




## Article

# ClimInonda: A Web Application for Climate Data Management: A Case Study of the Bayech Basin (Southwestern Tunisia)

Zaineb Ali <sup>1,2,\*</sup> , Amine Saddik <sup>2,3,4,5</sup>, Bouajila Essifi <sup>2</sup> , Brahim Erraha <sup>6</sup>, Adnane Labbaci <sup>7</sup>   
and Mohamed Ouessar <sup>2</sup> 

- <sup>1</sup> Higher Institute of Water Sciences and Techniques of Gabes (ISSTEG), University of Gabes, Gabes 6072, Tunisia
- <sup>2</sup> Laboratory of Eremology and Combating Desertification (LR16IRA01), Institut des Regions Arides (IRA), University of Gabes, Medenine 4119, Tunisia; amine.asaddik@e-polytechnique.ma (A.S.); bouajila.essifi@ira.agrinet.tn (B.E.); ouessar.mohamed@ira.rnrt.tn (M.O.)
- <sup>3</sup> Laboratory of Systems Engineering and Information Technology LISTI, National School of Applied Sciences, Ibn Zohr University, Agadir 80000, Morocco
- <sup>4</sup> Laboratory of Applied Geology and Geo-Environment, Ibn Zohr University, Agadir 80035, Morocco
- <sup>5</sup> Laboratory of Sustainable Innovation and Applied Research, International University of Agadir, Bab Al Madina, Quartier Tillila, B.P. 8143, Agadir 80000, Morocco
- <sup>6</sup> Science of Information Technology d', Data, Mathematics and Applications (ESTIDMA), National School of Applied Sciences, Ibn Zohr University, Agadir 80000, Morocco; b.erraha@uiz.ac.ma
- <sup>7</sup> Laboratory of Geosciences and Geo-Environment, Geology Department, Faculty of Sciences of Agadir, Ibn Zohr University, B.P. 8106, Agadir 80000, Morocco; labbaciadnane@gmail.com
- \* Correspondence: zainebali93@gmail.com

**Abstract:** The Bayech basin is located in southwestern Tunisia, a highly prone region to flooding risks. The Bayech basin is characterized by wadis that adopt a wide, sometimes ill-defined bed, often intersected by low-lying areas, resulting in a semi-endoreismo, greatly disrupting the flow regimes. The Bayech basin drains the slopes of the Nementchas and Tebessa mountains in Algeria, collecting water from the Medjen Bel Abbes plain in its middle course before crossing the Gafsa djebels chain at the Gafsa gap. In this basin, flooding is generally caused by high-intensity storms and is often relatively limited in extent. The slope shape and soil type can promote rapid surface runoff during intense rainfall. Therefore, the purpose of creating a web application, labeled ClimInonda, is to respond to a critical need of readily available information on climatic, environmental, and land use data collected in this basin and its morphometric characteristics using recent methods. The application consists of three essential components: the front-end, back-end, and database. The front-end focuses on the user interface, allowing users to interact with the application's features. It communicates with the back-end through Hypertext Transfer Protocol requests for data processing and retrieval. The back-end handles the server-side operations, processes requests, and provides responses by retrieving data from the database. The database stores and manages the application's data, ensuring integrity and efficient access. This modular architecture ensures a user-friendly interface, seamless data processing, and reliable data storage. Visualizations can include different types of data, such as satellite imagery, weather data, and terrain data, and can be displayed using various techniques, such as heat maps, contour maps, and 3D models, by providing easy-to-understand visualizations. ClimInonda is an application developed to expand upon existing platforms by providing a suite of exploratory data analysis features, including the ability to calculate the total precipitation depth recorded for any period, interpolate the annual recurrence interval for rainfall events, etc. A simple evaluation of the platform was performed to assess the usefulness and user satisfaction of the tool by professional users, and positive feedback was received. There is clear evidence that ClimInonda would provide the necessary basis for informed decision making by stakeholders and development agencies in arid and semi-arid Tunisia.

**Keywords:** web application; climate data; ClimInonda; Bayech Basin



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## 1. Introduction

The development of web applications dedicated to environmental and water resources has grown in popularity to serve a vast amount of data accessible to a specialized as well as a public audience, commonly helping professionals and scientists to derive conclusions and make decisions [1]. Several studies have reported such web development efforts that promote open analyses of the environment, hydrology, and hydraulics [2,3]. The web applications could provide obvious advances in conducting hydrologic research, environmental data extraction [4], mapping visualizations [3], geospatial data processing, statistical operations, as well as manipulating and analyzing data for specific domains [5].

The knowledge on hydrologic variability inferred from climate and rainfall data is the fundamental basis of the design and operation of most hydraulic facilities such as dams, reservoirs, and bridge piers. It also provides crucial information to develop water resources to plan against natural disasters such as floods, droughts, and landslides. However, such rainfall data are very often not available, because of the lack of a rainfall gauge at the study location or the malfunction of existing rain gauges [6,7].

Several platforms have been created for the collection and visualization of hydrological data from a variety of sources. Particularly, the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) HydroClient (<http://data.cuahsi.org/>, accessed on 22 January 2022) accesses hydrologic data from over 95 sources stored in the CUAHSI Hydrologic Information System (HIS). This system was designed to take into account the syntactical and semantic heterogeneity of environmental data using a standard observation data model (ODM) database format for data storage and WaterOneFlow web-based services for data communication [8]. A related platform, the Time Series Analyst (TSA) (<http://data.iutahescor.org/tsa/>, accessed on 26 January 2022), is capable of retrieving any dataset published in the CUAHSI HIS and provides more innovative tools for data visualization, including a mapping interface, faceted filters, and the possibility of displaying data using time series, box graphs, or histograms. Furthermore, the TSA includes the calculation of data summary statistics [9].

Also, the Great Lakes Dashboard (GLD) platform ([https://www.glerl.noaa.gov/data/dashboard/GLD\\_HTML5.html](https://www.glerl.noaa.gov/data/dashboard/GLD_HTML5.html), accessed on 26 January 2022) was specifically designed as a tool to visualize and download datasets from the North American Laurentian Great Lakes and displays plots for a multitude of different time series datasets [10]. In addition, the Virtual Observatory and Ecological Informatics System (VOEIS) Data Hub (<https://voeis.msu.montana.edu/>, accessed on 30 January 2022) is offering tools for users to compile, manage, view, and redistribute datasets. The VOEIS Data Hub can be used by users to download data or retrieve data from networked sensors with QA/QC (Quality Assurance (QA) and Quality Control (QC)) capabilities. Furthermore, the VOEIS Data Hub includes data access restriction features and allows users to publish data to a CUAHSI HIS Hydro Server [11]. Despite the advancements of these platforms, they are limited by the lack of data analytic tools.

Web mapping applications offer an effective way to provide geospatial information to non-technical end users [12]. Without any additional software, web applications offer increased responsiveness using modern techniques like Ajax (Asynchronous JavaScript and XML) and object-oriented architectures like the RESTful (REpresentational State Transfer) web service architecture [13].

Recently, researchers have dealt with the development of web GIS applications [14] on the basis of web services, cloud computing platforms [15], and mobile applications that critically depend on the same orientation [16].

In addition, this can provide interactive and dynamic visualizations of remote sensing data, allowing users to explore and analyze the data in a user-friendly way. This can help decision-makers and stakeholders to understand the current state of the environment and identify areas that are at high risk of flooding. The visualizations can include different types of data, such as satellite imagery, weather data, and terrain data, and can be displayed using various techniques, such as heat maps, contour maps, and 3D models. By providing easy-to-

understand visualizations, web applications can help decision-makers and stakeholders to make informed decisions about flood risk management. Additionally, the visualizations can be used to communicate the potential impacts of flooding to the public, raising awareness and encouraging preparedness measures.

In this research, a web application is proposed to enable its users to manage various data sources, i.e., rainfall, dams, and climate data in the study area. This application, labeled “ClimInonda”, is a web-based application, so any end users with internet access and an internet browser can synthetically generate various available data.

This paper is structured as follows: in Section 2, the overall architecture of the ClimInonda web application is explained. Then, the result and discussion are presented in Sections 3 and 4. Finally, Section 5 presents the main conclusions of the study. The problem rationale, related to visualizing and analyzing different data in Bayech basin, is addressed through the introduction of a novel and user-friendly web application. An open-access and interactive data visualization and analysis are performed via ClimInonda. The adopted approach is described, with a brief review of similar applications, data processing, and the discussion of the results.

## 2. Materials and Methods

### 2.1. Study Area

The Bayech basin is located in the southwest of Tunisia, stretching over 6491 km<sup>2</sup> and divided into two distinct parts: the Tunisian part covers an area of 4508 km<sup>2</sup> in two governorates (Gafsa and Kasserine), corresponding to approximately 69.5% of the basin total area, whereas the Algerian section has an area of only 1983 km<sup>2</sup>, in the province of Tebessa. The studied area is characterized by a diversity of natural landscapes, including deserts, oases, and mountainous landscapes, where the elevation ranges from 0 to 1704 m above sea level. The basin belongs to the arid to semi-arid Mediterranean climate, with the average rainfall not exceeding 300 mm. The most populated areas are in the plains, and along the river and its tributaries. Three dams are located in this basin: Safsaf El Ouesra, Sidi Aich, and Lekbir (Figure 1).

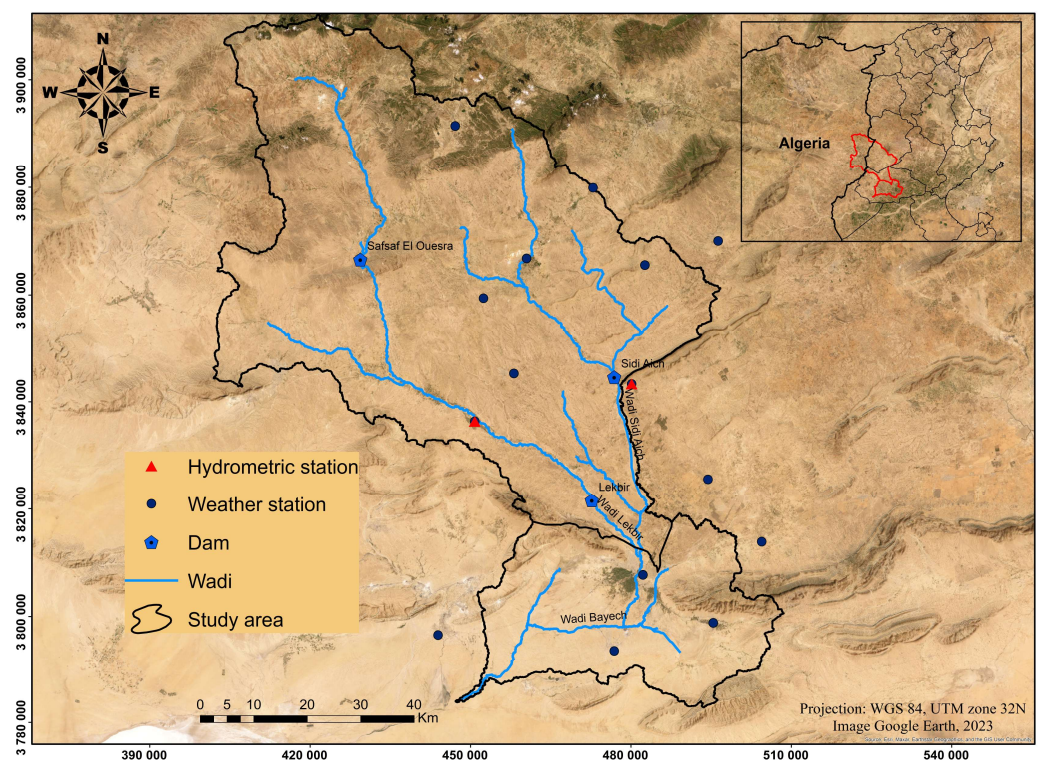
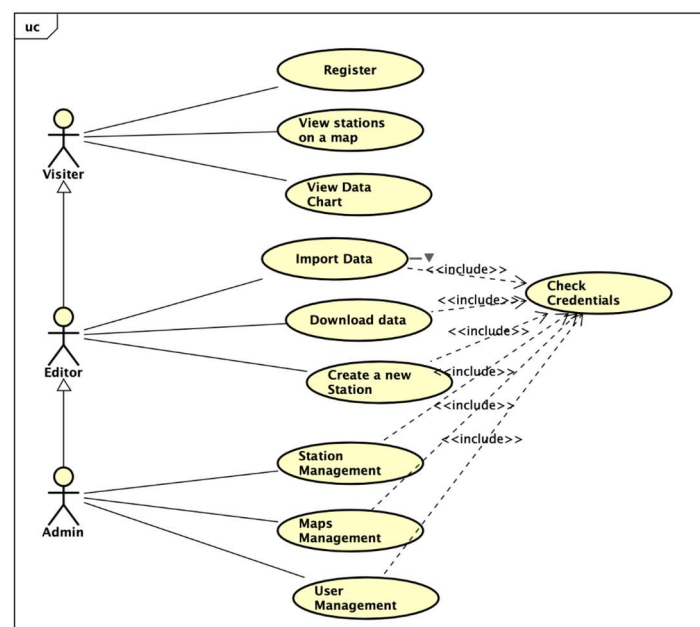


Figure 1. Location map of the study area.

## 2.2. Methodology

### 2.2.1. Design and Analysis

The application developed in this research serves a diverse array of users with varying needs and requirements. It is carefully designed to accommodate different user roles and is organized into three distinct modes of use. The first is the guest mode, which offers a user-friendly interface to explore the application's features without the need for signing up for an account. The aforementioned features include visualizing data charts and geolocating different stations, with the possibility of registration if additional functionalities are needed. The second is the editor mode, designed for users who require advanced capabilities, including importing and downloading data, as well as creating and customizing various stations within the application. Finally, there is the administrator mode, which oversees the overall functionalities (stations, maps, and accounts) and access levels of the application. Figure 2 illustrates the modes of use for the application, with an overview of the interactions between different modes.



**Figure 2.** Overview of the user mode.

### Sequence Diagram

This sequence diagram provides a comprehensive visualization of interactions within a web-based system involving various actors, namely the Administrator, the System, and the Editor. It highlights the specific actions and roles of each actor, in accomplishing specific tasks. At the top of this diagram is the Administrator, who initiates the process by assigning a map to the Editor. The Administrator, assuming their privileged role, ensures that the Editor has access to the necessary resources and permissions to carry out their responsibilities effectively.

Once the map is assigned, the Editor takes over and proceeds with creating a station on the designated map. This step involves leveraging the system's tools and features to define and establish the station's parameters, such as location, attributes, and associated data. Subsequently, the Editor's attention shifts toward importing data, an essential aspect of enriching the station's content. The data imported could originate from various sources, such as external files or databases. Through the system's capabilities, the Editor integrates the imported data into the station, ensuring its relevance and accuracy. With the station created and data imported, the Editor moves forward with the conversion of these data into a graph. This process may involve utilizing the system's built-in graphing functionality or employing external libraries and tools. By transforming the data into a graphical



representation, the Editor enables users to grasp and interpret the information in a more visual and intuitive manner. As a result, the graph is readily available and can be viewed and downloaded by users. This functionality enhances the ease of access and usefulness of the system, empowering users to interact with the data and make informed decisions based on the presented insights.

By presenting the sequence of interactions and the roles of different actors, the diagram, illustrated in Figure 3, gives a clear understanding of the system's workflow and the responsibilities of each participant. It serves as a valuable reference, enabling users to know the intricacies of the system's functionality and identify potential areas for optimization or refinement.

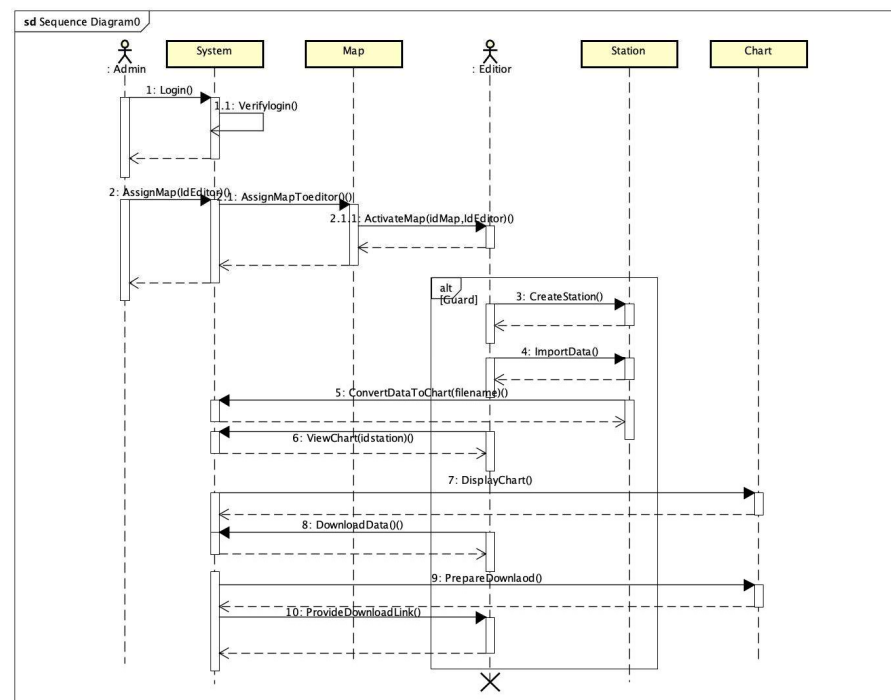


Figure 3. Overview of sequence diagram.

### 2.2.2. Database Diagram

The obtained database consists of seven distinct tables, each addressing a specific purpose. These tables are shown as follows:

**Maps:** This table stores comprehensive information about all derived maps. It includes details, i.e., map attributes, current status, and whether a password for access is required.

**Station:** This contains data directly associated with individual stations. It has information related to the station's name, latitude, longitude, and other relevant details. Additionally, it tracks the creator of each station and maintains a list of users who have access to a given station. A status field is incorporated to indicate whether a station is active, inactive, etc.

**Maps\_assign:** This table represents the assignment of users to specific maps. In addition, it stores information on granted permissions including the ability to create, modify, or delete content within those maps.

**Users:** This records user information, including their email address, name, and other relevant data. It also includes a role designation, indicating whether the user is an administrator, editor, or guest. The table includes a status field, allowing for tracking the user confirmation status (pending confirmation by the administrator), deletion status, and other relevant status. It is important to note that all passwords are securely stored in an encrypted format using a specialized library to ensure data security.

**Categories:** This table represents various available categories for stations. Users have the ability to add new categories and define default markers for all stations within a specific category.

**Station\_Data:** This stores all existing data associated with a particular station. These data are typically imported by users and stored as JSON files. The table maintains references to the location of these JSON files, serving as the data source for generating graphs and visualizations.

**Station\_icon:** This table stores icons or markers for each station. These icons visually represent the station on maps or within the application's user interface.

By organizing data into these distinct tables, the database enables efficient storage, retrieval, and management of information related to maps, stations, users, categories, and station-specific data. This structured approach enhances data integrity, simplifies queries and updates, and supports the overall functionality and usability of this application. Table 1 shows the keywords and the layout of the database, with A: Alphabetic, AN: Alphanumeric, N: Numeric, and D: Date.

**Table 1.** Layout of the database.

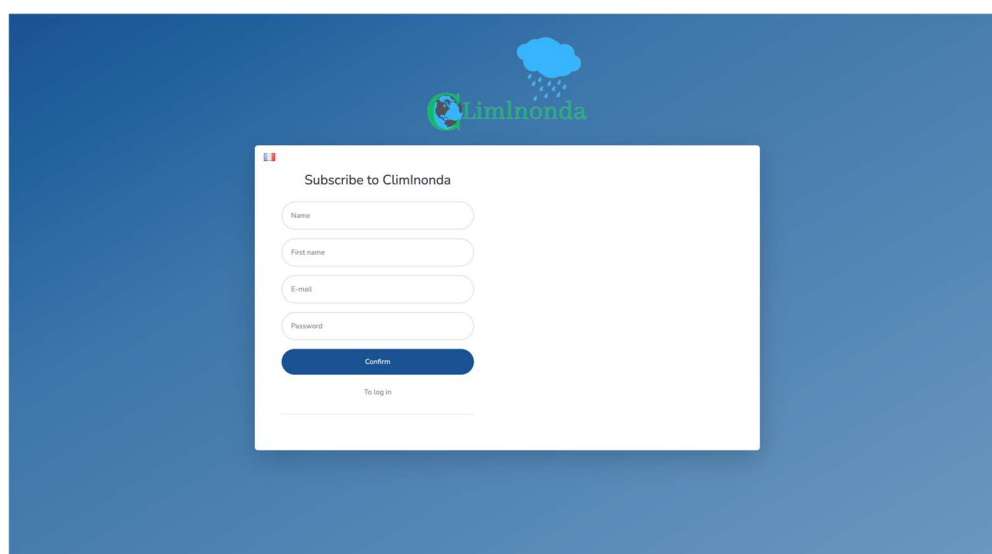
Entity	Attribute	Signification	Type	Length
Users	Id_user	User ID	N	10
	Firstname	User's name	A	30
	Lastname	User's first name	A	30
	Username	User's login	AN	10
	Password	User's Password	AN	30
	Email	User's email	AN	35
	role	User role	A	10
	Active	Account status	N	1
Maps	Id_map	Card ID	N	10
	Name_map	Card Name	A	30
	Code_map	Password to access a card	AN	30
	Map_style	Card Style	A	10
	Active	Card Status	N	1
Maps Assign	Edit_map	Permission to make a modification on a card	N	1
	Create_map	Permission to create a map	N	1
	Edit_station	Permission to make a modification on a station	N	1
	Delete_station	Permission to make a total deletion of a station	N	1
Categories	id_categorie	Category ID	N	10
	name_categorie	Name of a category	A	30
	Marker_color	Marker Color	N	5
	Marker_style	Marker style	A	10
	Marker_icon	Marker Icon	A	10
	Marker_img	Marker image link	AN	40
Stations	Id_station	Station identifier	N	10
	Lat	Latitude coordinates of a station	N	30
	Lon	Longitude coordinates of a station	N	30
	Station_name	Station name	A	30
	Bassin	Station Basin	A	30
	desc	Station Description	AN	120
Station_Data	Id_data	Station data identifier	N	10
	Id_station	Station identifier	N	10
	Description	Data type description	AN	120
	datapath	Station data path	AN	40

During the registration process, the application requests several pieces of information from users to create their accounts. These essential details include the following:

**Email Address:** Users are required to provide a valid email address, which will serve as their unique identifier within the system. This email address will also be used for communication purposes, such as account notifications and password reset requests.

**First and Last Name:** Users are asked to provide their first and last name, allowing us to personalize their experience within the application and facilitate effective communication.

Once a user submits their registration request, it is forwarded to the administrator for review and confirmation. The administrator interface plays a pivotal role in managing user registrations and ensuring the security and integrity of the user base. The administrator reviews the provided information, verifies its accuracy, and evaluates the request before proceeding with confirmation. The administrator interface provides an intuitive and efficient platform for administrators to review and manage user requests. This interface allows administrators to access pending registrations, view the details provided by the user, and make an informed decision regarding their confirmation. This step ensures that only valid users are granted access to the system, maintaining its security and preventing unauthorized access. Upon confirming a new user via the administrator interface, the user is granted access to the application, and their account is activated. This confirmation process adds an extra layer of security and ensures that the user base consists of verified individuals. By implementing this registration workflow, this app enhances the integrity and security of the user accounts. The involvement of the administrator in the confirmation process allows for careful screening of new registrations, preventing spam or malicious accounts from infiltrating the system. Additionally, this process enables administrators to proactively manage and maintain a trusted user community. Figure 4 shows the registration interface.



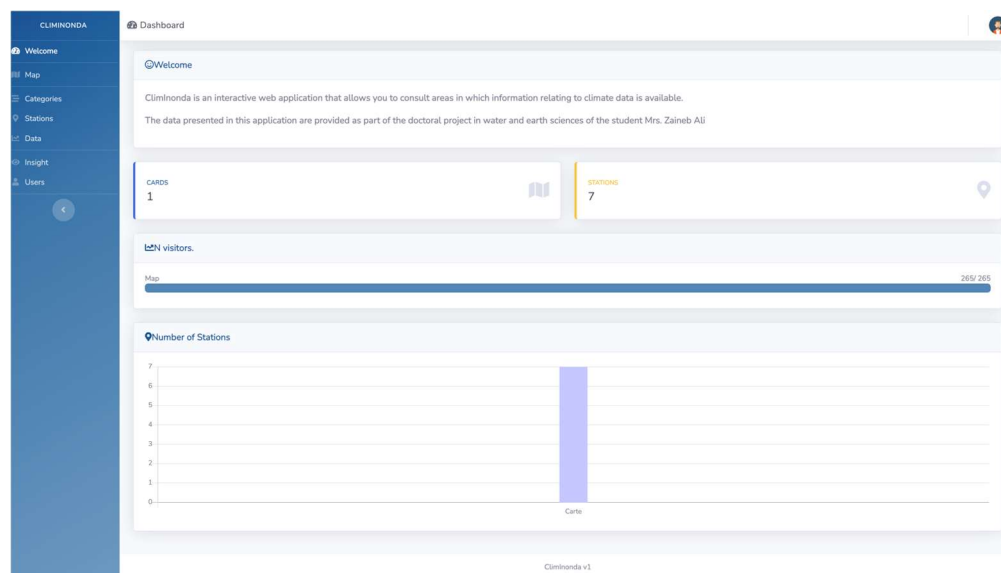
**Figure 4.** Registration interface.

On the login page, users can access their accounts only if their registration has been approved by the administrator. This additional layer of approval adds an important security measure, ensuring that only authorized users can log in and access the application. While attempting to log in, the users are prompted to enter their registered email address and password. Once the login credentials are submitted, the system checks whether the user's account has been approved by the administrator. If the account has not yet been approved, the user receives a notification mentioning that their account is still pending approval.

### 2.3. User Interface

The lateral menu provides users with easy access to the main tabs, functionalities, and module within the application. It presents a streamlined interface that enhances the

user experience with the various features of the system. These tabs serve as entry points to access different sections and actions, enabling users to seamlessly navigate through the application. Figure 5 shows the login menu.



**Figure 5.** Login menu.

Moreover, the lateral menu is dynamic, where certain functionalities are conditionally displayed based on the user's access authorization. This access control mechanism ensures that users only see and can interact with the features and modules that are relevant and permitted based on their assigned roles. For instance, an administrator may have access to an array of advanced administrative tools and settings, to manage users, configure system preferences, and perform administrative tasks. On the other hand, an editor or a guest may have access to a subset of functionalities tailored to their respective roles and responsibilities.

On the application's main page, in addition to the welcome message, users will find two handy widgets that provide valuable information.

The first widget on the main page presents an instant overview of the total number of stations within the system. By displaying this information prominently, users can gauge the extent of the station database and gain insights on available data.

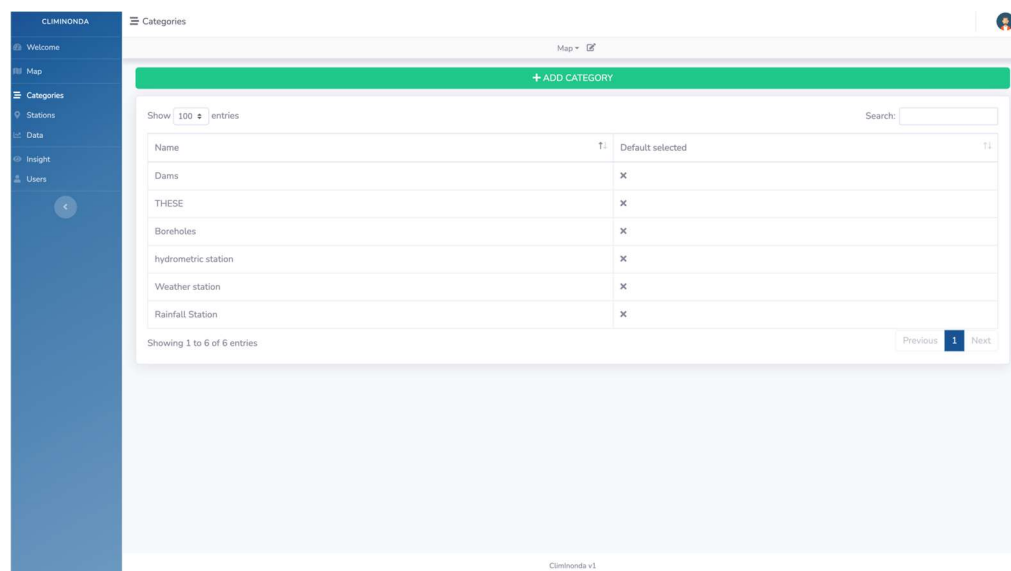
The second widget complements the first one by showcasing the number of available maps, providing users with a snapshot of the map collection in the application. Additionally, on the main page, a guest counter is integrated to capture effective data about the user engagement, usage trends, peak times, and overall user interest. This information can be used to optimize system performance and make informed decisions for future enhancements.

### 2.3.1. Map

In this section, the map manager, a powerful tool for handling maps within the application, is introduced. The map manager serves as a central hub for users to visualize, create, and modify maps, offering a comprehensive set of features to enhance their map-related activities. One of the primary functions of the map manager is to provide users with an overview of the maps already created. Through an organized interface, users can browse a visual list of existing maps and therefore quickly locate and access specific maps of interest, facilitating seamless navigation within the application. Furthermore, the map manager enables users to create new maps, making it possible to freely design and customize their own geographical representations. Users can utilize various tools and options to define the map's attributes, i.e., title, description, and other relevant metadata.



This flexibility empowers users to tailor maps according to their specific needs, ensuring that they align perfectly with their intended purposes. Figure 6 shows the different maps used in this application.



**Figure 6.** Different maps used.

In the dedicated tab, as illustrated in Figure 7, users can explore and manage the categories associated with each station. This tab offers a full overview of the existing categories of stations, enabling users to customize, edit, and create new categories based on their preferences and organizational requirements. By accessing this tab, users gain insights into the categorization system employed within the application. They can explore the various predefined categories that have been set up, each representing a distinct classification or grouping for stations. These categories serve as organizational labels or tags, helping users efficiently navigate and locate stations based on their specific criteria or interests. Furthermore, users are able to modify and edit them. This functionality ensures that the category structure remains up-to-date and adaptable to evolving needs. Users can modify category names, descriptions, or any other relevant attributes, to be aligned more accurately with their intended purposes or reflecting changes in the station landscape.

### 2.3.2. Stations

As a key processing mode within the application, the station management tab focuses on efficient data management. This tab offers users comprehensive control over their stations, providing various tools and functionalities to streamline station-related tasks. Upon accessing the station management tab, users are presented with a clear and organized list of stations. Each station is accompanied by relevant details such as its type and status, offering users a quick overview of the station database. This consolidated view facilitates the straightforward identification and tracking of stations, allowing users to monitor their data effectively. To further enhance usability, the station management tab includes a search bar and filters. These features enable users to quickly locate specific stations or filter the list based on their specific needs. The search bar allows users to enter keywords or station names, instantly narrowing down the list to the desired results. This functionality saves time and replaces manual scrolling and searching through a long list of stations. Additionally, the filters provide users with the flexibility to refine their station list based on specific criteria such as station type or status. By selecting the desired filter options, users can instantly update the displayed list, focusing only on stations that meet their specified criteria. This feature enhances user control and provides a customized view of stations. Users can easily locate specific stations or sort specific stations based on relevant criteria,

improving efficiency and productivity. This feature is particularly beneficial in scenarios where users deal with a large number of stations or need to quickly find stations that match specific characteristics or attributes. Figure 8 shows the station management part.

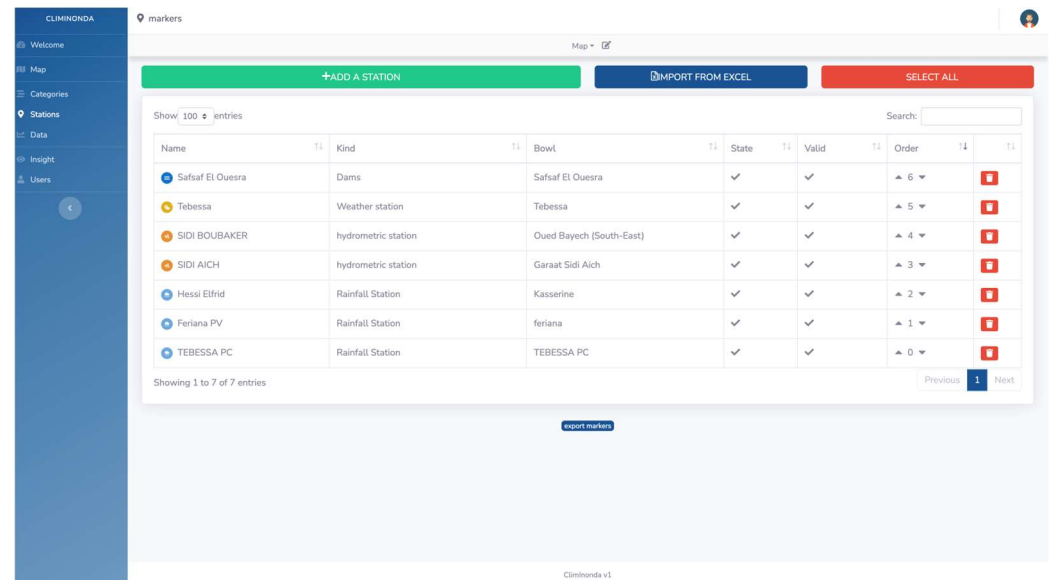


Figure 7. Stations.

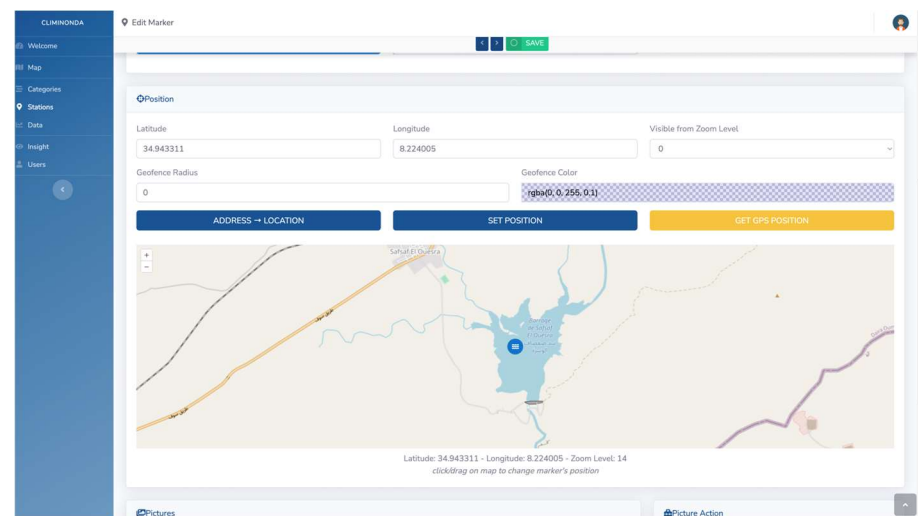


Figure 8. Interface of add a location.

To add a station to the application, users are required to provide specific information that accurately represents the station's characteristics. This process ensures that the station is appropriately categorized and its details are accurately captured within the system.

The following information are required to add a station:

**Station Name:** Users are prompted to enter a descriptive name for the station, for easy identification and reference.

**Type of Station:** Users are prompted to select the appropriate type of station from predefined options or a customizable list. This categorization helps in organizing stations based on their specific characteristics or purposes.

**Basin:** Users can specify the basin or geographical region to which the station belongs. This information facilitates the further categorization and organization of stations based on their location or regional relevance.

Description: Users have the option to provide a brief description or additional details about the station. This allows for a more comprehensive understanding of the station's purpose, features, or any other pertinent information.

Once the required information is provided, users can proceed to choose a suitable style for the station icon. The station icon serves as a visual representation of the station on maps or other graphical interfaces, enabling users to quickly identify and distinguish stations. Following the selection of the icon style, users need to input the latitude and longitude coordinates for the station's location. To simplify this process, an interactive map is integrated into the interface. This interactive map allows users to easily input the coordinates by clicking on the given location on the map. This feature eliminates the need for manual input and ensures accurate positioning of the station on the map. Users can visually confirm the accuracy of the selected location, improving the precision and reliability of the station's placement within the application shown in Figure 8.

#### *2.4. Implementation*

The application developed in this research work is structured into three distinct blocks, each serving a specific purpose in the overall functionality of the system.

**Front-end:** The front-end component encompasses the user interface and everything that users can see and interact with. It includes the visual elements, design, and layout of the application. Users can access various features and functionalities through the front-end, such as viewing maps, managing stations, and analyzing data. When the front-end requires data from the system, it communicates with the back-end using HTTP (Hypertext Transfer Protocol) requests. These requests serve as a means for the front-end to retrieve and send data to the back-end for processing and retrieval.

**Back-end:** The back-end component represents the server-side of the application. It is responsible for handling the processing, calculations, and logic required to provide the requested data and perform necessary operations. The back-end interacts with the front-end by receiving HTTP (Hypertext Transfer Protocol) requests and generating appropriate responses. It retrieves data from the database, performs required computations, and returns the results to the front-end. The back-end is designed to efficiently handle multiple user requests, ensuring smooth operation and responsiveness of the application.

**Database:** The database component plays a vital role in storing and managing the application's data. It serves as a repository for storing information related to maps, stations, user details, and other relevant data. The database communicates with the back-end through transactions, enabling seamless data retrieval, updates, and storage. It ensures data integrity, security, and efficient access to information when requested by the back-end. The database serves as a reliable and scalable storage solution, allowing the application to handle large volumes of data and support concurrent user interactions.

Designing the application in three blocks ensures a modular and scalable architecture. The front-end provides an intuitive and user-friendly interface, facilitating user interactions. The back-end handles the computational and processing tasks, serving as the core engine of the application. The database serves as a reliable and efficient storage solution, ensuring data integrity and accessibility. By adopting this architecture, the application achieves a separation of concerns, making it easier to maintain, update, and scale. It allows for flexible development and facilitates the integration of additional features and enhancements in the future. The collaboration between the front-end, back-end, and database components ensures a cohesive and robust application that meets the needs of users and effectively manages the data of the system. Figure 9 shows an implementation graph for the developed application.

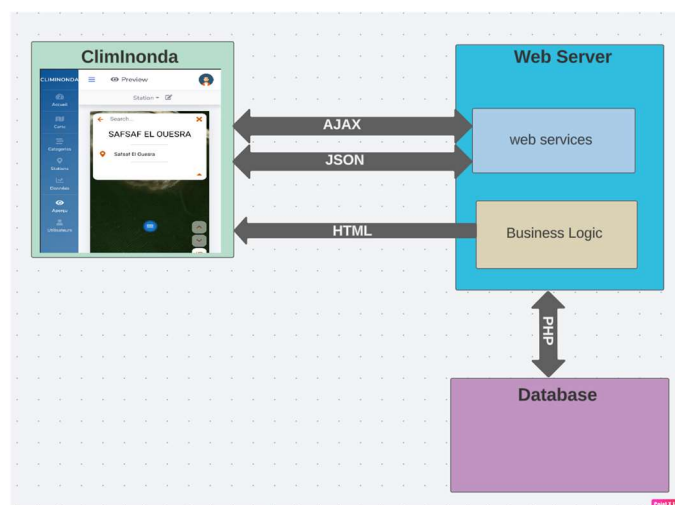


Figure 9. Implementation graph for the established application.

### 3. Results

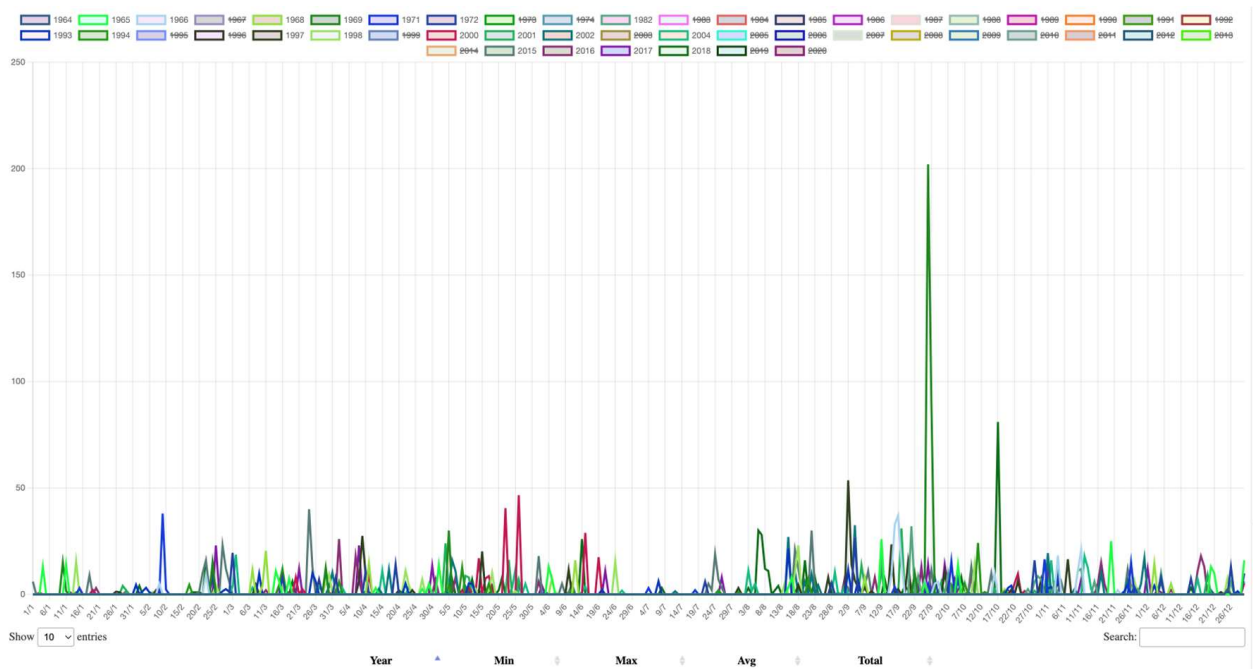
The described work presents a user-friendly web application, labeled ClimInonda, which provides an insightful platform for creating, processing, and visualizing various data sources, particularly climate and environmental data. The main objective of this application is to assist users in handling data and facilitating its use for different purposes and applications. ClimInonda is based on the principle of web data management, allowing users to easily upload, store, and organize climatic and geospatial data in a secure online platform. This functionality ensures data availability at any time and from any internet-connected device. An essential feature of ClimInonda is its real-time data processing. This means that users can instantly view updated information, i.e., if the data come from real-time weather sensors, users can monitor live weather changes and adjust their actions accordingly. The application also offers advanced visualization features to present data in a comprehensible and interactive manner. Graphs, maps, and other visualization tools are available to help users identify trends, correlations, and patterns in the data. This enables users to make informed decisions based on a deep understanding of the presented information. Since collecting data in the study area was very difficult due to the relatively large basin area, and its transboundary aspect, ClimInonda was created to respond to these needs in terms of data collection and management, as an essential step toward a better understanding of the basin hydrological model and its requirements, with regard to data types (precipitation, hydrometric, meteorology, topographic, etc.), which have great influence on the model production.

This web application is freely accessible through the following link: <http://ec2-3-92-49-95.compute-1.amazonaws.com/ClimInonda/>.

The ClimInonda application can be used via a web browser on a desktop or a mobile device (Android), since it is executed by means of a server gathering information from different databases. ClimInonda seems to be a valuable solution for using land use, environmental, climate, and hydrological data in the governorates of Gafsa and Kasserine (Tunisia), and Tebessa (Algeria), covering the entire study area of Bayech Basin.

Data visualization in ClimInonda allows the access and exploration of the available collected data for a specific station, with analysis capabilities to download and manage the collected information. In addition, the collected data are illustrated with graphs, which give insights into trends, patterns, or relationships within the dataset, and hence, users can make informed decisions based on these data. By selecting the download feature, users can obtain a copy of the data in a suitable format, such as CSV or Excel. This functionality enables users to perform in-depth analyses, share the data with colleagues or external stakeholders, or integrate them into other applications or systems as needed. Furthermore, the tab allows users to delete specific data entries if necessary. This feature grants users

the ability to remove useless or irrelevant data points from the dataset, ensuring data cleanliness and accuracy. Deleting data entries can be particularly useful in scenarios where inaccurate, invalid, or duplicate data have been collected or when data retention policies require the removal of certain records. By incorporating these features, the tab provides users with a comprehensive set of tools to manage the collected data effectively. Users can visualize the data through graphs, download them for further analysis, and selectively delete data entries when required. This functionality promotes data exploration, analysis, and decision making within the application, empowering users to derive valuable insights from the collected data. Figure 10 shows the data visualization.

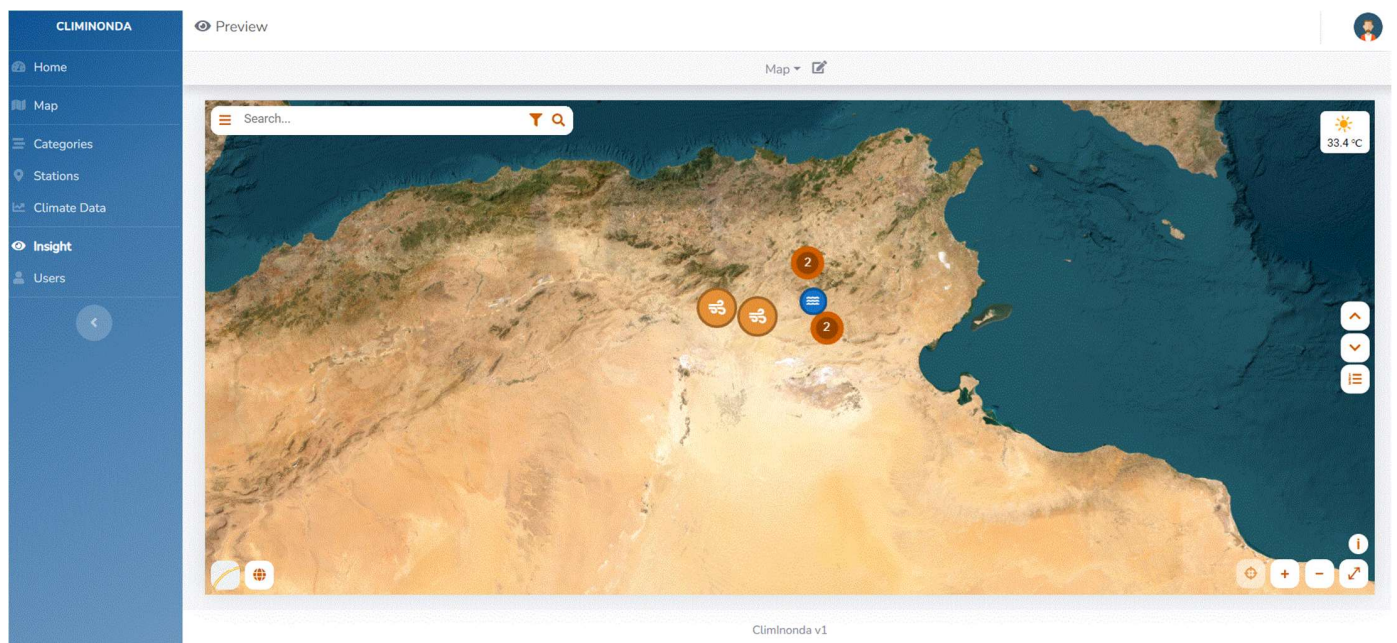


**Figure 10.** Data visualization.

Furthermore, the ClimInonda application includes a dedicated tab that provides users with a visual overview of all available stations and their corresponding status on a map. This tab offers a convenient and user-friendly interface to explore and interact with the station network. Upon accessing this tab, there is an interactive map that displays the geographic locations of all stations, showing the distribution and density of stations across different regions or areas of interest. Additionally, users have the flexibility to choose between two viewing options: satellite view or field view. The satellite view provides a realistic representation of the actual geographic surroundings. On the other hand, OpenStreetMap presents a simplified and schematic representation, focusing on the essential information and minimizing visual clutter. Furthermore, this tab offers a robust search functionality that enables users to locate specific stations with ease. By utilizing the search feature, users can enter relevant keywords or station names to filter and highlight specific stations on the map. This capability significantly streamlines the process of finding stations, particularly when dealing with a large number of stations or when searching for stations in a specific area. Figure 11 shows the geographical representation.

Consequently, ClimInonda aims to gather, integrate, and make valuable information readily available for users by means of a responsive and user-friendly web application on desktop and mobile devices.





**Figure 11.** Geographical representation.

#### 4. Discussion

The importance of technology in hydrology and water resources is discussed in many authors' writings about the relevance of technology in these fields [17].

According to [18–20], many researchers widely believe that the intensive utilization of data processing and GIS (Geographic Information System) tools serves as the primary catalyst for effective climate data management and successful flood visualization and prediction. The significance of leveraging data, especially climate-related information, in conjunction with GIS technology cannot be overstated. By harnessing the power of geospatial data, researchers can map and analyze climatic patterns, precipitation levels, and water flow, enabling them to gain profound insights into flood-prone areas and develop accurate predictive models. However, it is essential to acknowledge that while this perspective holds weight, various other factors and approaches may also contribute to climate data management and flood prediction research. Robust research and innovation in this field will continue to shape our understanding and response to climatic challenges.

Within this context, ClimInonda is well fitted for a critical need of data access and management as a decision-making tool for development professionals, stakeholders, researchers, and a public audience in various administrative districts in the study area, in terms of services and information on weather stations, dams, land use, etc. In Tunisia, these efforts behind the design of ClimInonda join and complement previous actions focusing on other fields, i.e., agriculture, irrigation, fire, crops, etc. However, in the field of hydrology and management of precipitation and hydrometric data, and of flood risk prediction in arid and semiarid regions of Tunisia, the ClimInonda application is the first model.

Smart Farm is developing a real-time decision-making plan for smart irrigation. Its solution consists of two parts: the hardware part (soil sensor) that acts as a data collector and the software part (web and mobile platform) that acts as a business advisor. In addition, Ezzayra has developed agricultural software (ERP) (Agriculture ERP Software–Dynamics, v. 365–folio3) to manage the daily operations of a company, by generating KPI (Key Performance Indicator)-monitoring dashboards for detailed, real-time management of production factors. The software has a reliable traceability system. In addition, the startup iFarming has developed Phyt'Eau, which is a smart precision irrigation solution based on scientific algorithms that enable real-time simulation of crop water requirements while taking into account their natural factors. All of this is for a water conservation greater than

40%. In addition, the available tools have been reviewed and tested to perform a data upload test with its automatically computed statistics.

Under current solutions, either an expensive tool is available through private weather stations, or an outdated public tool is available. Although a data tool is available, it does not allow interaction with the system for preventing extreme phenomena, which is the second purpose of the application. The application aims to present and visualize the different rainfall and meteorological data in the study site by reviewing past wet events and satellite imagery. It is important to note that such work has not been conducted in the study area. Additionally, the basin is a transboundary basin, making it challenging to gather data and verify the status of each rain, hydrometric, and weather station in the study area. Data quality plays a crucial role in this process. Computerized climate data management systems give users unprecedented control and insight into their land and operations. All of this is achieved through an inspiring combination of research and development in engineering, computer science, and hydrological sciences [21].

Figure 12 presents the implications of a very wet event for various cities in the study area.

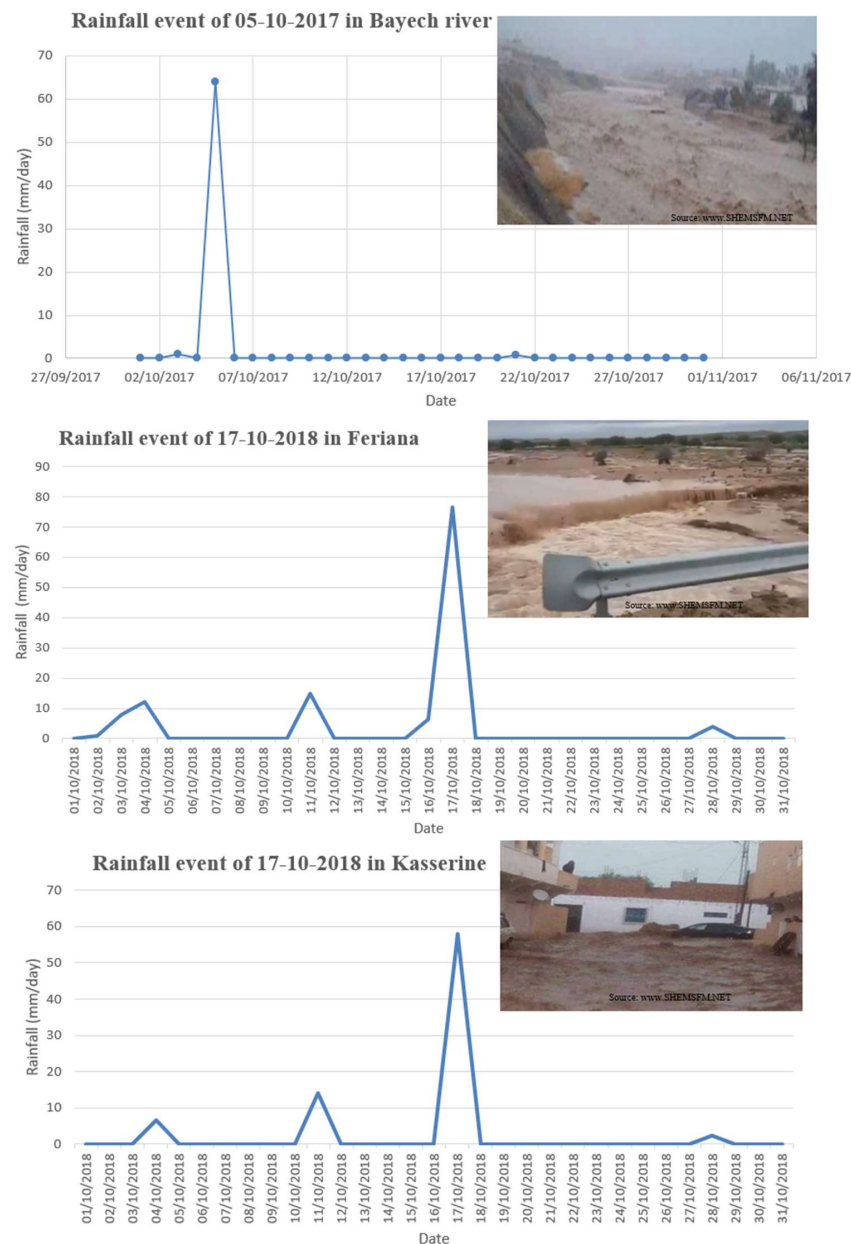


Figure 12. Rainfall events in the study area.

## 5. Conclusions

The ClimInonda web application innovatively presents the different data collected from meteorological and hydrometric stations supplied or held by different organizations. With the data offered by these stations, an adaptive and responsive web application has been developed that makes it possible to consult daily, monthly, or annual rainfall data for various stations. With the developed web application, access can be obtained to all the information from any device in a much easier and more convenient way to consult the different data types, weather forecasts and station information. As result, there is a second part of the application, which will focus on predicting the risk of flooding in real time from Landsat and Sentinel images and from previous flood observation points in different areas, including the type of land use (urban area, bare land, forest, wadis, agricultural area, etc.) on the study site.

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