Web-GIS based Dashboard for Real-Time Data Visualization & Analysis using Open Source Technologies

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Abstract: Real-time visualization is the requirement for immediacy of decision making, which tends to be role-based. Using maps to visualize data can enable quicker interpretation of complex geographical phenomena, identify patterns, and aid in planning, resource allocations for policy and decision making. In present study, an interactive Web GIS Dashboard is developed with the objectives to display the work progress of Department of Soil & Water Conservation. The data includes activities and schemes undergoing in the department which was validated and geo-tagged with district & block boundary. For real-time data visualization, the graphs for different year, activities and schemes are developed for number of beneficiaries and area benefitted in ha. Various filters i.e. Year, Scheme and District are provided for viewing map. Different levels of User Authentication are provided for uploading new data and updating data.

Keywords: Dashboard, Data Visualization, Web-GIS, Geo-tagging, Spatial Data, Decision.

1. Introduction

Data in excel format is bulky which makes it bit difficult for the user to view details in less time. Therefore, there is a need to develop a web application in order to show data in systematic manner. An interactive dashboard is a data management tool that tracks, analyses, monitors, and visually displays key information while allowing users to interact with data, enabling them to make well-informed, data-driven, and healthy decisions. The point of such dashboards is not only to simplify the working environment but also to analysis processes since there are massive volumes of data collected at various levels, need solutions that will bring them to the right answer at the right time.

Dashboards are popular information system elements that provide advantages in terms of managing data. Using a dashboard for providing meaningful information in graphical and other forms of visualization has been increasingly used. Web dashboards can be configured in three different ways, as operational, tactical, and strategic dashboards (Bovkir & Aydinoglu, 2021). The field of geographic information science and its associated technologies have undergone rapid technological advancement and geographic information systems (GIS) now have functional capabilities which include geo-statistical analysis, network analysis and geographic modelling (Visner et al., 2021). The field is characterised by specific expertise, one with a longstanding history of forward thinking and a track record for ongoing innovation. Over the past few decades, in line with the increasingly expansive presence of the internet in daily activity, both personal and commercial, the availability of spatial information online has grown exponentially and has led to the rapid transition of GIS technologies from stand-alone GIS systems for the GIS expert to networked systems supported by distributed client-server applications (Lemmens et al., 2006).These distributed applications, also known as web mapping applications or web GIS in the Cloud, are defined by Esri (Rowland et al., 2020), the leading commercial provider of GIS technologies, as any GIS interface which makes use of web technology to communicate between a client and server and is available as a web browser, desktop application or mobile application(Rowland et al., 2020).In the past decade Web-GIS tools have become increasingly popular as a result of advances in computer technologies, improved and established geographic standards (e.g. OGC standards) which have helped the dissemination of spatial data to different audiences and the shift from expert tools to community-based tools that are accessible to a wider range of users(Kienberger et al., 2013). Web-based GIS tools are spatial decision support systems (SDSS) that are interactive GIS-based platforms, including integrated database management systemsdesigned to support place-based decision making at the various stages of a planning process(Duncombe et al., 2012;Amiruddin, 2016).

1.1 Web-GIS architecture

The basic architecture of a web GIS application is the client-server architecture as described in Figure 1; this is because the standard of geo-data is very specific in the sense that it requires a Map server on top of the web server and a database server compliant with geo-data, while most other websites do not require these extra technologies to function properly (Ismanto et al., 2016). GIS engine is installed in application server which will exposes certain services. Open Geospatial Consortium (OGC) defined a set of standards for distributing geographic data and make layers of information more accessible. GIS engine take input in the form of Georeferenced data and converts into compressed formats like PNG (Portable Network Graphics), JPG (Joint Photographic Experts Group) or GIF (Graphics Interchange Format). Output can be of XML (Extensible Markup Language) based like yielding as a vector format e.g. KML (Keyhole Markup Language), GML (Generalized Markup Language).

WebGIS applications have web browser as a client for sending the request and a web server for responding to the request. The non-spatial web applications usually contain only web server, but in case of WebGIS, there is an additional server called data or map server for spatial data. This server handles the geospatial data, provides geospatial data compatible services like WMS and WFS, and is able to perform GIS functionalities like editing, routing, and object tracking. The client can make the request to the server located at any place using middleware technologies like Remote Procedure Calls (RPC) or Open Database Connectivity (ODBC) (Tsou & Buttenfield, 2002). In 'thin client' approach, most of the processing is done at the server side after a simple request from the client. And in 'thick client' approach the client is more powerful by augmenting its capabilities with the help of plug-ins, applets or some additional modules (Agrawal & Gupta, 2017) as . The WebGIS architecture grows from multi-tier approach to plug-and-play to SOA (Service oriented Architecture) to cloud computing (Yang et al., 2010). Spatial cloud computing architecture is described in Figure 2. Virtual pool of resources is provided to users in cloud by Internet. Users can easily access the data uploaded on the cloud by Internet, which provides more flexibility and availability of resources at a lower cost.

The GIS Based open source dashboards had been created for many purposes. The dashboard for big urban data visualization approaches within the smart city is developed by BOVKIR (Bovkir & Aydinoglu, 2021) and Michael Visner created dashboard for Monitoring Spatio-Temporal Changes of Hotspots of Bushfires over 100 Years in New South Wales, Australia (Visner et al., 2021). Tsou developed Smart dashboard for Social Media Analytics (Tsou et al., 2015). Geospatial dashboards have been created to determine the performance of smart cities (Achachlouei & Hilty, 2016; Batty, 2015; Jing et al., 2019; Kitchin, 2016b), which have attracted extensive interest from industry, academia and government due to the geospatial nature of city development, function, and management, the need for sustainable urban development, and the interest in new managerialism systems. The geospatial dashboard supports smart city sustainability goals by tracking city performance measurements(Achachlouei & Hilty, 2016; Diaz-Sarachaga et al., 2018; Kitchin, 2016b; Miola & Schiltz, 2019). Most of the WebGIS based dashboards have been developed to support urban management but little work has been carried out for conservation of soil and water. The new managerialism involves citizens who generate geospatial data, interact collaboratively with the government (Spyratos et al., 2014), and look for evidence-based decision-making (Kitchin, 2016a; Stoddart & Godfrey, 2020). Therefore, these characteristics of new managerialism result in the need for geospatial dashboards to support soil and water management.

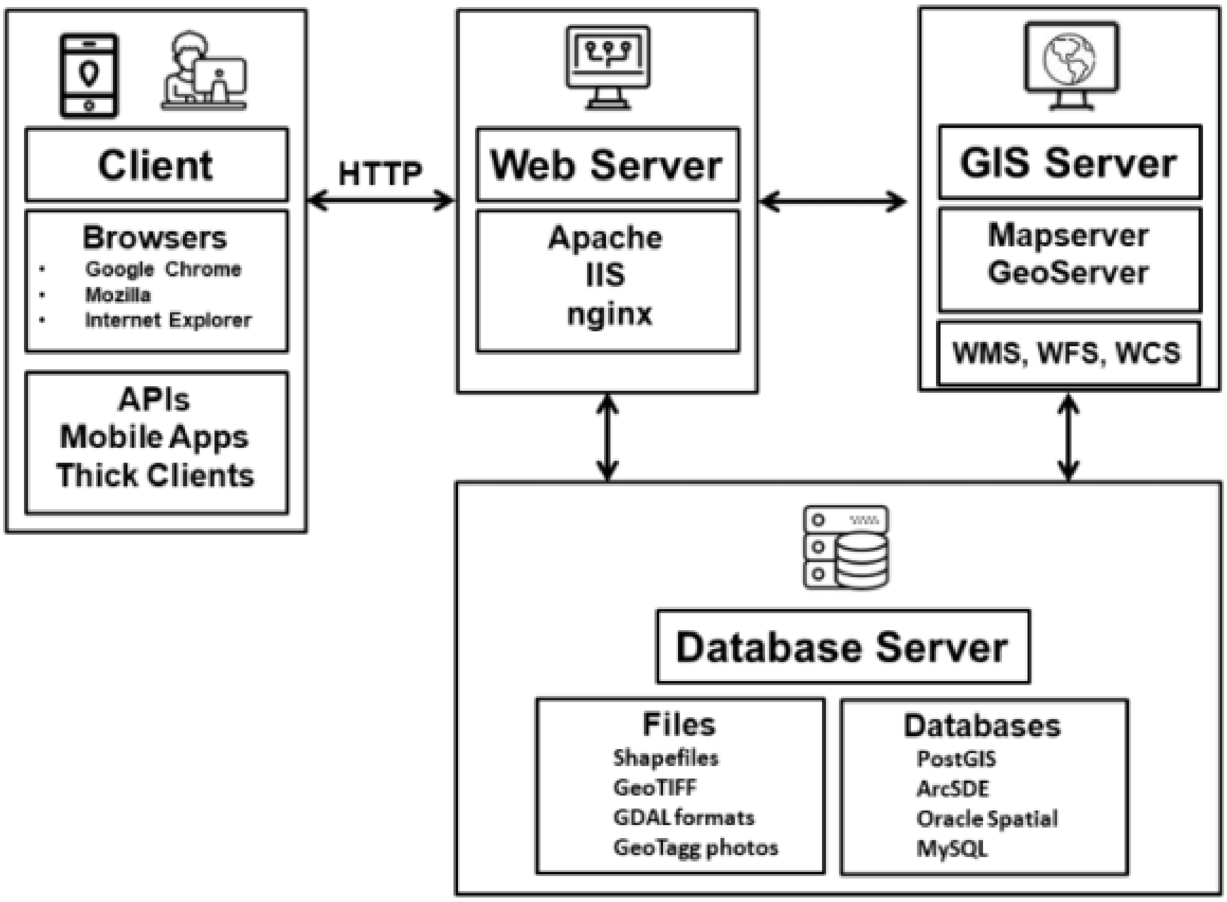

Figure 1. WebGIS Architecture (Giribabu et al. 2018)

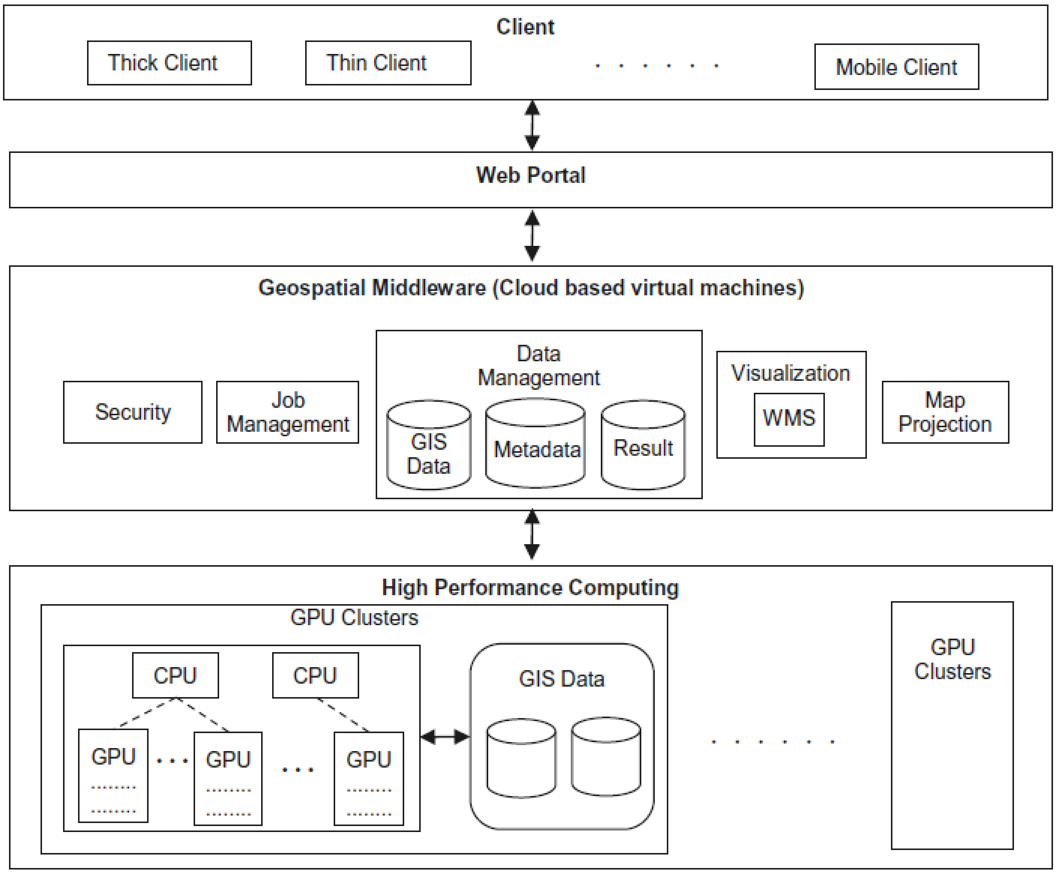

Figure 2. Spatial cloud computing architecture (Agrawal & Gupta, 2017)

1.2 Open Source Technologies

The design of open source technology is publicly accessible to modify and share among other users. Free and open-source software (FOSS) libraries grant the four basic freedoms of running, studying and adapting, redistributing, and releasing improvements to the public (Steiniger & Hunter, 2013). Traditional GIS software was robustly platform-dependent as they were generally written in programming languages which has to be recompiled between different hardware architectures and operating systems (e.g., C, C++) (Farkas, 2017). A platform independent client is needed to use server resources on place of local geoprocessing which can be done through browsers. Web processing Service can be used to make the product used on different Operating Systems and Devices.

Open-source web mapping libraries are helpful for the development of Web-GIS Applications. Many APIs and Web Mapping libraries are available, out of which Leaflet is the lightweight solution for creating web mapping applications which is highly capable due to its extensibility, and huge amount of third-party extensions developed. This library is used to develop the dashboard in present work due to rich vector format support and has the capability to write features in GeoJSON format natively, and WFS transactions with an extension (Farkas, 2017). The tools for zoom in, zoom out, searching, measuring distance between points are available in the web page by using this library.

2. Study Area

The state of Punjab can be broadly divided into three socio-cultural regions, viz. Majha, the land between the Ravi and Beas rivers (8660 sq. km); Doaba, the land between rivers Satluj and Beas (8892 sq. km) and Malwa, encompassing area south of river Satluj (32,810 sq. km), out of which South-West zone (cotton belt) covers 14923 sq. km area. The state of Punjab is divided into 23 districts, which are further divided into 152 development blocks. Study area covers the whole state of Punjab (Figure 3), a part of Indus plain, covers a geographical area of 50362 sq. km. It lies between 29° 32′ & 32° 31′ N latitude and73° 52′ & 76° 52′ E longitude. It shares the International border with Pakistan in western side while in the north it is bounded by Jammu and Kashmir, in the north-east by Himachal Pradesh, in east, south-east and south by Haryana and in south-west by Rajasthan.

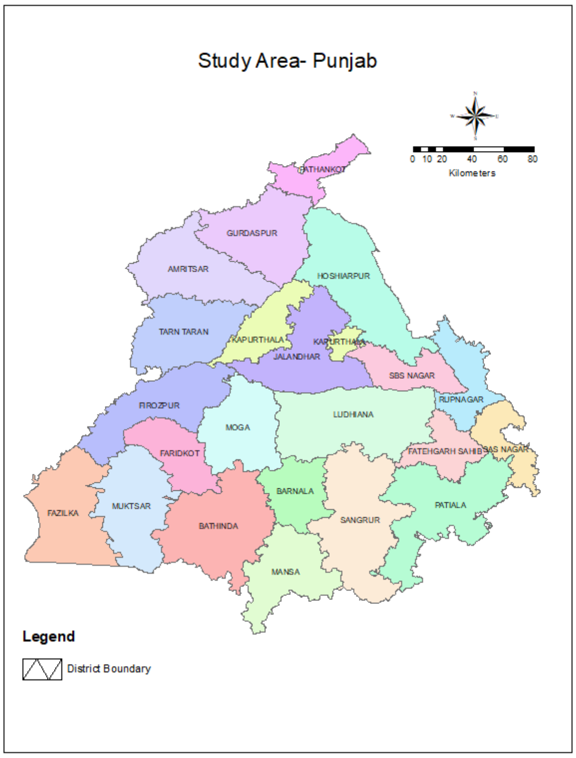

Figure 3. Study area – Punjab State

3. Data visualization approaches

Data visualization techniques consist of a combination of many disciplines such as computer graphics, image processing, computer vision, and user interface design (Balzer et al., 2020).
Visualization techniques vary according to the processed data types.

a) One-Dimensional data: One-dimensional data has only one variable. Temporal data can be an example to one-dimensional data(Keim, 2002).

b) Two-Dimensional data: Two-dimensional data has two different dimensions. Geographic data with two different dimensions (latitude and longitude) is a typical example of two-dimensional data. Maps with X-Y plots are a typical method for displaying two-dimensional data(Keim, 2002).

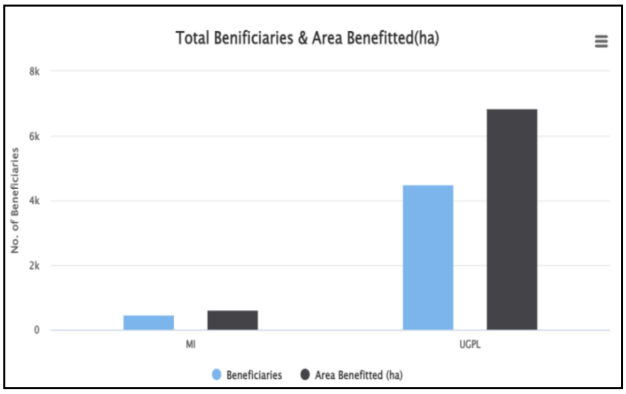

Figure 4. Example of 2D Graph

c) Multidimensional data: Many datasets contain more than three dimensions, so they cannot be observed with simple visualization techniques such as 2D or 3D graphs. Sophisticated visualization techniques are used in order to represent this type of data(Keim, 2002).

d) Text and hypertext: It is not possible to demonstrate all data types in sizing terms. Multimedia sources like web pages consist of text and hypertexts. Principle component analysis (PCA) and multi-dimensional scaling (MDS) are two of the leading methods applied for dimensional reduction of this data type.

e) Hierarchies and graphs: Data records are often associated with other pieces of information and graphs are often preferred to show these types of ordered, hierarchical or arbitrary relationships. A graph composes of a set of objects, called "node"s, and connections between these nodes, called "edge". File structures in computers, e-mail relations between people or shopping behaviours can be given as examples(Keim, 2002).

f) Algorithms and software: The purpose of software visualization is to enable the development of the software by helping to understand algorithms. Graphical techniques can be classified according to the graphical possibilities of the software(Keim, 2002). In the present study, Two-Dimensional data is used for creating graphs & Plotting Maps. 2D graph example is shown in Figure 4.

4. Methodology

Web-GIS Dashboard is created using Open source technology. The Open source tools used for implementing Geospatial Dashboard are QGIS, HTML (Hypertext Markup Language), CSS (Cascading Style Sheets), JavaScript, jQuery, PHP (Hypertext Preprocessor) and PostgreSQL. HTML and CSS are used for designing the different elements on web pages in the dashboard. PostgreSQL is object-relational database which stores the spatial data to visualize on the Map. The spatial data of the present study is stoted in the PostgreSQL Database Version 9.4.PHP is used for database connectivity to visualize the real-time data i.e. connectivity of PostgreSQL database with web page.2D charts are implemented on the dashboard for real time data visualization. The flowchart (Figure 6) given below represents the methodology for creating dashboard, which follows System Development Life Cycle.

4.1 System development life cycle

There are many Software Development Life Cycle (SDLC) models. A project's quality, timeframes, budget, and ability to meet the stakeholders' expectations largely depend on the chosen model. Today, there are more than 50 recognized SDLC models in use. None of them is perfect, and each brings its favourable aspects and disadvantages for a specific software development project or a team (Purwonegoro & Setiawan, n.d.).

In the present study, waterfall model is used to develop the application as given in Figure 5. The waterfall model is

Sequential Development Model. A schedule can be set with deadlines for each stage of development and a product can proceed through the development process model phases one by one(Adel & Abdullah, 2015). The advantages of waterfall development are that it allows for departmentalization and control. Development moves from concept, through design, implementation, testing, installation, troubleshooting, and ends up at operation and maintenance (Balaji, 2012). Each phase of development proceeds in strict order as given in the requirement phase by the Department of Soil & Water Conservation.

4.2 Steps for development of dashboard:

As described in Figure 6, the steps for development of dashboard are:

1. In requirement analysis phase, the data is collected in CSV format from the department of Soil and Water Conservation, Punjab and validated by geo-tagging with district and block boundary for each activity and scheme implement by them.
2. It is converted to spatial data in shape file format and then stored in the PostgreSQL database.
3. In System Design Phase, Layouts, Data Flow Diagram, UML Diagram and flowcharts for design of the web pages are created.
4. In Implementation phase, Frontend or Web pages are designed by using HTML, CSS and JavaScript etc and Database connectivity is done by PHP language built in functions. User authentication is implemented for security of the information and different types of users are created.
5. Open source scripts and Ajax is used to create the 2-D graphs.
6. In System Testing Phase, Guidelines are followed for creating Government department's Websites and testing of the dashboard is done.
7. In System Deployment Phase, System is deployed to the department of Soil & Water Conservation.
8. In System maintenance phase, new data will be added to the dashboard.

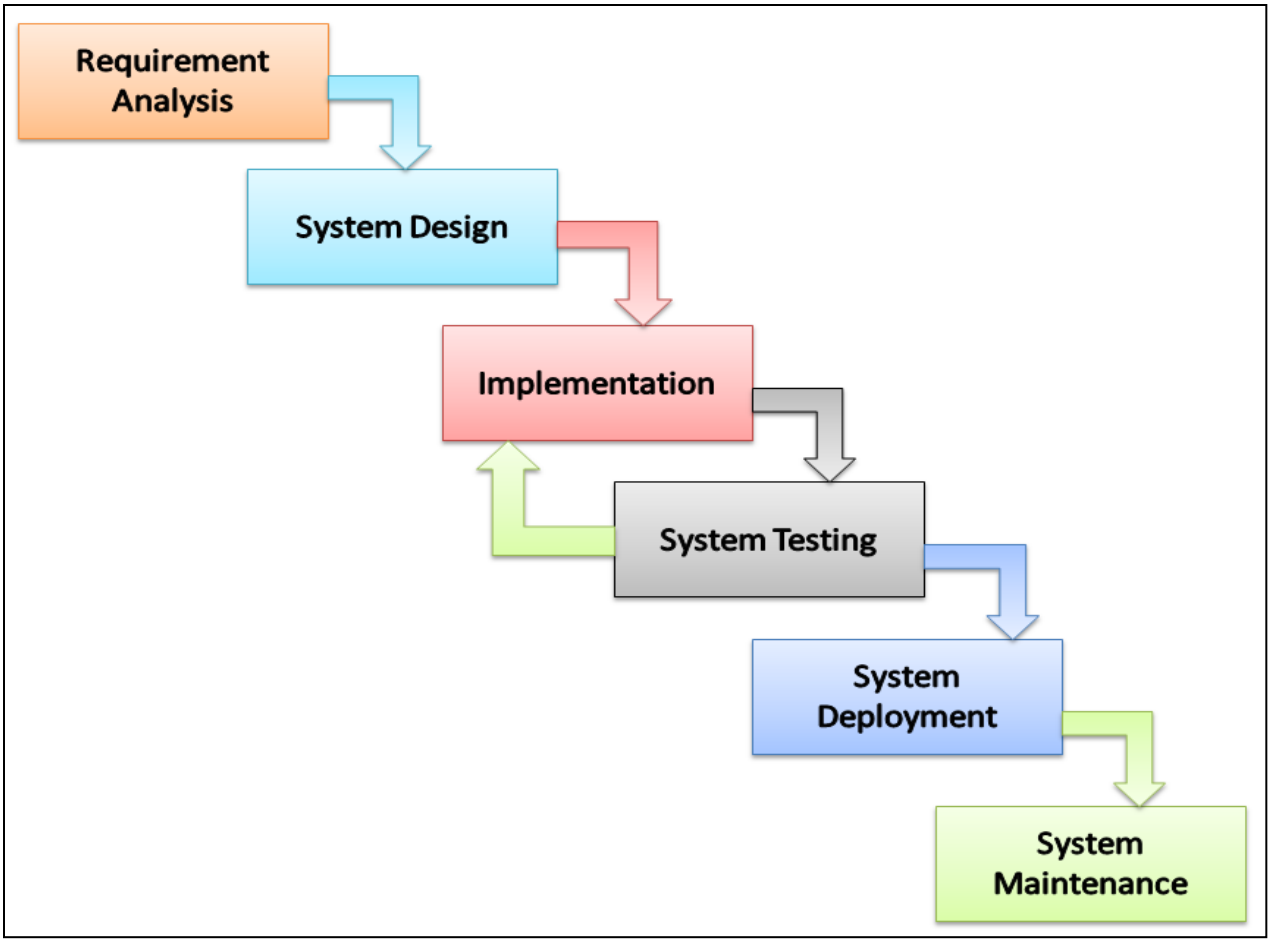

Figure 5. Waterfall Model (Boris, 2018)

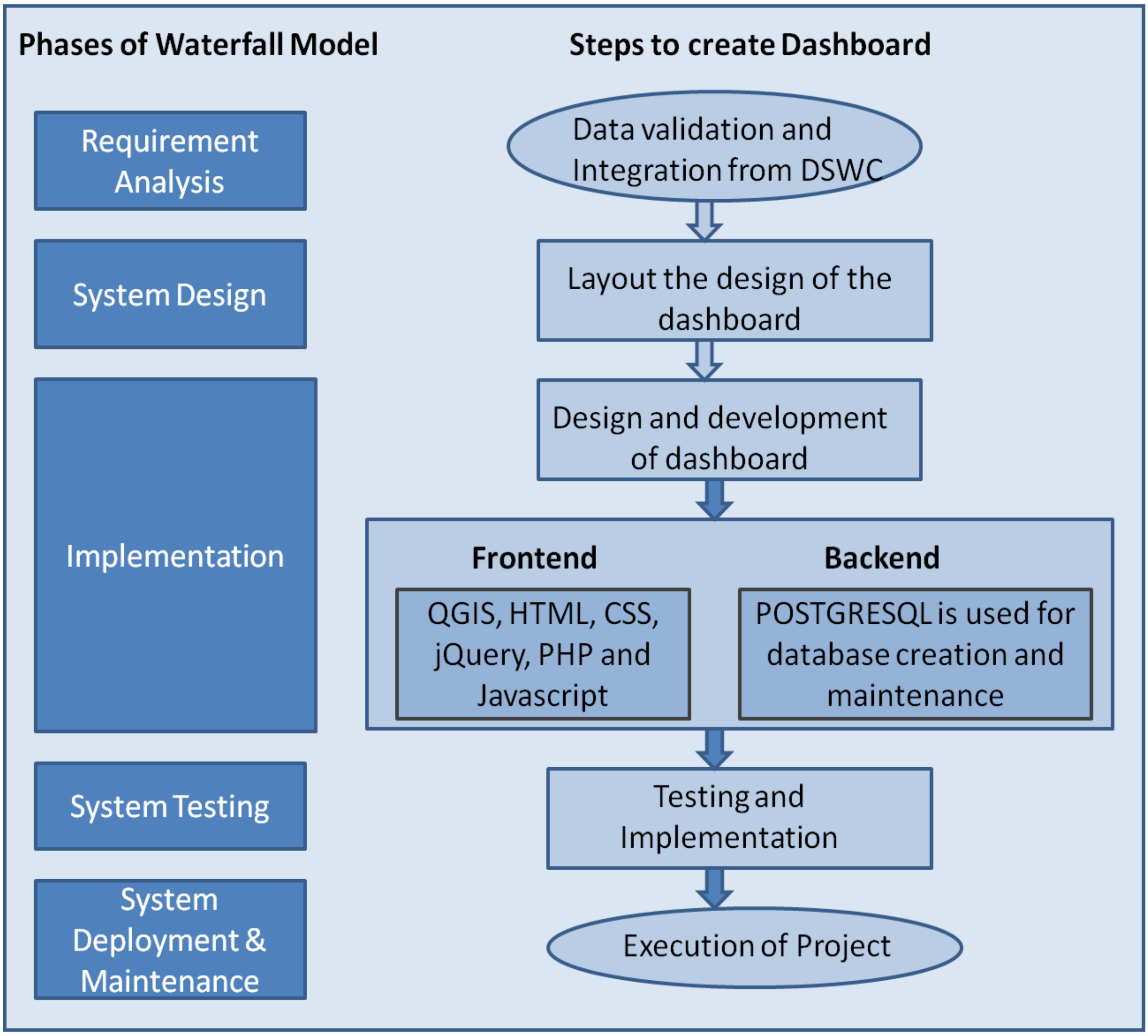

Figure 6. Methodology for developing Dashboard

5. Results and discussion

In present study, web-GIS based interactive dashboard is created for real time data visualization and analysis for the various schemes running under the department of Soil & Water Conservation, Punjab. The data for dashboard is collected and provided by department of Soil & Water Conservation, Punjab in excel format which includes various activities i.e. Underground Pipeline Systems, Micro-Irrigation Systems, Rainwater Harvesting cum Recharging Projects, Sewerage Treatment Plants & Watershed Based Projects and various schemes under these activities as shown in Figure 7. The data for different activities as given in table 1. is validated and geo-tagged with district & Block Boundary. Field images of the same have been geo-tagged. For real-time data visualization, the graphs for different year, activities and schemes are developed for number of beneficiaries and area benefitted in ha. Various filters i.e. Year, Scheme and District are provided for viewing map.

Different levels of User Authentication are provided for Uploading new data and Updating data. Soil Conservation officers can only view the data and upload new data. The nodal officers can upload the new data and also update existing data (Figure 8). The Open-Source dashboard shows different activities under department of Soil & Water Conservation as shown in the homepage of the Dashboard in Figure 7. The work is done under 5 activities i.e. Underground Pipeline System, Micro-Irrigation Systems, Sewerage Treatment Plants, Rainwater Harvesting cum Recharging and Watershed Based Projects under different schemes. i.e. RKVY, PMKSY, PIDB etc. in different years.

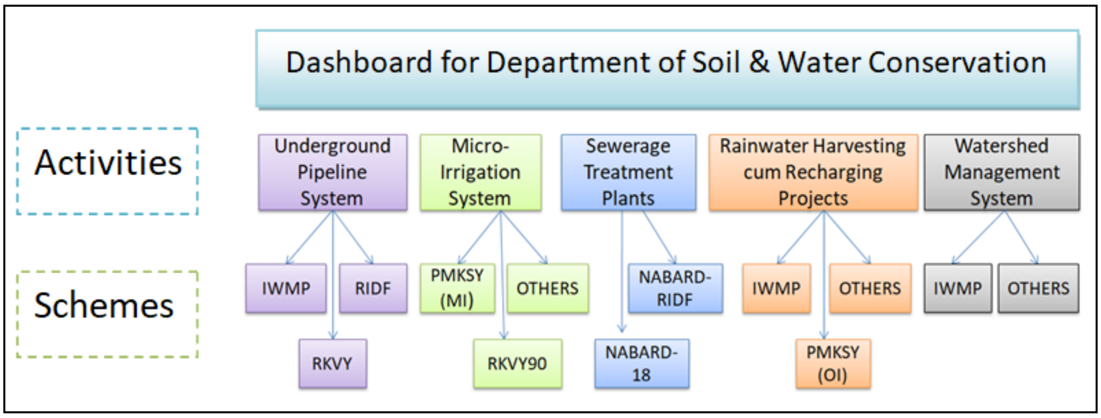

Figure 7. Activities and Schemes for Dashboard of Soil & Water Conservation

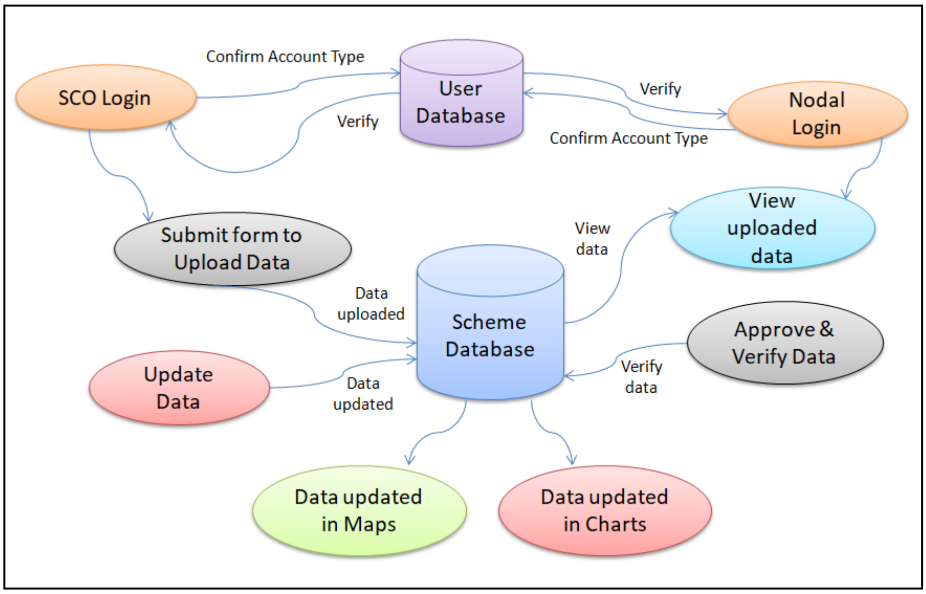

Figure 8. Data Flow Diagram of real-time Data Visualization

Homepage is designed by following the Guidelines for Indian Government Websites (GIGW) and Rights of persons with disabilities act, 2016 so that it is made accessible to persons with disabilities. Any user can view the information by the link http://202.164.39.172:2345/test/acm/schemes_Dashboard/index.php.

Certain information is not made available publicly; user authentication is required for the security of information. Different types of User Logins are provided on the online dashboard for authenticity of data. First type of users is Soil Conservation officers. They can upload new data by filling form along with location and field image and view the existing data in form of maps and graphs Second types of users are nodal officers. They can verify the data uploaded by Soil Conservation officers and make modifications Also view the existing data and graphs and Upload the verified data in CSV Format. Third type of user is Admin, which has full privileges for storing, editing and updating the database, which is depicted in the Use Case Diagram (Figure 9). Use case is used in system analysis to identify, clarify and organize system requirements. It includes the graphs for area benefitted and number of beneficiaries for the all activities and schemes under that activities as well as map for each activity, which can be filtered year-wise, scheme-wise and district-wise. Different utilities are provided in map view i.e. to zoom a particular area, measuring distance, searching particular place etc. Info window on click of any point gives information about all attributes i.e. Name of Beneficiary, Number of Beneficiaries, District, Tehsil, Block, Village, Type of Activity, Type of Scheme, Area Benefitted, Subsidy Disbursed, Type of Pipeline or Micro Irrigation, Type, Date of commencement of project, Financial Year, Date of completion of Project and field image of that location. On homepage (Figure 10), total subsidy, number of beneficiaries and area benefitted is displayed till the date which is real time information. Facility for zooming of image is also provided which is shown in Figure 11. Figure 12 shows the form for uploading the data, as Soil Conservation Officers can upload the data from the field along with location after login and Figure 13 also shows the form for uploading the new data, which is for nodal officers to upload the data in CSV format and they can also verify the data uploaded by Soil Conservation Officers by using form to view data and give the remarks to them (as given in Figure 14).

Table 1. List of various Activities and its associated data

Activity	Underground Pipeline System	Micro Irrigation System	Rainwater Harvesting cim Recharging Projects	Sewerage Treatment Plants
Spatial Data	**Associated Data**	**Associated Data**	**Associated Data**	**Associated Data**
District Boundary	District_Name	District_Name	District_Name	District_Name
Block Boundary	Block_Name	Block_Name	Block_Name	Block_Name
OpenStreetMap	Google Map with labels	Google Map with labels	Google Map with labels	Google Map with labels
Location of UGPL	Sno	Sno	Sno	Sno
	Financial_year	Financial_year	Financial_year	Financial_year
	Scheme	Scheme	Scheme	Scheme
	No_of_Beneficiary	No_of_Beneficiary	Division	Division
	Beneficiary_Name	Beneficiary_Name	SubDivision	SubDivision
	Beneficiary_Father_Name	Beneficiary_Father_Name	Section	Section
	Beneficiary_Contact	Beneficiary_Contact	District	District
	Beneficiary_Aadhar	Beneficiary_Aadhar	Block	Block
	Division	Division	Village	Town where STP Located
	SubDivision	SubDivision	Latitude	No. of Beneficiary Villages
	Section	Section	Longitude	Village Name
	District	District	Type_of_Structure	Latitude
	Block	Block	Benefitted_Area	Longitude
	Village	Village	Total_cost	Discharge (MLD)
	Latitude	Latitude	Financial_Assistance	Benefitted_Area
	Longitude	Longitude	Present_Status	Type_of_Pipeline
	Type_of_Crop	Type_of_Crop	Date_start_of_project	Length_of_Pipeline
	Benefitted_Area	Benefitted_Area	Date_completion_of_project	Total_cost
	Type_of_Pipeline	Type_of_MI	Photograph	Subsidy Disbursed
	Length_of_Pipeline	Total_cost		Maintenace
	Total_cost	Subsidy_Disbursed		Date_start_of_project
	Subsidy_Disbursed	Present_Status		Date_completion_of_project
	Present_Status	Date_start_of_project		Photograph
	Date_start_of_project	Date_completion_of_project		
	Date_completion_of_project	Photograph		
	Photograph			

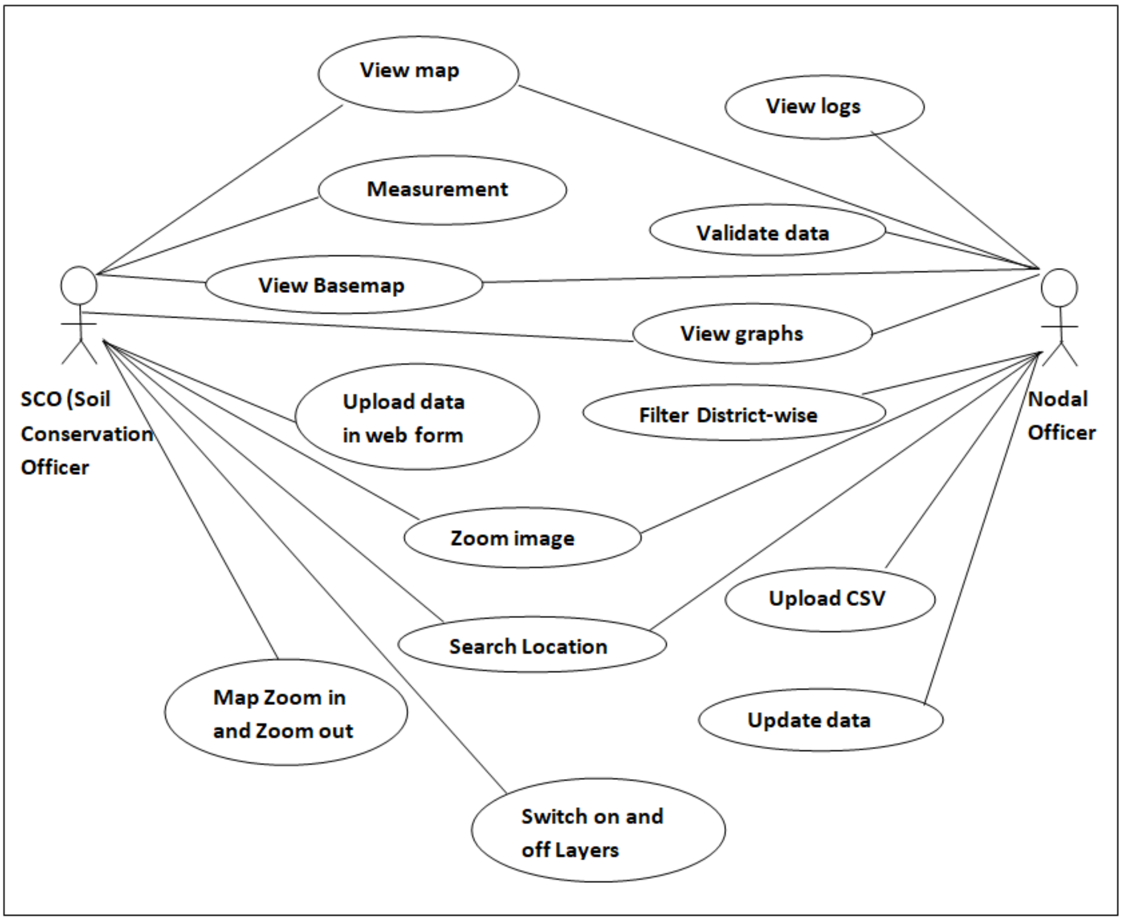

Figure 9. Use Case Diagram

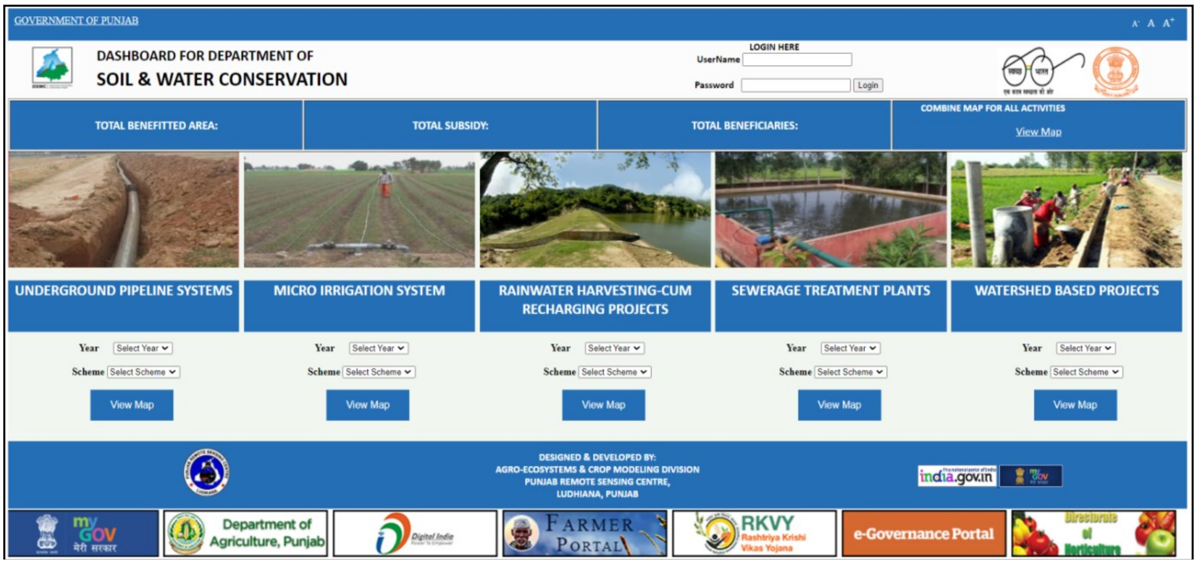

Figure 10. Homepage of Web-GIS Based Interactive Dashboard for Dept of Soil & Water Conservation

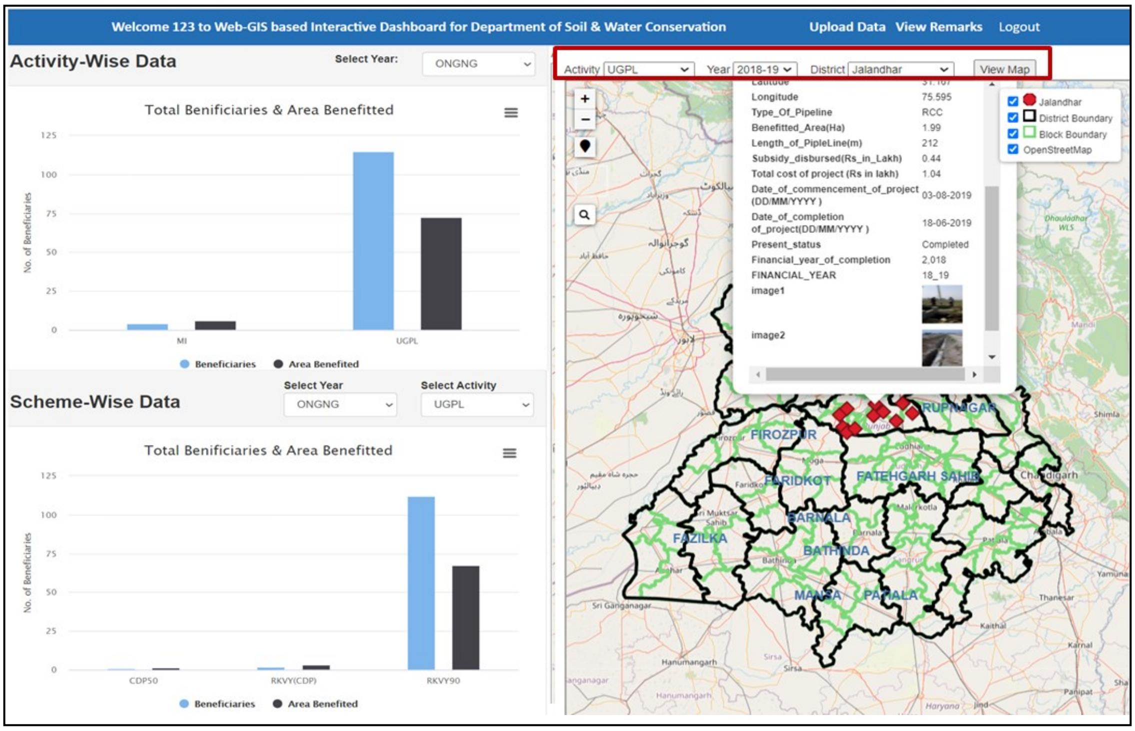

Figure 11. Data Visualization in Web-GIS Based Interactive Dashboard for Department of Soil & Water Conservation

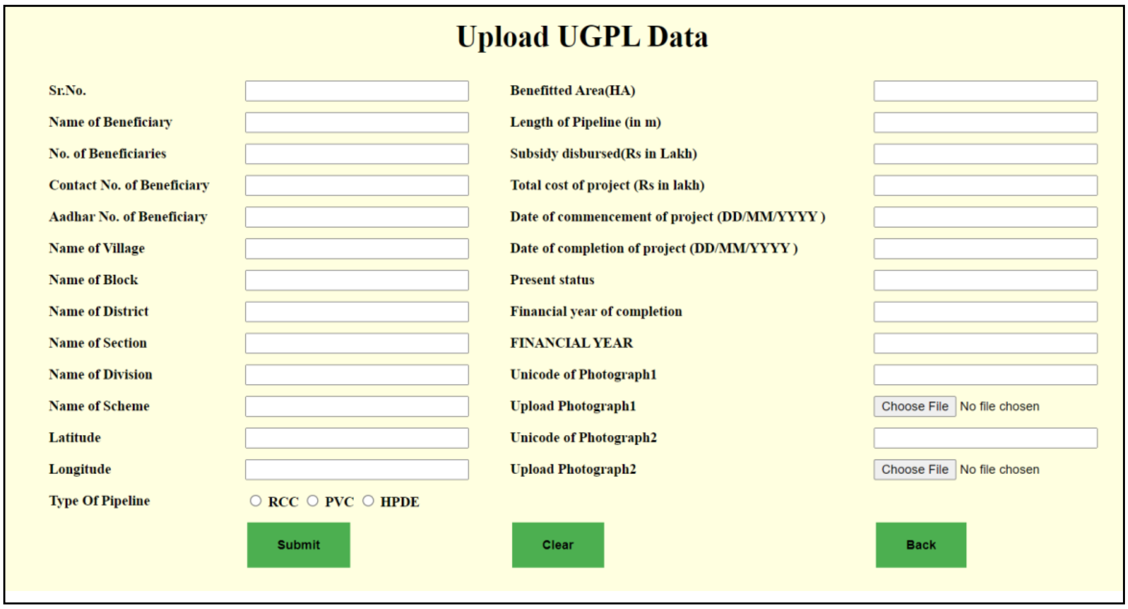

Figure 12. Form for uploading data in Web-GIS Based Interactive Dashboard for Department of Soil & Water Conservation

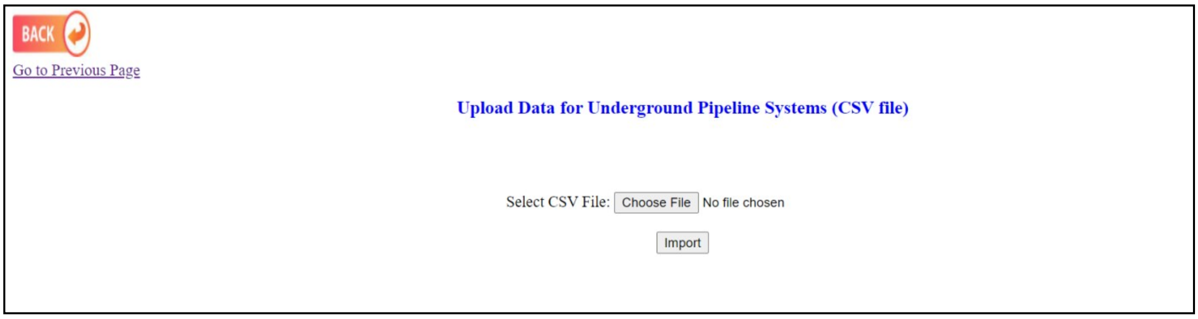

Figure 13. Form for uploading data in CSV format for Nodal Officers in Web-GIS Based Interactive Dashboard for Department of Soil & Water Conservation

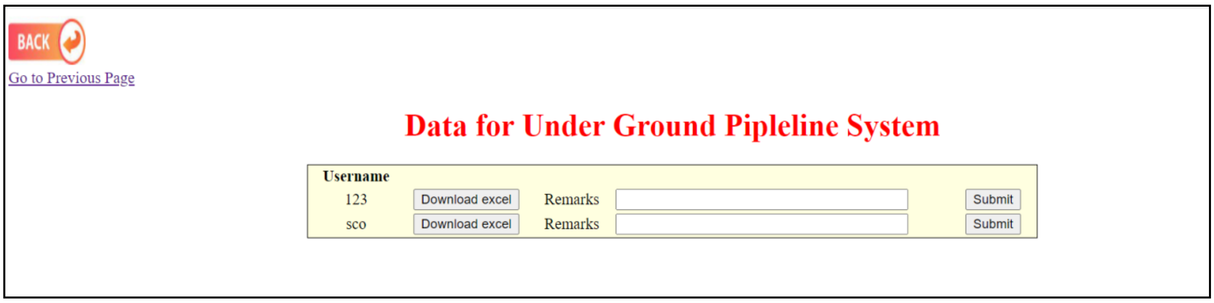

Figure 14. Form for Viewing uploaded data in CSV format in Web-GIS Based Interactive Dashboard for Department of Soil & Water Conservation

6. Conclusion

To visualize data on a dynamic dashboard with charts, maps, and other visual elements that show the status and performance of vital assets and events in real time, user friendly Web GIS dashboard is developed for real-time data visualization and analysis, where, one can visualize the work carried out in any particular block/district/state on the click of the mouse on a particular point. It also helps the officials to take further analysis based on the gap analysis, where less work has been carried out for a particular activity or scheme. Web GIS is a powerful tool for helping management, since it provides the information, geo-located data and capabilities to make the information accessible to everyone and everywhere in the world.

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