but also contribute practical techniques, thereby creating a dynamic ecosystem for sustainable water management.

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