Development of a Web-Based Geospatial Application for Efficient Spatial Data Management

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***Abstract*—Today, digitization and dynamic representation of geospatial data generated on different Geographic Information System (GIS) platforms are mainly performed by location-based information applications called Web-based GIS (Web-GIS). Web-GIS technology encompasses multiple levels of technology for publishing maps on the web, ranging from simply publishing static web maps to dynamically serving maps, interactive custom maps, and more complex sites that support multiple computer platforms and operating systems. In this work, a Web-GIS application has been designed and developed by using different programming languages (and libraries) and implemented by providing interoperability between different open-source software, which form the basis of the Web-GIS application such as GIS software database/GIS data entry interface, and map server. A Web-GIS application that can be accessed from a computer or mobile device, allowing the dynamic presentation, analysis, and manipulation of spatial or non-spatial data for various purposes. Furthermore, it can be applied to quickly access data obtained from different disciplines within an institution and stored in databases from anywhere in the world if the user can connect to the Internet. Web-GIS applications can be used as an efficient decision support mechanism for decision makers and authorities for quick and accurate decisions because there is no need for data pre-processing, and all the spatial data stored in the system are post-processed and the data displayed in a user-friendly interface with the arranged styles. While Web-GIS applications are designed to be accessible and user-friendly, it should be recognized that some level of GIS knowledge may still be necessary to fully interpret and understand geospatial data. This work's significance lies in its demonstration of the integrated use of open-source software and interoperability between them to develop a Web-based GIS application that caters to the needs of decision-makers and authorities, promoting collaboration and data sharing within organizations and institutions.**

***Keywords*—Dynamic and interactive maps; geographic information system; geospatial database; Web-GIS applications; web mapping.**

I. INTRODUCTION

The geospatial data contains general (maps) and specific (attributes) information about a data (i.e., layer). The development of computer and Internet technology has also accelerated the speed of accessing graphical and geospatial data using Web-GIS applications. A Web-GIS system is a kind of internet-based GIS application that uses an online map and presents spatial data on the web. Several terms are commonly used in the context of Web-based GIS, including Desktop GIS, Distributed GIS, Internet GIS, and Web-GIS. These terms are all types of GIS services, however, they differ in their characteristics and functionalities. Desktop GIS is a powerful GIS software that is installed on a desktop computer, requiring specialized knowledge and training in GIS. Distributed GIS stores spatial data in distributed locations, enabling multiple users to access and work collaboratively on spatial data. Internet GIS uses the Internet to share spatial data and is commonly used for disseminating information related to environmental planning, disaster management, and public health. Web-GIS, on the other hand, is a user-friendly GIS system that is accessed through a web browser and used for accessing and analyzing spatial data related to environmental planning, urban development, and public infrastructure management.Therefore, Desktop GIS, Distributed GIS, Internet GIS, and Web-GIS are all types of GIS services with different characteristics and functionalities, designed for specific purposes and user groups.

The terms Web-GIS and web mapping are used synonymously, even if they do not mean the same. In fact, the boundary between web maps and Web-GIS is blurry. Web-GIS uses web maps and provides analytical capabilities to web mapping end users. A web map typically includes a web browser or other user agent capable of performing client-server interaction. Web maps are a presentation environment for Web-GIS, and are gradually gaining analytical capabilities. In other words, web mapping is the process of designing, implementing, and presenting maps provided by GIS on the World Wide Web (WWW) and its products [1] [2].

Web-GIS applications are developed for many different purposes as they serve and provide advantages in various fields. Tourism, environment, e-commerce, managing land use, and planning and designing transportation systems are the most widely used areas of Web-GIS applications. The Web-GIS application is considered to be the first system to meet the needs of tourism [3]. The easy-to-use Web-GIS applications attract environmental scientists and decision-makers to better understand the spatial, socioeconomic, and historical aspects of the hazards and the associated risks to society and to increase people's awareness of these risks [4]. E-commerce companies and the private sector benefit from the potential of Web-GIS to present and promote themselves. Even though 2D and 3D Web-GIS systems can be applied to different projects and fields, it provides more opportunities to increase the use of these applications [5] [6].

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Recent studies have explored the potential of Web-GIS applications in a variety of fields. For example, [7] developed a Web-GIS approach for evaluating the effects of green infrastructure on urban thermal environment. The authors used a combination of remote sensing data and field measurements to assess the thermal performance of different types of green infrastructure in an urban setting. The resulting Web-GIS platform enabled users to visualize the spatial distribution of temperature and vegetation cover, and to compare the thermal performance of different green infrastructure types. The authors concluded that the Web-GIS approach could provide valuable insights into the effectiveness of green infrastructure in mitigating the urban heat island effect.

In another study, [8] developed a Web-GIS platform for monitoring and predicting air pollution in urban areas. The authors used a combination of satellite data and ground-based measurements to create a real-time air quality monitoring system. The resulting Web-GIS platform provided users with up-to-date information on air quality at the neighborhood level, and enabled them to visualize the spatial distribution of air pollutants. The authors concluded that the Web-GIS platform could be a valuable tool for urban planners and policymakers in developing strategies to mitigate air pollution and improve public health.

In the most recent work, [9] proposed a web-GIS based approach for flood risk assessment and management in urban areas. The authors developed a web-GIS platform that integrates various data sources such as topographic data, hydrological data, and land use data, to identify flood-prone areas in urban regions. The platform also includes a decision support system for flood risk management, which allows users to explore different scenarios and evaluate the effectiveness of various flood management strategies.

The aim of this work was to develop a Web-GIS application for geospatial data management, analysis, and presentation. Specifically, the methodology is demonstrated through the development of a Web-GIS application that can provide a platform to better manage, analyze, and present large datasets in the web environment for efficient use of processed data. While previous studies have used Web-GIS applications for similar purposes, our methodology provides a systematic and efficient approach to creating such applications that can be applied to a wide range of environmental projects. This contribution is particularly valuable in the context of increasing interest in using geospatial technologies to manage and analyze and present environmental data in an efficient manner, making it a useful tool for decision support systems in a variety of environmental projects.

The paper is organized as follows: Section II describes the methodology for developing the Web-GIS application, including the system development process and the key features of the developed application. Section III provides a discussion of the potential benefits of using the developed Web-GIS application. Finally, Section IV concludes the paper and suggests avenues for future research.

II. METHODOLOGY

This section provides an overview of the methodology used in the development of the Web-GIS application. The following sub-sections describe the different phases of the development process in detail, including system design and implementation, and interface development. The software used and their interoperabilities are also discussed to provide a better understanding of the development process.

A. System Development

The global nature of Web-GIS is inherited from the widely supported Hypertext Transfer Protocol (HTTP). Almost all organizations open their firewalls on certain network ports to allow HTTP requests and responses to pass through their local networks, thus increasing accessibility. Web-GIS can be designed as a web-based mapping application with multiplatform features, easy to use for end users, and compatible with different web browsers, such as Google Chrome, Internet Explorer, and Firefox. Web-GIS based on HyperText Markup Language (HTML) clients typically supports different operating systems (e.g. Win, Linux, Mac OS, iOS) as web browsers largely adhere to HTML and JavaScript standards. In a web-GIS application, information exchange takes place between a server and a client, where the server is a GIS server and the client is a web browser, mobile application, and desktop application. The server has a unique “Uniform Resource Locator” (URL; used to show the location of a resource on the internet) so that clients can find this information on the web and perform various actions. Figure 1 shows the main components of the Web-GIS application system and the interaction between the components.

Within the scope of this study, different processes were carried out for the realization of the Web-GIS system. Depending on the purpose of the Web-GIS project, where a server system is provided, the server needs to provide a specific URL on the web so that clients can easily access it. Clients rely on the HTTP specification to send requests to servers. The server performs the requested GIS operation and sends a response to the client via HTTP. The format of response sent to the client can be in many formats such as HTML, binary image, JavaScript Object Notation (JSON), and Extensible Markup Language (XML). The software and hardware infrastructure has been created for the project to be displayed on the web, including server setup, user account, and application access management, provision of security policies, interface design of applications and transactions, etc. In the design of the Web-GIS application, establishing a database for entering, processing, and keeping spatial data is carried out for the processes of importing the GIS data into the spatial database, maintaining the existing databases, and publishing the data on the web. For the establishment of a map server to display spatial data on the web, the map server needs to be set up to convert the selected spatial data (maps) into a set of display elements and make the created maps visible to the user on a suitable display device. Styles such as symbols, lines, and fill styles are added to spatial properties, annotations are created from alphanumeric

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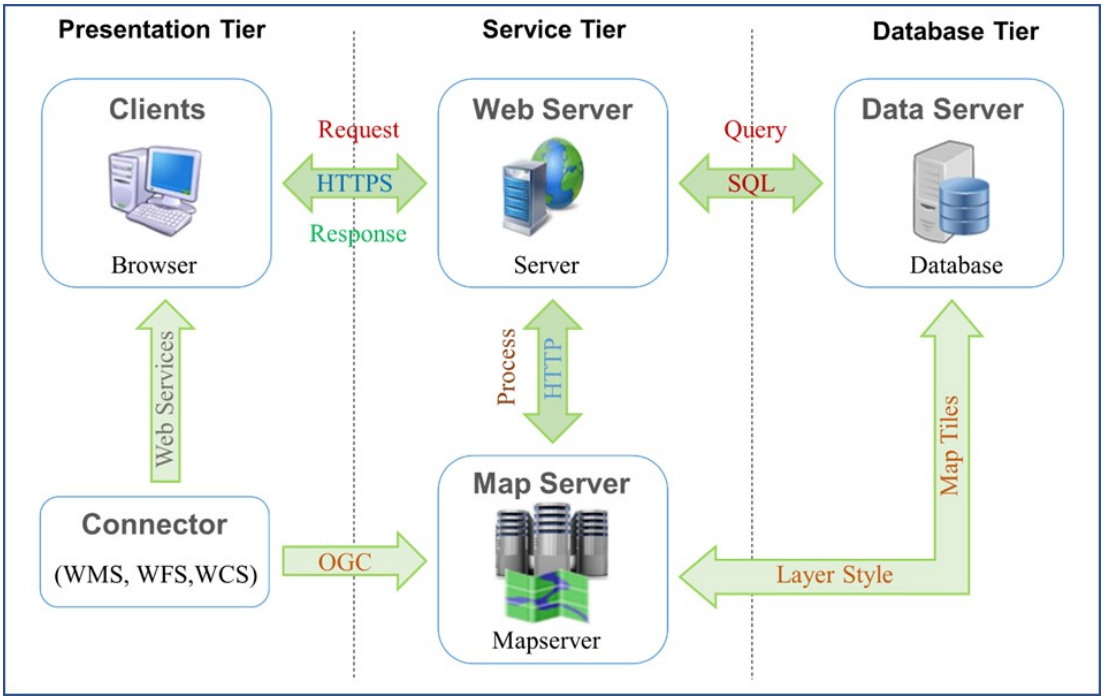

Figure 1. The structure and main components of the web-GIS application system.

properties, image elements are sorted in a specific order, and other graphics operations take place within the map server process. The features and extents obtained from the selection process are prepared from data acquisition and conversion into a format (raster or vector) suitable for processing into a database. Generated data and maps are prepared in GIF files or postscript files. In this work, open source software that forms the basis of the Web-GIS system, such as JavaScript and QGIS, PostgreSQL/PostGIS, and GeoServer are conducted to develop the Web-GIS application by providing interoperability between GIS software, database/GIS data entry interface and map server, respectively. Features used as spatial data can also be in different formats, such as vector and raster layers (Shapefile and GeoTIFF) or text (XML) data types. GeoServer functions as the Web Feature Service (WFS) reference implementation of the Open Geospatial Consortium (OGC) standard, as well as using the Web Map Service (WMS), Web Coverage Service (WCS), and web render service features.

B. The Developed Web-GIS Application

The developed Web-GIS application in this work can be accessed through any web browser and can be accessed from the URL [10]. The application login screen and interface components are shown in Figure 2. The components are numbered and each component is thoroughly explained below.

The username/password entry screen (number 1) is the first part that appears after the user/customer opens the application via the web browser. The login part of a Web-GIS application is a critical component that plays a crucial role in ensuring the security and privacy of the data stored in the application. It allows users to authenticate themselves and gain access to the different features and functionalities of the application based on their level of authorization. The importance of the login part lies in its ability to categorize users on the back-end of the application in terms of storing existing, confidential, and undesirable data in the database. This categorization enables the application to store sensitive data and confidential information in a secure and protected environment, inaccessible to unauthorized users. Additionally, the login part helps in managing user access to the application, restricting or granting permissions based on the user's role or responsibilities, ensuring that users only access the information and data that is necessary for their tasks. Overall, the login part of a Web-GIS application is a critical feature that ensures the security, confidentiality, and integrity of the data stored in the application, while also enabling users to access the features and functionalities they need to perform their tasks.

After successfully logging into the Web-GIS application, the user can move on to the second component (number 2), where they select the data group they want to examine (i.e., the spatial query section). The spatial query component plays a critical role in enabling users to navigate through the vast amounts of data stored in the database and search for specific information. The spatial query help filter the data within a specific group or project, enabling the user to focus on the most relevant and important information. In another word, a user working on a project may want to filter the data to show only the data that meets specific criteria or conditions. The pre-defined conditional rules as the Structured Query Language (SQL) modules in the application enable the user to do the spatial

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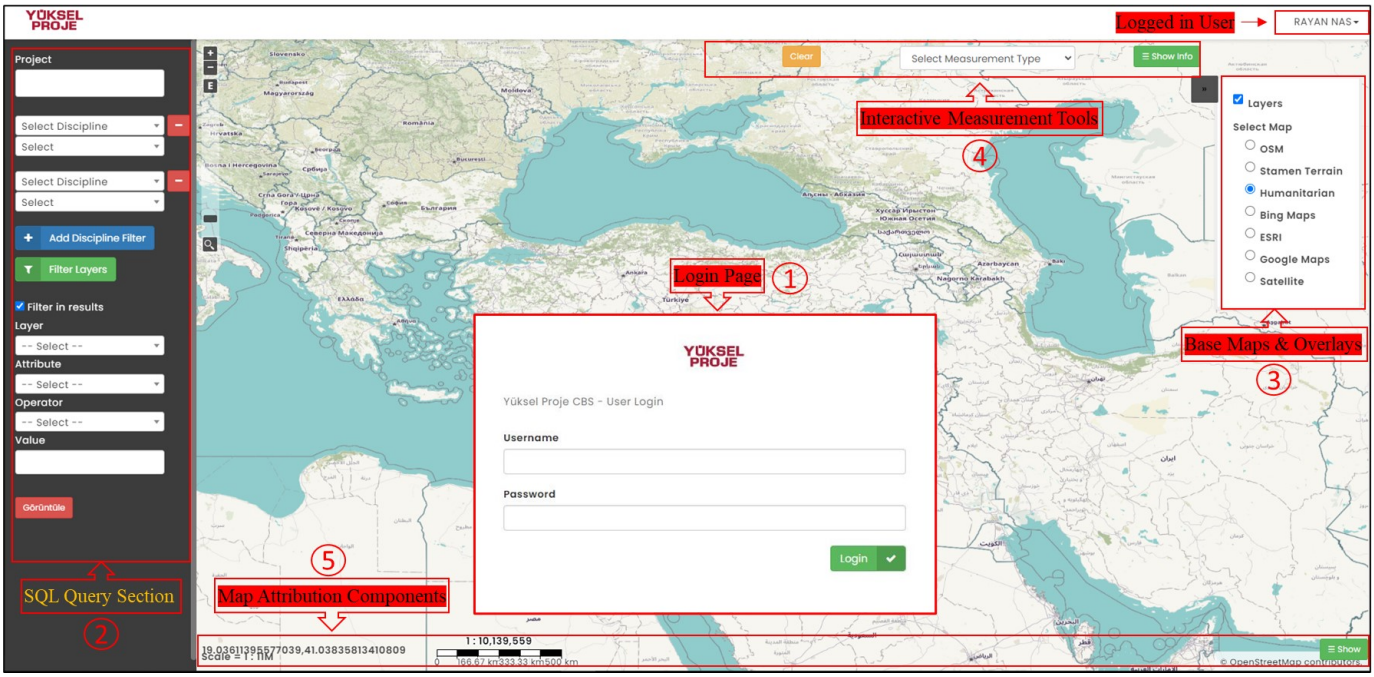

Figure 2. The Web-GIS application interface login screenshot.

queries easily and efficiently, without the need for filtering using expressions. Hence, this component of the Web-GIS application plays a critical role in enabling users to access and analyze the data they need to perform their tasks, making the application a valuable tool for managing and utilizing large amounts of spatial data. The third component (number 3) of the Web-GIS application is where the user can select different base maps and overlays to display on the application interface. This component plays an important role in providing users with a customizable view of the spatial data stored in the geospatial database. Base maps provide the underlying context for the spatial data, and users can choose from a variety of options such as Open Street Map, Google Satellite, and others, depending on their needs and preferences. Overlays, on the other hand, are layers of spatial data that are called from the database and displayed on the map interface, allowing users to visualize and analyze the data in a meaningful way. Examples of overlays could include population density, land use, transportation networks, and others. By providing users with a wide range of base maps and overlay options, the Web-GIS application enables them to view and analyze spatial data in a way that best meets their needs. For example, a user working on a project related to land use may want to use a base map that shows terrain features or vegetation, while also displaying overlays related to land use patterns and zoning regulations. Another user working on a project related to transportation planning may want to use a base map that shows roads and highways, while also displaying overlays related to traffic patterns and transit routes. Thereby, the base maps and overlays management section of the Web-GIS application provides a useful feature and enables users to customize their view of the spatial data, making it easier to analyze and interpret the information they need.

The fourth component (number 4) of the Web-GIS application is an option for measurement tools, which allows users to make interactive measurements on the map interface. This feature enables users to accurately measure distances and areas on the map, providing them with a valuable tool for analyzing and interpreting spatial data. The measurement option in the application allows users to select different measurement types, such as length or area measurements, depending on their needs. For example, a user working on a project related to land use planning may need to accurately measure the area of a particular parcel of land to determine its zoning or permitted land use. The measurement option in the application would enable them to do this quickly and easily, using a variety of measurement tools and techniques. The interactive nature of the measurement option also enables users to make adjustments and refinements to their measurements as needed, ensuring that they are as accurate and precise as possible.

The last component (number 5) of the Web-GIS application that is shown in Figure 2 is the attribution component, which displays information related to the map interface, including the geographic coordinates of the cursor location on the map, the map scale, and the source reference of the map or satellite image (map contributors) being used as the base maps. By displaying this information, the application ensures that users make informed decisions based on the data they are working with. The geographic coordinates provide users with the exact location of their cursor on the map, which can be particularly useful for identifying specific features or locations. The map scale information provides users with an indication of the level

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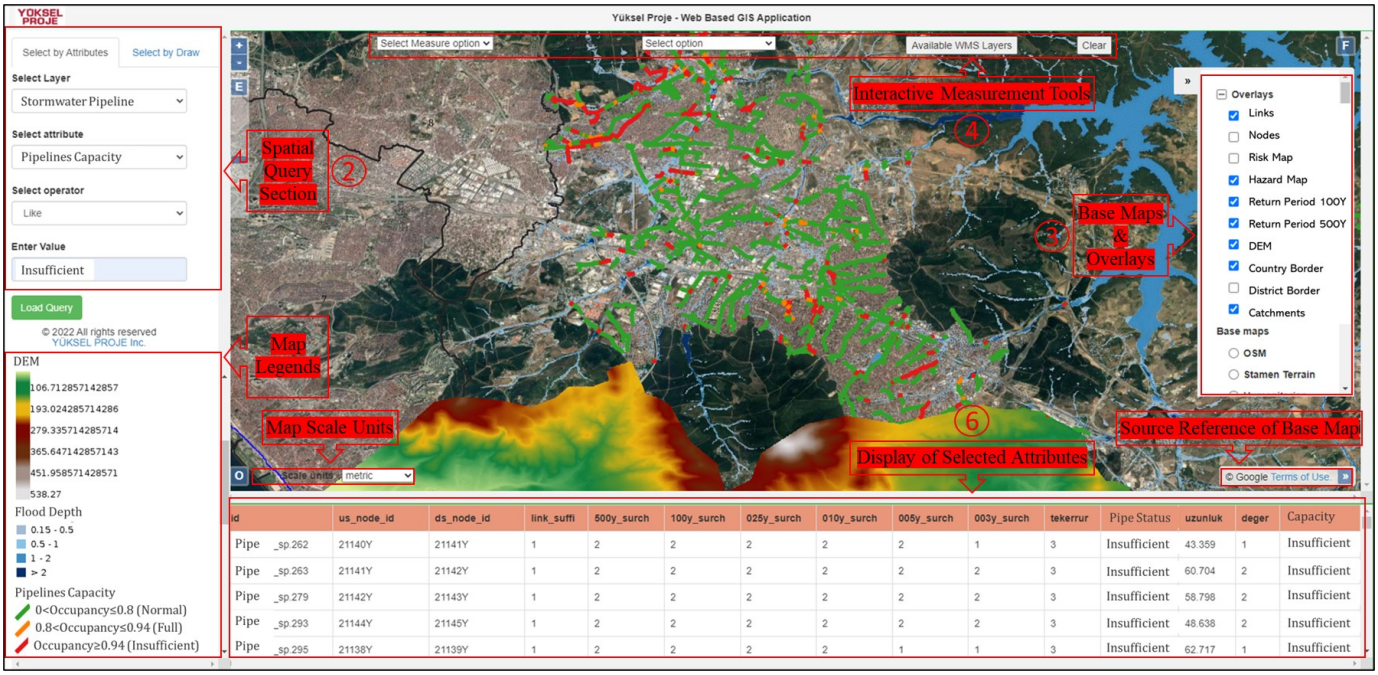

Figure 3. Developed Web-GIS application interface.

of detail being shown on the map, helping them to understand the spatial relationships between different features and elements. Figure 3 presents the developed Web-GIS application's interface, which showcases the functionality and features of the application.

The example data that is called from the database is displayed on the interface, along with the preferences and filters that have been applied to the data. The interface is designed to be user-friendly and intuitive, allowing users to easily navigate and interact with the application. To display the preferred data set on the application interface screen, conditional filtering within the preferred data set can be done with the help of the pre-defined SQL operators as shown in component number 2. The sample opened data in the applications' interface shows whether the capacity of the stormwater pipelines is sufficient or not for a certain rainfall period. The green, orange, and red colors indicate the pipelines' capacities being sufficient, full, and insufficient. The application automatically creates map legends based on the user's data set preferences. The legend appears below Component 2, as shown in Figure 3. Component 6, as shown in the application interface, according to the SQL query made on component 2, displays spatial filtering on the layer based on selected attributes of the data. For instance, in the sample stormwater pipeline data, the user has made a query based on the "Pipeline Capacity" attribute to filter and display the insufficient pipelines. Any data attribute can be selected on this screen, and the selection is dynamically displayed on the map. In addition, as a base map, the user can switch between different base maps, such as satellite images or OpenStreetMap (OSM) invoked via the Internet, as shown in component 3.

III. Discussion

Web-GIS applications have become increasingly popular in recent years, as they provide an easy-to-use and accessible way to process and analyze spatial data. This is particularly useful for decision-makers, who need to quickly access and analyze data in order to make informed decisions about public projects. The Web-GIS application presented in this paper is designed with the needs of a broad audience in mind, making it an ideal tool for users with some level of GIS knowledge. This study presented a Web-GIS application that was designed and implemented with a focus on its features and functionalities. The application allows users to interact with spatial data and utilize its features to explore, analyze, and visualize it. The paper provided an example interface of the application, showcasing its ability to process and display spatial data. The work highlighted the importance of transparency, accountability, and ease-of-use in a Web-GIS application, and emphasized its potential to enable informed decision-making and effective action. In addition, the developed Web-GIS application provides a powerful platform for location-based data analysis, offering various capabilities such as making spatial queries, filtering data, and enabling interactive measurements. These capabilities can be utilized for a wide range of purposes, from environmental monitoring and urban planning to disaster response and emergency management.

One of the key advantages of Web-GIS over traditional desktop GIS is its ease of use. Web-GIS applications are designed to be simple and intuitive, allowing users to quickly and easily process and display geographic data. This makes it an ideal tool for decision-makers who need to take quick measures against certain events, such as floods or other natural

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disasters. With the Web-GIS application presented in this paper, flood spread maps can be easily classified and visualized for the detection of vulnerable areas according to different flood recurrences, without the need for the complex operations required by traditional desktop GIS. Another advantage of Web-GIS is its ability to enable a large number of users to access and share spatial and non-spatial data within and outside an organization. The Web-GIS application presented in this paper provides global access to data obtained from all disciplines within an institution, making it a valuable tool for collaboration and data sharing. Overall, Web-GIS applications are a powerful and accessible tool for processing, displaying, and analyzing geographic data. Its ease of use and accessibility make it an ideal tool for decision-makers, while its ability to enable data sharing and collaboration makes it a valuable asset for organizations across a range of industries.

Our future work is centered around the development of a dynamic geospatial application that includes several key features, such as a mobile client, 3D Web-GIS, quick and easy query tools, hydrological processing tools, and an integrated BIM and GIS web-based platform. These enhancements are aimed at better meeting the needs of decision-makers and authorities and facilitating collaboration and data sharing within organizations and institutions, particularly those dealing with large datasets. By implementing these improvements, we believe our application will be a valuable tool for promoting effective decision-making and advancing geospatial research.

IV. Conclusion

GIS software is not accessible to everyone, nor spends the time necessary to use it effectively. Desktop GIS is designed for professional users with months of training and experience in GIS. The Web-GIS application developed in this study is based on open source software, including JavaScript, QGIS, PostgreSQL/PostGIS, and GeoServer. This choice of software was made to ensure interoperability between GIS software, database/GIS data entry interface, and map server, respectively, resulting in an efficient and cost-effective Web-GIS system. The Web-GIS application presented in this paper is aimed at a broad audience, primarily for users with some level of experience with GIS programs. In fact, Web-GIS applications are often designed to be simple, intuitive, and convenient, making them easier to use than desktop GIS. Thus, the Web-GIS system becomes a fast and easy way to disseminate the data as a tool for processing, displaying, and analyzing geographic data, while supporting a large number of users at the same time. Therefore, the Web-GIS application is an interesting and powerful tool for decision-makers in designing and planning public projects. Specifically, in order to take quick measures against a certain event, for example, to classify and visualize a flood spread map for the detection of vulnerable areas according to different flood recurrences, the flood spread maps available in the database can be easily displayed on the interface of the application without the need for the operations performed in traditional desktop GIS. In addition, Web-GIS applications enable a large number of users to use services (spatial or non-spatial data) to share with others (global access) within and outside the organization. Therefore, as a result of this work, a web-based GIS application that can be accessed from a computer or mobile device has been designed and presented. This web-based GIS application provides spatial data obtained from all disciplines within an institution and provides quick access to this data when necessary, via the web, regardless of the user's location. Hence, Web-GIS applications have the potential to greatly expand the reach of geospatial analysis and enable a wider range of individuals to engage with geospatial data, fostering greater understanding and informed decision-making in a wide range of fields, from urban planning and environmental management to public health and transportation.

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References

[1] P. Fu and J. Sun, "Web GIS: principles and applications." Redlands: Esri Press, pp. 89-114, 2011.

[2] R. Nasirzadehdizaji and R. N. Celik, "Open source geo-information technology for making special purpose web-mapping application," Coordinate, 11, pp. 23-26, 2015.

[3] G. Kakaletris, D. Varoutas, D. Katsianis, and T. Sphicopoulos, "Design and Implementation Approaches for Location Based Tourism Related Services" Chapter 18, Geographic Information Systems: Concepts, Methodologies, and Applications, pp. 258-294, 2013.

[4] R. Nasirzadehdizaji, "A web mapping infrastructure design and implementation with open source geo-information technology: A case study of ITU Smart Campus," Master Thesis, Istanbul Technical University, Informatic Institute, Higher Education Council Presidency (YÖK), 2015.

[5] X. M. Chen, "Remote sensing and GIS in environmental risk assessment. Geographic Information Systems: Concepts, Methodologies, and Applications," Chapter 4.15, pp. 840-847, 2013.

[6] M. Ü. Gümüşay, "WebTabanlı Coğrafi Bilgi Sistemi Uygulamaları (YTÜ Davutpaşa Kampüsü) (in English: "Web Based Geographic Information System Applications (Yildiz Technical University Davutpaşa Campus)), Journal of Science and Engineering Sciences, AKU (Afyon Kocatepe University), J. Sci. Eng.17 Special Issue, pp. 215-222, 2017.

[7] X. Wang, Y. Zhu, and L. Yu, "A web-GIS approach for evaluating the effects of green infrastructure on urban thermal environment," Sustainable Cities and Society, vol. 96, p. 103223, 2022.

[8] Y. Zhu, X. Wang, X. Li, and J. Li, "A web-based GIS platform for monitoring and predicting air pollution in urban areas," Environmental Pollution, vol. 287, p. 117395, 2021.

[9] J. Zhang, H. Chen, and Z. Li, "A web-GIS based approach for flood risk assessment and management in urban areas," Natural Hazards, vol. 116, no. 1, pp. 367-383, 2022.

[10] Yüksel Proje International Company. *Web-GIS: User Login.* [Online]. Available from: https://ypnet.yukselproje.com.tr/YpCbs/ 2023.04.05

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