Development of Web Based Geospatial Application Using FOSS4G for Matara District of Sri Lanka

Manamperi A.M.

Map Technological Officer, GIS Branch, Surveyor General's Office, Sri Lanka

amilamanamperi@outlook.com

Abstract *This study presents the development of a web-based geospatial application for the Matara district of Sri Lanka, employing Free and Open Source Software for Geospatial (FOSS4G) to enhance the accessibility and analysis of spatial data. By integrating with Geo-Spatial Science and Geographic Information Systems (GIS), the application addresses critical needs in natural resource management, disaster management, tourism, and governance. The methodology involved a three-tier architecture with* Apache Tomcat *as the web server, GeoServer as the GIS server, and PostgreSQL/PostGIS for geospatial data management. The MapStore framework was used to build the application, providing a flexible platform for data visualisation and interaction. Key features include a Geospatial Viewer that supports OGC-compliant Web Map Service (WMS) standards for detailed layer visualisation and map generation, and a Geospatial Dashboard that enables interactive data exploration, filtering, and interaction with charts and widgets. The application enhances geospatial data management by allowing non-programmers to engage with complex spatial datasets effectively. The outcomes underscore the potential of FOSS4G tools in creating scalable and user-friendly GIS solutions that support informed decision-making in the Matara district.*

Keywords: Web-Based Geospatial Application, FOSS4G, Geospatial Viewer, Geospatial Dashboard, Geo-Spatial Science, GIS, Matara District, Sri Lanka

1. INTRODUCTION

1.1. BACKGROUND

The use of maps has been used since antiquity to facilitate the everyday work of man. People have recognized the importance and value of maps in their lives. The history of mapping can be traced back 5,000 years ago. Maps are essential tools. In the main, we can consider two things. That is, for the mapmaker, record the location of the points of interest and, for others, whether the mapped area is a prototype for learning about geography. Maintaining a series of maps with a successful basis is very important for the communication of a particular country.

Almost every government was moving towards sustainable development strategies. Mapping services are provided to the same Conveyor process.

Printed maps, the pattern of a tradition that has existed in the past, are the production of printed maps. But out of paper printed in Germanic, cartography is digitized, and everyone has come up to their mobile phone. Internet connection, an electronic device that can be connected to it (e.g., Smartphone, Smart tab and Computer), and the ability to use digital maps for anyone with the help of using them. Here, thematic data (spatial data) and numerical data (non-spatial data) are performed using the spatial data delineation method of point, line and polygon. In addition, another important thing is symbolization. It is through this that a final recompilation of data to the user is carried out. It should be very sensitive and in the right condition.

For over 5,000 years, maps have formed an important tool for man in recording locations and understanding geography. Printed maps were the means of communication in times past, but with digitized technology, cartography has now become accessible through smartphones and computers.

Digital maps integrate spatial and non-spatial data utilizing points, lines, and polygons, among other means, through conscious symbolization in service of appropriate communication. The real world sometimes thought of as a literal representation of reality, is different from maps in that they are a set of symbols representative of the decisions and priorities of the cartographer. They reduce detailed information into a simpler form in order to increase clarity and utility.

Maps are still useful, especially in GIS, where they offer an intuitive and visually attractive means of presenting and analysing data. Printed maps still have their value despite the arrival of digital maps for their wide contexts; they often feature exceptional workmanship in their artwork and are even capable of conveying large amounts of information. GIS technologies have progressed in such a manner as to support both digital and printed maps, which continue to be fundamental tools for professionals in this line.

Source: Techexpert.lk

Figure 1: Revolution of the maps

However, providing accurate and accurate data and information to users will be a function of the Provider. It will be better to use high-tech methods and use them for dissemination purposes while reaping successful results in GIS.

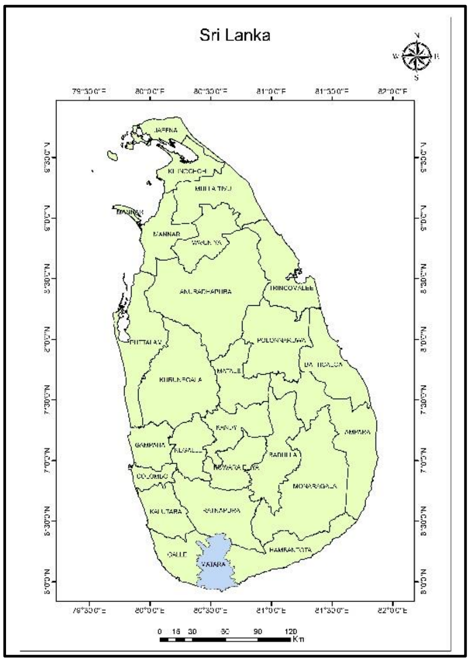
1.2. GEOSPATIAL DATA

The Survey Department of Sri Lanka is the only authenticated organization for mapping purposes in the country. In 1979, the ABMP started replacing the one-inch topographic maps with 1: 50,000-scale maps. A new project relating to the Northern Province in 2010 saw the publication of the "Digital Topographic Mapping North Area Reversion Project" report in 2012 in collaboration with JICA.

The Survey Department distributes geographic maps on the basis of the guidelines provided by Survey Act No. 17 of 2002, in printed thematic maps format. The Surveyor General controls national cartographic output to achieve standards in signs and abbreviations usage, standardization of map sheets, but when necessary, new signs or abbreviations can also be adopted.

Historically, a 1:50,000-scale mapping was compiled using ground and aerial surveys between 1985 and 1996; the first national map was published in 1988. Later, these were updated through photogrammetric techniques and satellite imagery, while recent works also include LiDAR data and 1:20,000-scale aerial photography.

These two major kinds of maps that the Survey Department produces are: Topographic maps, which include basic spatial information, generally relating to land use and transport features; and Thematic maps, which emphasize a specific theme, including from geology to population.



Source: GN Boundary 2017-Survey Department Based Data

Figure 2: District map of Sri Lanka

The Southern Province of Sri Lanka includes three districts: Galle, Matara, and Hambantota. Matara is a coastal city in the Southern District of Sri Lanka, 160 km east of Colombo. It borders the Galle District to the west, Hambantota District to the east, and Ratnapura of the Sabaragamuwa Province to the north, while the Indian Ocean forms its southern boundary.

The district essentially has a coastal plain extending inland, with the Sinharaja Rainforest in the northern part. Matara lies in the lower wet zone and receives quite a lot of rainfall during the Southwest Monsoon. The major sources of water are the Nilwala and the Polathumodara rivers, while their catchments are in the Rakwana Mountains and the Sinharaja and Kanneliya forests. Land use varies between urban building up, coastal gardens, and paddy fields irrigated by the Nilwala water project. The central area of the district is renowned for the cultivation of coffee, cinnamon, and pepper. Tea is grown in the higher reaches.

Matara has a generally stable climatic environment throughout the year, while annual floods in the Nilwala River basin during the monsoon season are preordained. The district population exceeds 800,000 and is divided into 16 Divisional Secretariat divisions, 650 Grama Niladhari divisions, and 7 electoral divisions, while administrative matters are conducted by municipalities and local authorities.

1.3. GIS AND WEB GIS

These systems were little more than a collection of ground-breaking computer-based programmes for processing map data when they were initially created in the early 1960s, and they were only utilised by a few institutions and government organisations. Today, GIS has developed into a significant academic discipline, one of the fastest-growing industries in the computer industry, and, most importantly, a crucial pillar of the contemporary world's information technology (IT) infrastructure. We will first define GIS by identifying the characteristics that uniquely distinguish them from other classes of information systems. We will then explain how GIS has come to its current state of development by tracing its evolution over the years. This will be followed by an overview of the working principles of GIS from the perspectives of their key components: data, technology, application, and people.

Attempting to define GIS is not a simple task. Some people see GIS generally as a branch of IT; others see it more specifically as a computer-assisted mapping and cartographic application, a set of spatial-analytical tools, a type of database system, or a field of academic study. In the following sections, we will define GIS from the first principles by examining the generic meanings of "information," "system," and "information system" and explaining why the word "geographic" makes GIS a unique class of information systems.

Web GIS stands for Web Geographic Information System. It is a type of GIS that uses web technologies to share and manage geographic information on the Internet. Web GIS allows users to access and interact with geographic data from anywhere in the world using a web browser. Some examples of Web GIS include ArcGIS Online, Google Maps API, and OpenLayers. Benefits of using Web GIS include the ability to access and share geographic data from anywhere in the world using a web browser, the ability to collaborate with others on geographic data, and the ability to create interactive maps and applications.

The main distinction between web GIS and traditional GIS is that web GIS makes use of net technology to percentage and manage geographic information on the net, at the same time as conventional GIS is commonly used for computing device programs. Popular open-source web GIS equipment includes GeoServer, MapServer, and QGIS Server. There are several open supply systems for showing digital maps. One of the most famous is OpenLayers. It is one of the first web mapping libraries and has been used internationally to display maps on the net. It became an exceptional open supply opportunity for Google Maps API. Model three has been completely remodelled from scratch to include new browser possibilities, and lives with an energetic network on account that 2013, today is version sixty-one. Another alternative is Grass GIS, which is an open source and free software program that may run on home Windows, Mac, and Linux with a built-in GUIQGIS is every other open-supply GIS software that lets you visualise, control, adjust, analyse, and create revealed maps.

1.4. PROJECT RATIONALE AND MOTIVATION

The main objective of the Web GIS initiative is to improve the access and usability of Geographic Information Systems (GIS) in current technological systems. Geographic Information System (GIS) tools in traditional format are commonly presented with complex and required software, and many individuals and entities may not have access to them. The project seeks to improve the accessibility and usability of GIS technology by creating a web-based GIS platform. In addition, users can facilitate data entry, data editing and data deletion. It is important to use non-spatial data for administrative purposes in a district. This is the total population of the respective division, the population classification, and the number of eligible voters and the area extent of the administrative division. In addition, landuse classification allows you to understand how much they can be used to comb in such areas.

The Web GIS project combines the coherence of access, user-friendliness, collaboration, and Web-based architecture. This innovative platform effectively expands the approach of GIS technology. Furthermore, the Web GIS project also acts as a medium for collaboration and knowledge sharing. Most importantly, this project promotes fair access and nationalization to spatial analysis and mapping practices.

1.5. OBJECTIVES

Develop a web-based geospatial application that provides easy and intuitive access to geospatial information specific to Matara District using FOSS4G.

1) Spatial Database preparation, organization, and management
2) Develop web-based visualization and analysis tools

1.6. SCOPE AND LIMITATIONS

The project focuses on developing essential GIS functionalities such as map visualization, data management, spatial analysis and geoprocessing. These core features enable users to effectively explore, analyse and manipulate geospatial data. The project aims to create a user-friendly web interface that allows users to interact with the GIS functionalities using standard web browsers. The interface should provide intuitive controls, responsive design, and support for various devices and screen sizes.

The Survey Department of Sri Lanka has lots of thematic data in the Matara district, but only the data selected from which it has been used for this purpose. For example, contour lines data consisting of 5m intervals, buildings with a district in the form of a polygon, etc. The objective is to provide clarity on the map and the availability of data repertoire according to the necessary data. That is the data that is most used by users on the same day for the purposes. But it is also possible to easily collect additional data at any time of need.

The availability and quality of geospatial data may be a limitation for Web GIS projects. Open-source projects rely on publicly available data sets or user subscription data, which do not cover all geographic areas or may be up to date. Access to proprietary or restricted data sets may also be limited. Integrating with other systems or working with proprietary GIS models can pose challenges. Adjust issues may arise when trying to connect to different data sources, databases, or third-party tools.

2. LITERATURE REVIEW

This chapter presents a literature review on the development of web-based geospatial applications using Free and Open Source Software for Geospatial (FOSS4G) in the context of the Matara District in Sri Lanka. The review aims to provide an overview of the current state of the field, identify existing research and projects relevant to the topic, and highlight the key findings and gaps in the literature.

2.1. OVERVIEW OF WEB-BASED GEOSPATIAL APPLICATIONS

Web-based geospatial applications refer to software systems that utilize web technologies and geospatial data to provide users with interactive and dynamic mapping capabilities through a web browser. These applications have gained significant popularity due to their accessibility, ease of use, and ability to integrate and visualize spatial data in a user-friendly manner. FOSS4G plays a crucial role in the development of web-based geospatial applications, offering a range of tools, libraries, and frameworks that enable developers to create robust and scalable systems without incurring high costs associated with proprietary software. The use of FOSS4G promotes open data standards, interoperability, and community-driven development, which are essential for sustainable and inclusive geospatial solutions. Research by Smith et al. (2018) demonstrated the significance of FOSS4G in web-based geospatial application development. They compared the development costs and capabilities of FOSS4G tools with proprietary software in a project focused on urban planning in a developing country. The findings showed that FOSS4G tools not only significantly reduced costs but also facilitated data integration and collaboration among stakeholders, highlighting their importance in supporting sustainable urban development initiatives.

2.2. FOSS4G TOOLS AND FRAMEWORKS

This section provides an overview of the key FOSS4G tools and frameworks commonly used in web-based geospatial application development. It covers widely adopted technologies such as MapStore, GeoServer, PostGIS, PostgreSQL, and Apache Tomcat highlighting their features, capabilities, and use cases. GeoServer is a Java-based open-source server that allows for the publishing of geospatial data as web services. It supports standard protocols such as WMS, WFS, and WCS, making it easy to share geospatial data across different platforms and applications.

2.3. WEB GIS APPLICATION ARCHITECTURE

The Web GIS application architecture usually follows a client-server model, where the client is the web browser or application interface, and the server handles data storage, processing, and serving the application. Specific components and technologies used in a Web GIS application may vary based on project needs, programming languages, frameworks, and preferences. The modular and scalable architecture allows easy maintenance, upgrading, and expanding functionalities as the application evolves. The Map Viewer component allows users to interact with geospatial data. It provides functions such as panning, zooming, layer visibility control, querying, and spatial analysis tools. Handles client-side user input and interaction including mouse clicks, keyboard input, and form submissions. It communicates with client-side components to receive data and update the interface.

2.3.1. Server-Side (Back-End)

Web server: The web server acts as the intermediary between the client and the follow-end components. It receives HTTP requests from the client and responds to them, providing web pages, data and application resources. Popular web server software includes Apache, Nginx, and Microsoft IIS. The application server handles business logic and data processing. It manages client requests, processes spatial queries, performs reprocessing tasks, and interacts with the database.

2.3.2. Geospatial Database

Geospatial Database stores and manages spatial data, including vector data (points, lines, polygons) and raster data (images, elevation models). Common geospatial databases include PostgreSQL with Postages extension, MySQL with spatial extensions, or specialized databases such as MongoDB or Observer.

2.3.3. Data Sources and Services

Web GIS applications rely on a variety of geospatial data sources, including public data sets, personal data sets, user subscription data, and real-time data synths. These may include data formats such as Shape files, Godson, KML, or WMS/WFS services provided by external sources.

2.4. MAP/GIS SERVER

These Maps/GIS server options offer a range of features and support for various data formats and protocols. They enable geospatial data publishing, management, and servicing, allowing users to access and interact with maps and spatial information in their applications or through web services. The choice of Map/GIS server depends on the specific needs, budget and available resources.

In EServer, select the data sources provided. This may include spatial databases, shape files, GeoTIFFs, or other supported formats such as PostgreSQL with PostGIS extension. Create data stores in GeoServer to connect to your data sources.

GeoServer uses the Styled Layer Description (SLD) standard to define layer styles. SLD is an XML-based model that allows you to describe how to render features on the map. GeoServer Map Service supports Web Map Service (WMS) and Web Map Tile Service (WMTS) standards. Including service URLs, supported Coordinate Reference Systems (CRS), and layer visibility.

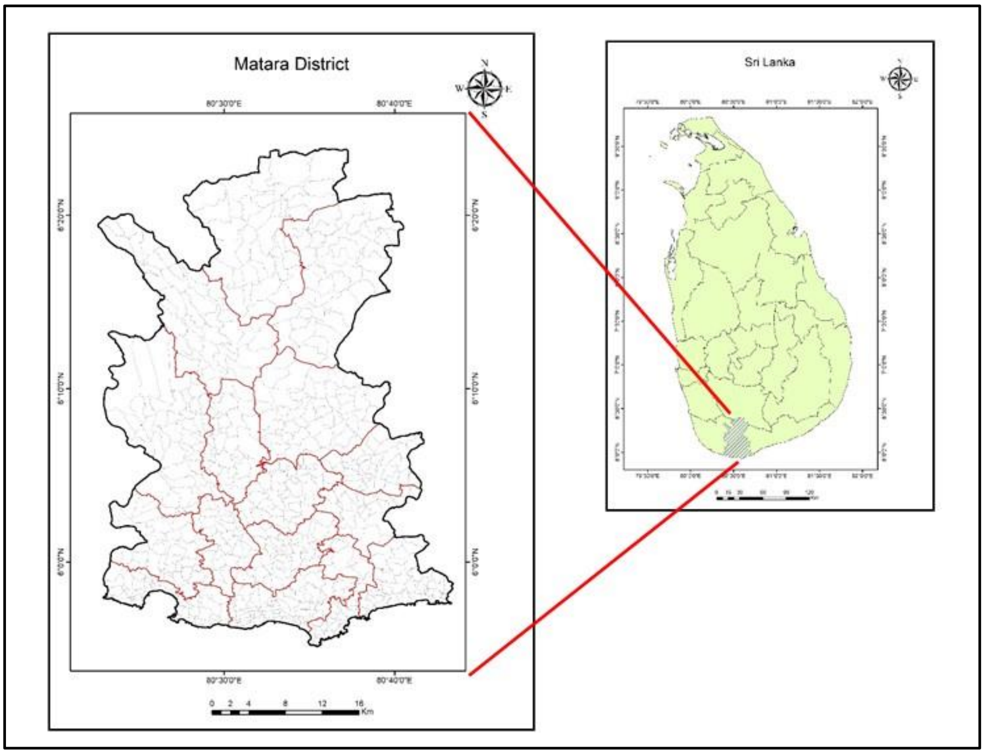
2.5. CHALLENGES AND LIMITATIONS

The literature review also addresses the challenges and limitations associated with developing web-based geospatial applications using FOSS4G. These challenges include data management and integration, performance optimization, security considerations, user experience design, and the need for skilled developers with expertise in FOSS4G technologies. Example: Research by Chen et al. (2017) identified data management as a major challenge in developing web-based geospatial.

3. STUDY AREA AND MATERIALS

3.1. STUDY AREA

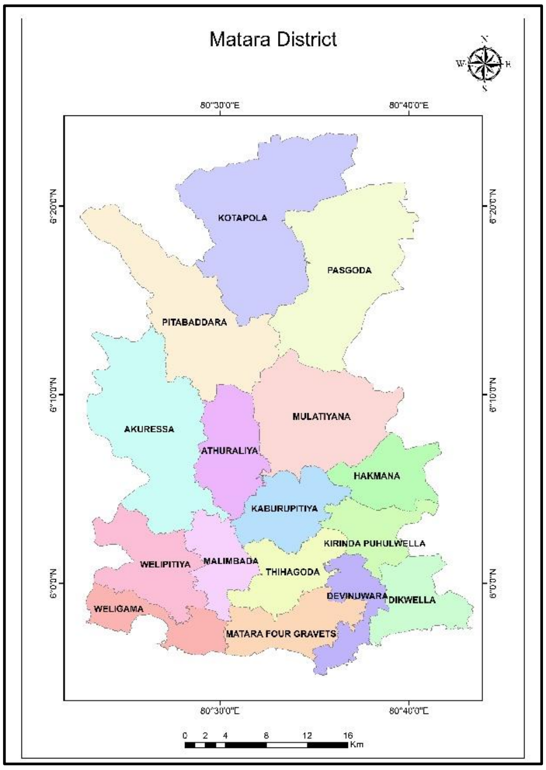
The study area selected for this project is Matara district of India. The Matara District is in the southern coastal region of Sri Lanka. It is situated in the Southern Province, bordered by the Indian Ocean to the south and the districts of Hambantota to the east, Rathnapura to the north, and Galle to the west. Matara is the district’s capital city and serves as the region's major economic and administrative centre. The district covers an area of approximately 1,283 square kilometres and encompasses diverse landscapes including coastal areas, agricultural lands, and forested regions. Matara District is known for its beautiful beaches, historical sites, and cultural heritage. Figure 3 represents the study area map of the Matara District of Sri Lanka.



Source: GN Boundary 2017-Survey Department Based Data

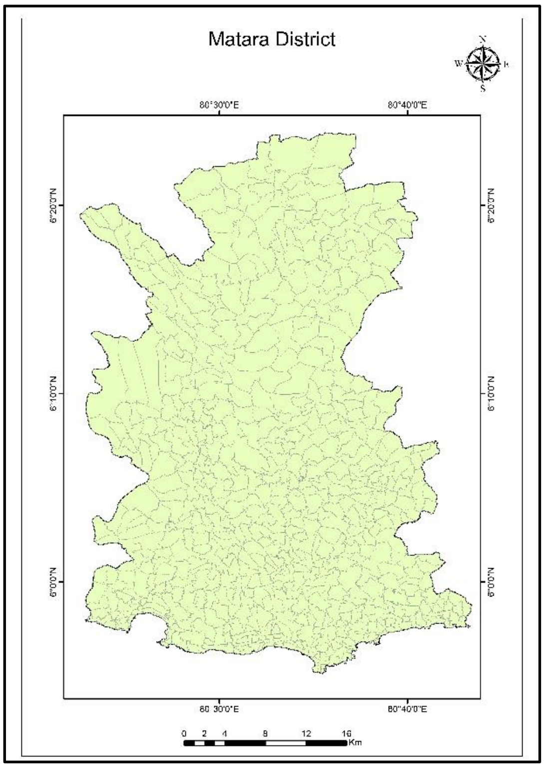
Figure 3: Matara District of Sri Lanka

There are 16 Divisional Secretariats in Matara District and in addition, there are 650 Grama Niladhari Divisions and 1658 villages in administrative terms. Divisions have been carried out into Municipal Councils and local authorities to consider the principle of public welfare. Administrative activities are handled in the area by the Agencies about the division. Figure 5 below shows the divisional secretariats map of the main division of Matara district and the GN map shown in Figure 4.



Source: GN Boundary 2017-Survey Department Based Data

Figure 4: Divisional Secretariat's Division



Source: GN Boundary 2017-Survey Department Based Data

Figure 5: Grama Niladhari Division

3.2. DATASETS USED

In this study, two types of data are used. First, spatial data is used in the Matara district, and second, non-spatial data is used in statistical data. These data sets will serve as valuable inputs for web-based geospatial applications enabling data visualization, analysis, and decision-making for various purposes within the Matara District. It is essential to ensure that the data are accurate, up-to-date, and obtained from reliable sources to ensure the reliability and effectiveness of the application.

3.2.1. Spatial Data

Spatial data for Sri Lanka, Matara District, therefore, consists of different geospatial data that becomes very important in regional analyses and planning. To be specific, it covers boundary data from districts up to divisional secretariats and Grama Niladari divisions, serving as a base for organizing other spatial data sets. Transport data include information on roads, highways, and main routes showing the classification of the roads and the names among other information. The water body data enumerates rivers, lakes, and reservoirs within the district, which is necessary to understand hydrological features. Land use data provides a classification into agricultural lands, forests, urban zones, and wetlands, which is useful for land management and planning. Still, other points of interest like schools, hospitals, and tourist sites are mapped for easy access and location. Vegetation data, from various vegetation types and coverage, supports ecological and biodiversity studies. Ensuring this spatial data is accurate and up to date may be considered critical in deriving reliable results in the geospatial application field.

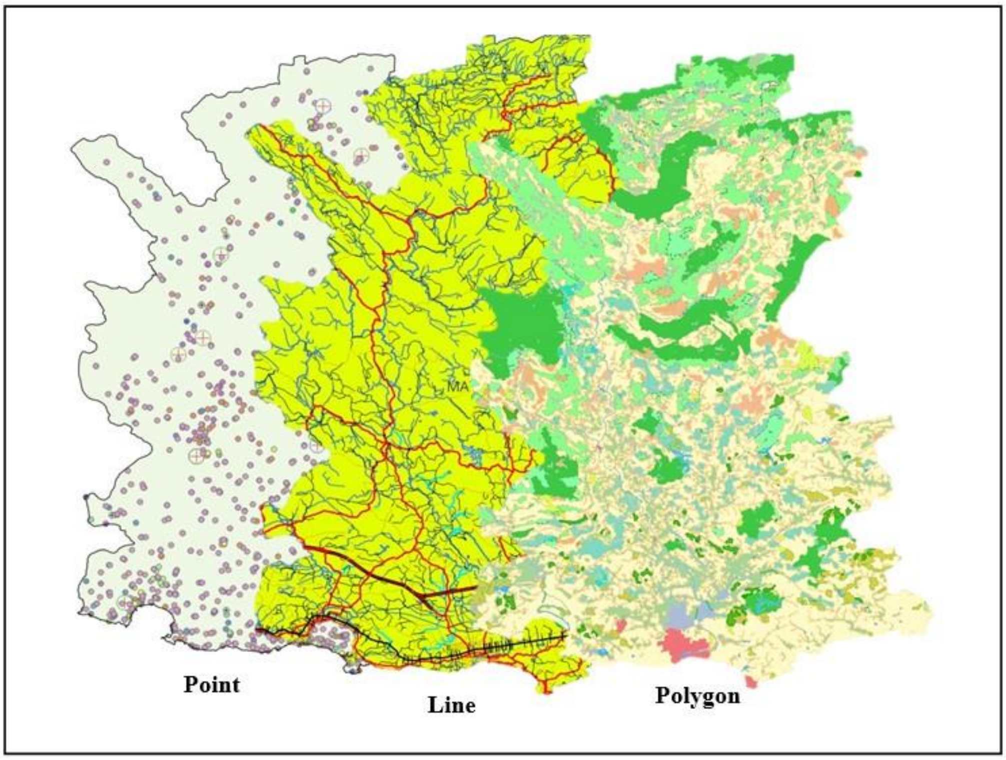
All thematic data are data used by the Surveyors Department of Sri Lanka for cartographic design and are all from the WGS 84 Coordinate system. All of them have been obtained for this project in the shapefile format. The Survey Department of Sri Lanka is responsible for conducting surveys, mapping, and maintaining geospatial data across the country. They provide various spatial data products and services. The department produces detailed topographic maps covering different regions of Sri Lanka. These maps provide information about the terrain, elevation contours, water bodies, roads, and other geographical features. The Survey Department captures and maintains aerial imagery of different parts of Sri Lanka.

The data used for this project are from 1:20000 aerial photographs; those obtained are also included in field verification. The accuracy of data provided by the Survey Department of Sri Lanka can vary depending on the specific dataset and the methods used for data collection and processing. For this project, point, line and polygon are the main classification of spatial data. Point, line, and polygon are the fundamental geometric representations used in spatial data to represent different types of geographic features. A point is the simplest spatial object and represents a single location in space, typically defined by its coordinates (latitude and longitude or x and y coordinates). A line represents a series of connected points, forming a path or route. Lines are used to represent linear features like roads, rivers, and trails. A polygon is a closed shape consisting of a series of connected lines. It represents an area or a boundary. Polygons are used to represent regions like administrative boundaries, land parcels, or lakes. They are defined by a series of coordinates that connect the vertices of the polygon in a specific order. Points, lines, and polygons are essential elements in spatial data modelling and analysis. They allow for the representation and visualization of various geographic features and enable spatial operations such as buffering, intersection, and spatial querying.

In the context of the Matara District in Sri Lanka, point features refer to specific geographic locations or points of interest within the district. These can include buildings, institutions, natural features, transportation hubs, or any other notable points on the map. Examples of point features, Points representing hospitals, clinics, and medical centres within the district, schools, universities, and other educational facilities, and government administrative buildings, including district offices, police stations, and municipal offices. Bus stations, train stations, and other major transportation terminals within the district.

Line features refer to linear geographic elements or features that exist within the district. These features represent objects that have lengths but negligible widths, such as roads, rivers, and transportation routes (Road and Railway). Line features provide valuable spatial information and can be used for various purposes in geospatial applications. Examples of line features, Lines representing major roads, highways, and streets within the district, including their classifications (e.g., national highways, local roads), rivers, streams, canals, or other water bodies flowing through the district.

Polygon features refer to closed geometric shapes that represent distinct areas or regions within the district. These features are characterized by having a boundary defined by a series of connected lines and enclosing a specific area on the map. Polygon features provide spatial information about the extent and boundaries of various geographic entities within the district. Examples of polygon features, Polygons representing the boundaries of administrative units within the district, such as district boundaries, divisional secretariat boundaries, different land use or land cover categories, including residential areas, agricultural lands, forests, water bodies, or industrial zones, lakes, ponds, reservoirs, or other significant water bodies within the Matara District.



Source: 50K Version 2.0-Survey Department Based Data

Figure 4: Thematic (Spatial) Data of Matara District

Non-spatial data refers to information that is not explicitly associated with geographic locations. This includes population statistics, age distribution, gender composition, ethnicity, and other demographic information about the people of Sri Lanka. It helps in understanding the social makeup and characteristics of the population. Health-related data encompasses information about healthcare infrastructure, disease prevalence, immunization rates, mortality rates, and other health indicators in Sri Lanka. It helps in assessing the healthcare needs and priorities of the population. Education-related data covers aspects such as literacy rates, school enrolment rates, educational attainment levels, and educational infrastructure in Sri Lanka. It helps in evaluating the state of education and identifying areas for improvement. This includes data on government structure, public administration, legal frameworks, public services, and other governance-related information in Sri Lanka. The relevant data was provided on the website of the Department of Census and Statistics of Sri Lanka. Those data are data that belong to the period from 2015 to 2017. (http://www.statistics.gov.lk) Further, the election data was obtained from the National Election Commission. The data is relevant to the year 2022. (https://elections.gov.lk)

Non-spatial data, also known as attribute data or tabular data, has several advantages in various domains and analytical processes. Non-spatial data provides valuable context and additional information about spatial features. It allows for a deeper understanding of the characteristics, attributes, and relationships associated with geographic locations. For example, demographic data can help analyse population patterns and understand the social dynamics of an area. Non-spatial data can be easily analysed using statistical and mathematical techniques. It allows for the application of various analytical methods such as regression analysis, clustering, classification, and data mining to gain insights and make informed decisions. Below is a table of data disaggregated for this project as shown in Figure 7.

DSD_Polygon_WGS84 — Features Total: 16, Filtered: 16, Selected: 0

	DSD_N	Population	Employed	Unemployed	Male	Female	Popu_Densi	Area_Km2_	No_of_Scho	No_of_gov
1	AKURESSA	56318	30637	25681	27106	29212	375.00000000000	150.04	28	2
2	ATHURALIYA	34387	18810	15577	16550	17837	545.00000000000	63.04	17	1
3	DEVINUWARA	51359	27852	23507	24719	26640	1346.00000000...	38.15	17	1
4	DIKWELLA	58193	31657	26536	28008	30185	1139.00000000...	51.1	24	2
5	HAKMANA	33687	18528	15159	16214	17473	680.00000000000	49.51	25	2
6	KABURUPITIYA	51308	28117	23191	24695	26613	887.00000000000	57.88	21	1
7	KIRINDA PUHU...	21599	11815	9784	10396	11203	516.00000000000	41.9	11	4
8	KOTAPOLA	67330	37705	29625	32406	34924	376.00000000000	178.95	25	1
9	MALIMBADA	37103	20073	17030	17858	19245	866.00000000000	42.85	14	1
10	MATARA FOUR ...	123262	66561	56701	59326	63936	2177.00000000...	56.62	38	4
11	MULATIYANA	53499	29692	23807	25749	27750	444.00000000000	120.38	23	2
12	PASGODA	62971	35012	27959	30308	32663	409.00000000000	153.99	30	3

Show All Features

Source: Department of Census and Statistics of Sri Lanka 2015 - 2017

Figure 5: Non-Spatial Data (Attribute Table)

3.3. SOFWARE AND HARDWARE USED

The software was used to develop a web-based geospatial application using FOSS4G (Free and Open Source Software for Geospatial) for the Matara district project in Sri Lanka. FOSS4G stands for "Free and Open Source Software for Geospatial." It refers to a collection of open-source software tools and frameworks that are specifically designed for geospatial data management, analysis, and visualization. FOSS4G software provides a cost-effective and accessible alternative to proprietary geospatial software solutions.

QGIS Desktop Version 3.28.1

QGIS is a powerful open-source desktop GIS software that can be used for data preparation, analysis, and visualization. It provides a user-friendly interface and extensive geospatial tools for working with spatial data. (https://www.qgis.org/en/site/forusers/download.html)

PostgreSQL and PostGIS Version 12

PostgreSQL is a robust open-source relational database management system, and PostGIS is an extension that adds spatial capabilities to PostgreSQL. They provide a reliable and spatially enabled database environment for storing and managing geospatial data. (https://www.postgresql.org/)

Apache Tomcat version 9.0

Apache Tomcat is an open-source web server and servlet container. It can be used to deploy and run Java-based web applications, including the geospatial application developed for the Matara District project. (https://tomcat.apache.org/)

GeoServer Version 2.22.2

GeoServer is an open-source server software that allows for publishing geospatial data as web services. It supports standard protocols such as WMS (Web Map Service) and WFS (Web Feature Service) and facilitates the dissemination of geospatial data over the web. (https://geoserver.org/)

MapStore

MapStore is an open-source web-based GIS client application. It offers a user-friendly interface for creating interactive maps, querying data, and customizing the visualization. It can serve as a front-end interface for the web-based geospatial application. (https://docs.mapstore.geosolutionsgroup.com/en/latest/)

Server infrastructure is required to host and deploy the web-based geospatial application. The server hardware should have sufficient processing power, memory, and storage capacity to handle the application's requirements, including data storage, processing, and serving web services. A laptop computer with this specification was used for that project.

Processor: Intel Core i5-1135G7; 2.40 GHz, Memory: 8GB, Storage: 120 SSD + 1 TB HDD, OS: Windows 11 (64-bit).

4. METHODOLOGY

The methodology for the project is shown in Figure 8. It is divided into three parts, spatial data storage and management, Server-Side and Client-side. Spatial data storage and management are essential components of any geospatial application. Proper storage and management of spatial data ensure efficient data organization, retrieval, analysis, and sharing. Data pre-processing in QGIS involves a series of steps to prepare geospatial data for analysis, visualization, or further processing. In the context of a web-based geospatial application, the server-side refers to the components and processes that are executed on the server to handle data processing, storage, and interaction with clients. In the context of a web-based geospatial application, the client-side refers to the components and processes that are executed on the user's device (client) to interact with the application and visualize geospatial data.

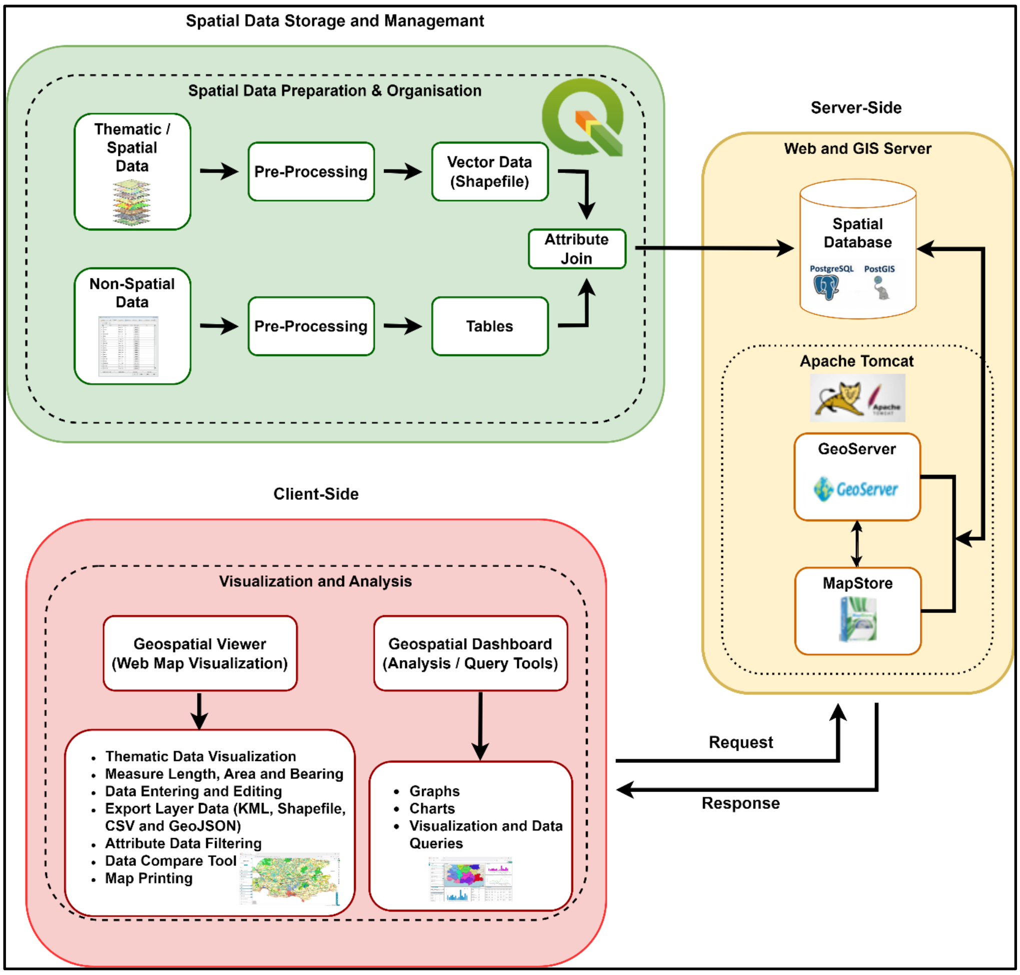


Figure 6: Methodology diagram

4.1. SPATIAL DATA STORAGE AND MANAGEMENT

4.1.1. Data Collection

Spatial data storage and management is a crucial aspect of developing a web-based geospatial application. The data collection process involves gathering relevant spatial data for the project. Determine the specific spatial data required for web-based geospatial applications. This may include administrative boundaries, transportation networks, land use, places of interest, handheld photos, or other data relevant to the purpose of the project. According to a request made to the Geographic Information System Division of Survey Department of Sri Lanka as the source of spatial data, it was possible to obtain thematic data related to Matara District. Accordingly, the Department provided the data in the shapefile format in separate layers, which are in the SLD99 (SLD99 Datum 99) Coordinate system. But the Coordinate system I hope for is due to EPSG 4326, so all layers were made.

SLD99 is a geodetic datum specifically designed for Sri Lanka. It provides a reference framework for defining the positions of points on the Earth's surface in Sri Lanka. The datum is based on a specific ellipsoid, geodetic parameters, and coordinate transformations. The SLD99 coordinate system is commonly used in surveying, mapping, and geospatial applications in Sri Lanka. EPSG 4326, also known as WGS84 (World Geodetic System 1984), is a widely used geographic coordinate reference system (CRS). It defines a global coordinate system based on a spherical Earth model. The EPSG 4326 CRS is commonly used for representing and working with latitude and longitude coordinates.

The second type of data in the project is non-spatial data. Matara district population, gender, population density, information about schools in one division and land use data have been used. They were obtained from various government agencies established in Sri Lanka. They can be described as follows. Demographic data includes information about the population, such as population size, age distribution, gender distribution, ethnicity, literacy rates, and household characteristics. Sri Lanka is an agricultural country, and collecting agricultural data is crucial for understanding farming practices, crop yields, land use patterns, and the contribution of the agricultural sector to the economy.

4.1.2. Data Pre-Processing

Spatial and non-spatial data pre-processing is an essential step in preparing data for analysis and integration in a web-based geospatial application. Identify and address any errors, inconsistencies, or outliers in the spatial data. This includes removing duplicates or faulty records, correcting geometric errors, and solving topological problems. The resolution or detail level of spatial data was adjusted to match the desired level of analysis or visualization. Generalization techniques such as simplification or addition can be applied to reduce complexity and improve performance. Preparation of spatial data, symbol, and labelling in such a way that I Finally, the data was adjusted to each layer in the SLD format. The feature symbol and the corresponding symbols to the label are shown in Figure 9. In QGIS, the SLD (Styled Layer Descriptor) format is used to define the visual styling and symbology for spatial data layers. SLD is an XML-based format that allows us to specify how the features in our data layer should be displayed on a map.

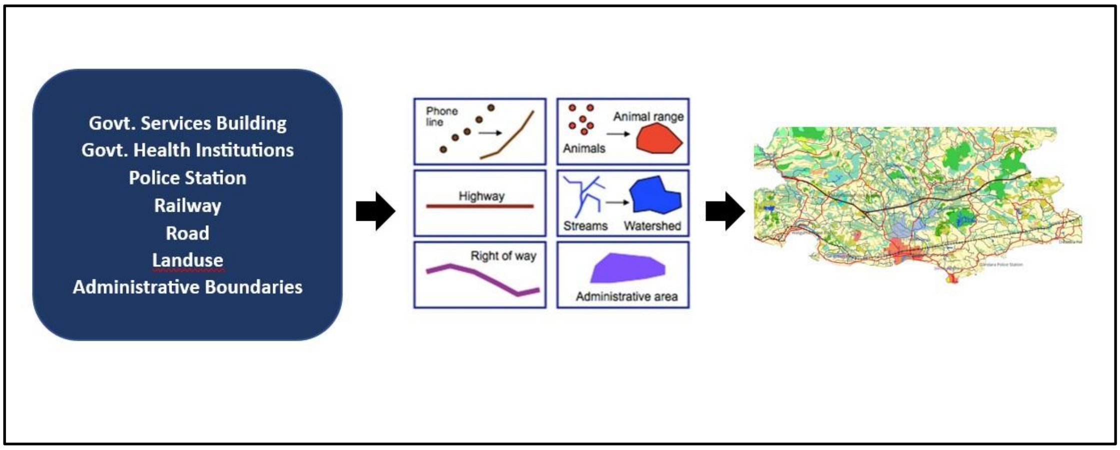


Figure 7: Feature Symbolisation and Labelling

Cleaning non-spatial data by eliminating duplicates, correcting errors, handling missing values and ensuring consistency of attribute values is a mandatory activity. This may include data validation, standardization, and formatting. These pre-processing tasks help ensure data quality, consistency, and compatibility before utilizing spatial and non-spatial data in a web-based geospatial application. By performing these steps, the data is prepared for analysis, visualization, and integration, enabling more accurate and meaningful insights for the users.

Finally, the non-spatial data collected with the spatial data is carried out. To it we name the attribute join. Attribute join, also known as attribute table, join or data join, is a process in GIS where data from one attribute table is combined with another attribute table based on a common attribute or field. This operation allows us to merge or append additional information to a spatial dataset based on matching attribute values. Attribute joins are useful for combining different datasets with common attributes, such as adding demographic data, land-use information, or other attributes to a spatial dataset. It allows for more comprehensive analysis and visualization by integrating multiple sources of information into a single layer. For this, the population, gender, number of schools located in each division and health service locations have been linked with the divisional secretariat division's shapefile and added to the database. A diagram of the related attribute table can be seen in figure 10 below.

DSD_Polygon_WGS84 — Features Total: 16, Filtered: 16, Selected: 0

	DSD_N	Population	Employed	Unemployed	Male	Female	Popu_Densi	Area_Km2_	No_of_Scho	No__of_gov
1	AKURESSA	56318	30637	25681	27106	29212	375.00000000000	150.04	28	2
2	ATHURALIYA	34387	18810	15577	16550	17837	545.00000000000	63.04	17	1
3	DEVINUWARA	51359	27852	23507	24719	26640	1346.00000000...	38.15	17	1
4	DIKWELLA	58193	31657	26536	28008	30185	1139.00000000...	51.1	24	2
5	HAKMANA	33687	18528	15159	16214	17473	680.00000000000	49.51	25	2
6	KABURUPITIYA	51308	28117	23191	24695	26613	887.00000000000	57.88	21	1
7	KIRINDA PUHU...	21599	11815	9784	10396	11203	516.00000000000	41.9	11	4
8	KOTAPOLA	67330	37705	29625	32406	34924	376.00000000000	178.95	25	1
9	MALIMBADA	37103	20073	17030	17858	19245	866.00000000000	42.85	14	1
10	MATARA FOUR ...	123262	66561	56701	59326	63936	2177.00000000...	56.62	38	4
11	MULATIYANA	53499	29692	23807	25749	27750	444.00000000000	120.38	23	2
12	PASGODA	62971	35012	27959	30308	32663	409.00000000000	153.99	30	3

Show All Features

Figure 8: Attribute Table

4.2. SERVER-SIDE

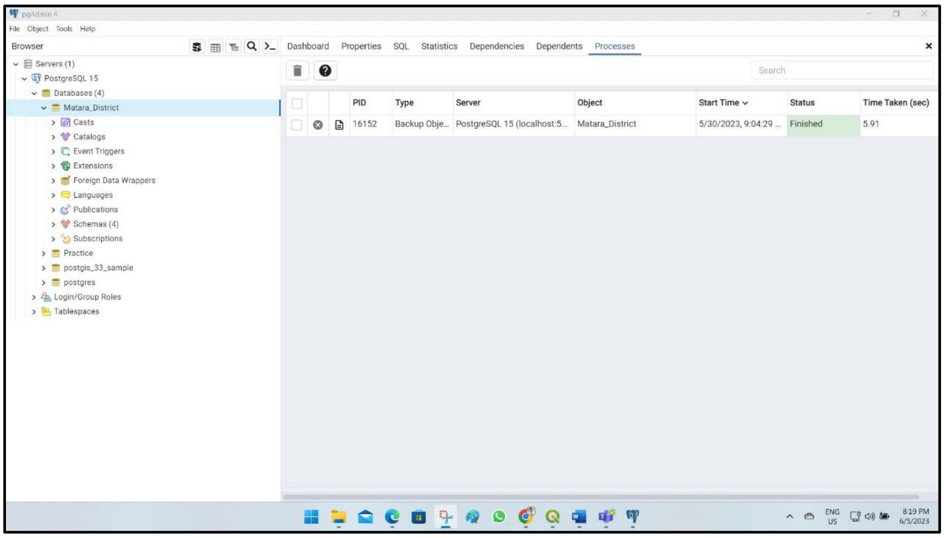
In the development of a web-based geospatial application using FOSS4G for the Matara District of Sri Lanka project, the server-side components play a crucial role in data storage, processing, and serving. DBMS is essential for storing and managing spatial and non-spatial data. In this project, PostgreSQL, an open source DBMS with PostGIS extension, is used to store and manage geospatial data. A web server handles HTTP requests received from clients and serves the web application. Apache Tomcat, a popular open source web server, is used to deploy and run the web application developed for this project. The server-side components include GeoServer and MapStore. Together, GeoServer and MapStore form a powerful combination for developing web-based geospatial applications. GeoServer serves as the backend for storing and serving geospatial data, while MapStore acts as the frontend interface for users to interact with the data.

4.2.1. PostgreSQL/PostGIS

PostgreSQL is a powerful, open-source object-relational database system that supports the creation of domains and is extensible by users in many ways. It offers scalability both in the sense of handling large loads and supporting very large databases, as well as features like ACID compliance and support for SQL. It is highly extensible; users can define their own custom data types, functions, and even stored procedures.

PostGIS is the spatial extension for PostgreSQL, offering objects for geographic data and spatial queries. Specially, PostGIS extends PostgreSQL with the following spatial objects, indexes, and functions that allow storage and processing of the geospatial data types: point, line, polygon, and raster. PostGIS supplies almost all functions and operators defined in the OGC/SQL standard, for example, those for determining distances, intersection, and overlay.

Within the context of the project in the Matara District of Sri Lanka, PostgreSQL/PostGIS will be storing and managing spatial data, providing the basis for spatial analysis, and providing data to Geoserver and MapStore in the web-based geospatial application. Figure 11 indicates a database that includes the relevant Matara district data created in PostgreSQL.



Source: PostgreSQL Database

Figure 9: Spatial Database Management- Matara District Sri Lanka

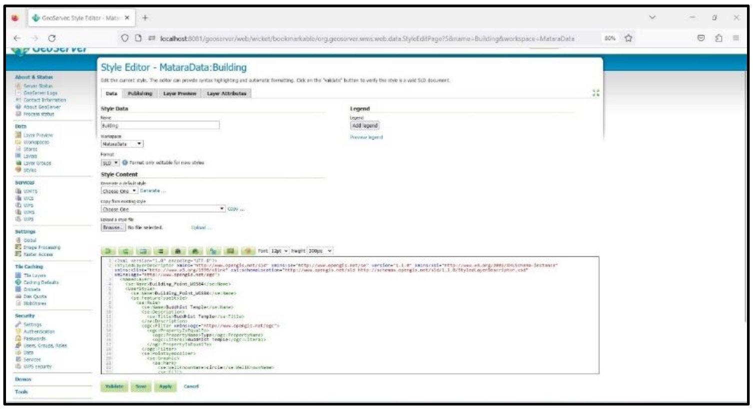
4.2.2. Apache Tomcat

First, download and install Apache Tomcat from. Second, download the GeoServer and MapStore WAR files from their respective websites. Deploy these WARs in Tomcat; by default, GeoServer will be available at http://localhost:8080/geoserver and MapStore will be available at http://localhost:8080/mapstore.

After deployment, GeoServer should be configured by going to its web interface, and then finishing the setup wizard by setting up the data directory, doing security settings, connecting to a PostgreSQL/PostGIS database, and so on. Likewise, configure MapStore by setting application settings-like default locale, map projections, and additional plugins.

GeoServer can be connected with PostgreSQL by login into GeoServer, go to the "Data" section, add a new database, and select "PostGIS" as the type. Then, after setting up the connection information, one can add data from PostgreSQL, such as "Matara_Data", and publish as WMS or WFS services.

For GeoServer styling, the prepared SLD files in QGIS can be added into each layer. Thus, you will be able to make your own style for every geospatial data as shown by Figure 12.



Source: http://localhost:8080/mapstore

Figure 10: SLD File Import to GeoServer

4.3. CLIENT-SIDE

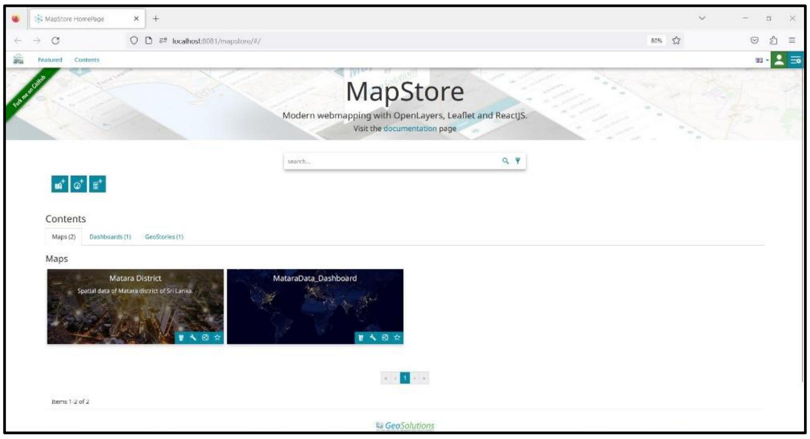
In MapStore, you can perform data visualization and analysis using various tools and functionalities. MapStore allows to creation interactive maps by adding multiple layers, including raster and vector layers, and configuring their symbology and styles. We can adjust the transparency, labels, and visibility of each layer to create visually appealing and informative maps. MapStore enables to perform spatial queries and select features on the map based on different criteria. We can define attribute-based queries, spatial queries (e.g., within a specific area), and combination queries to extract specific subsets of data for analysis or display.

4.3.1. Geospatial Viewer

The main component of the interface is the map viewer, where can be view and interact with maps. It displays the basemap and any additional layers add. Can be zoom in and out, pan the map, and perform various interactions such as selecting features, querying attributes, and measuring distances or areas.

4.3.2. Geospatial Dashboard

MapStore supports the creation of dashboards and storytelling presentations. Can be create customized dashboards by combining maps, charts, and other visual components. This allows to create interactive visualizations and tell stories using geospatial data. Figure 13 below shows a picture of MapStore's interface.



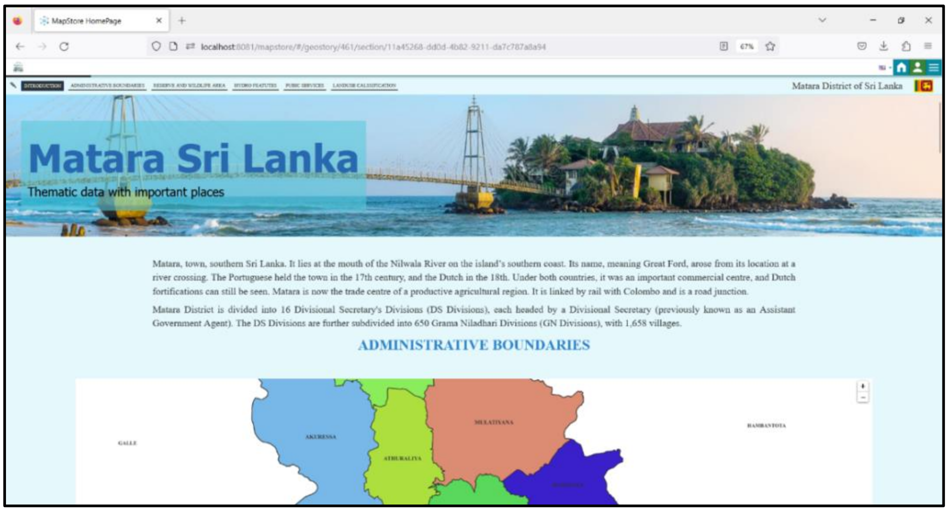
Source: http://localhost:8080/mapstore

Figure 11: MapStore Interface

5. RESULTS AND DISCUSSION

5.1. HOME PAGE

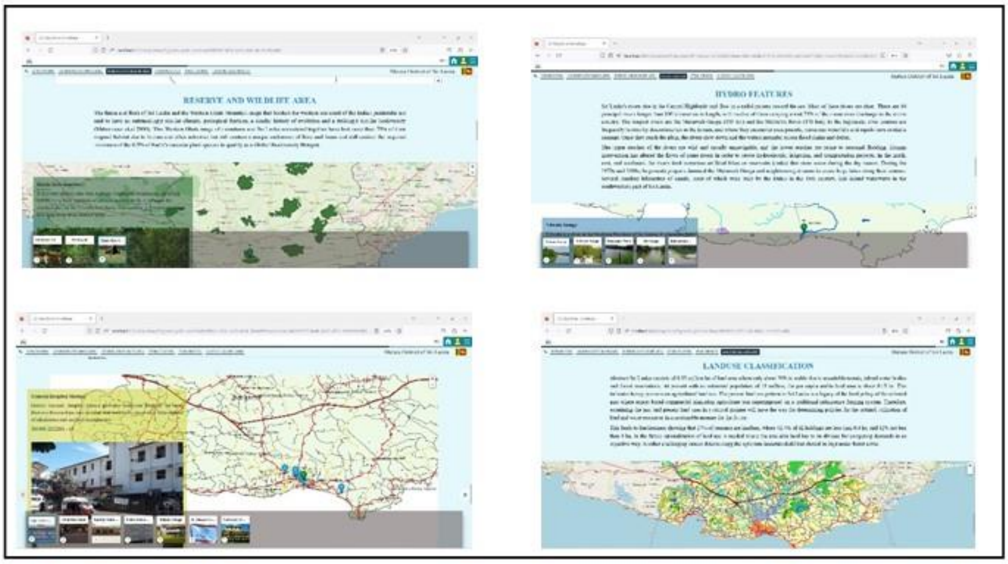
The GeoStories feature in MapStore allows users to create interactive and narrative-driven presentations using geospatial data. By combining maps, text, images, and multimedia elements, GeoStories enable users to tell engaging and informative stories. The GeoStory editor provides the flexibility to add various components such as maps, images, text, videos, and charts, and customize their appearance and layout to suit the storytelling needs.



Source: http://localhost:8080/mapstore

Figure 12: Home Page

When incorporating a map component into our GeoStory, we have the ability to define several aspects. Firstly, we can specify the map extent, which determines the initial visible area of the map and the boundaries of the displayed region. As build GeoStory, can be added text descriptions, captions, or titles to provide context and guide the narrative. Can be arranged the components in a sequential order or create branching paths to offer different perspectives or storylines. Within the Reserve and Wildlife area, notable features like the Sinharaja Rain Forest and the Kirala Jungle are prominently displayed. By simply clicking on the corresponding symbols for each feature, users can instantly access a wealth of information, including captivating photographs and detailed descriptions. Moreover, the hydro feature also includes a captivating collection of photographs, enabling users to visually explore water-related elements in the area. This interactive and immersive functionality greatly enhances the user experience, allowing them to delve deeper into the GeoStory and engage with the diverse content associated with each feature and description of the Nilwala River, Gin River and the large and attractive reservoirs located in Matara District. It also includes places that provide government services (for example, railway stations, universities, and schools) that are very helpful for the activities of the day. Finally, the land structure in Matara district has also been described by thinking. One of the main objectives of this design is to develop and promote tourism. The related data can be seen in the Figure 15 diagram below.



Source: http://localhost:8080/mapstore

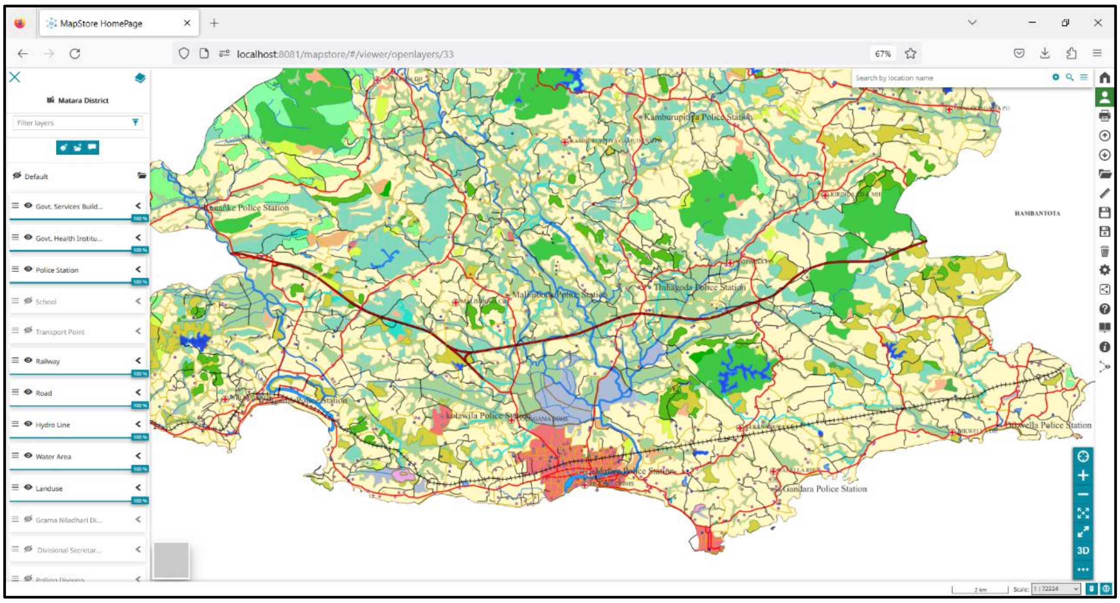
Figure 13: Different Features in Home Page

5.2. GEOSPATIAL VISUALIZATION INTERFACE

The Map Viewer is a crucial component of our application that enables users to interact with maps and explore geospatial data. It serves as an intuitive interface for navigating, visualizing, and interacting with spatial information. Within our application, the Map Viewer plays a central role in displaying maps and their associated layers. Through the Map Viewer, users can seamlessly view the geographic extent of the map and the overlaid spatial data. They have the flexibility to zoom in and out using zoom controls or the mouse scroll wheel, allowing them to examine the map at different levels of detail. Additionally, users can easily pan the map by dragging it, enabling them to explore various areas of interest.

One of the key features of the Map Viewer is the ability to control the visibility, opacity, and order of the map layers. Users can toggle layers on or off, adjust their transparency, and modify the layer stacking order to precisely control how different layers are presented on the map. This empowers users to customize their map view and focus on the specific layers of interest. To enhance the representation of geospatial data, users can customize the styling of individual layers within the Map Viewer. They can modify properties such as colours, line thickness, fill patterns, labels, and other visual aspects, allowing for a more visually appealing and informative map display.

In addition, the Map Viewer supports geolocation capabilities, enabling users to identify and view their current location on the map. This feature enhances the user experience and facilitates location-based interactions. Lastly, our application integrates printing facilities within the Map Viewer, allowing users to generate printable maps based on their current map view and configuration. This feature enables users to capture and share map visualizations in a tangible format. Overall, the Map Viewer within our application offers an interactive and versatile platform for users to explore maps, interact with geospatial data, and perform various spatial operations. The diagram related to the map viewer is shown below in Figure 16.



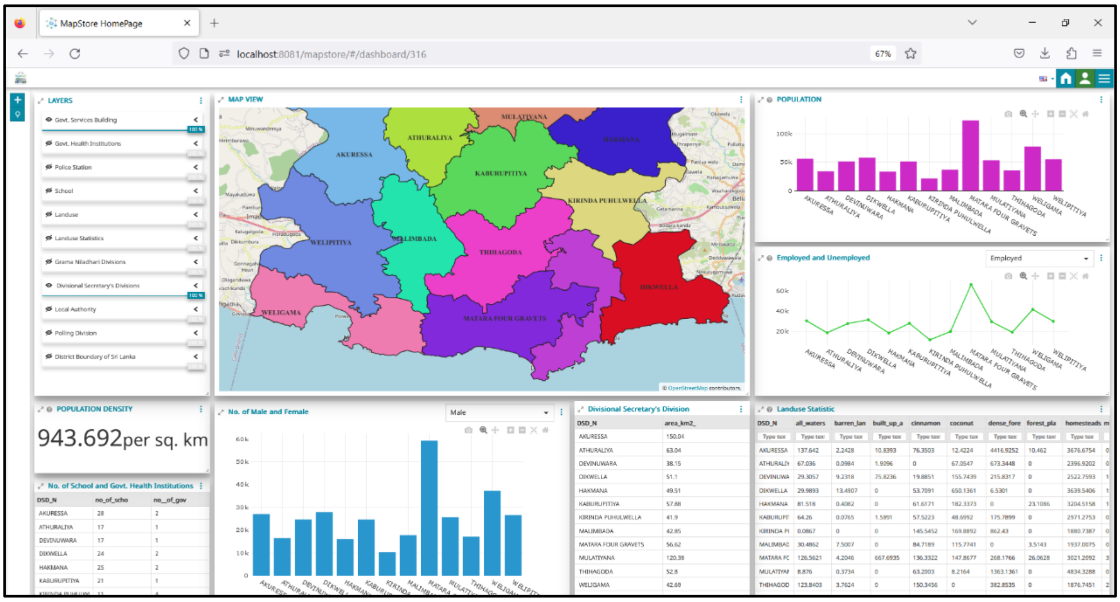
Source: http://localhost:8080/mapstore

Figure 14: Geospatial Visualization Interface

5.3. GEOSPATIAL DASHBOARD

MapStore provides a Dashboard feature that allows users to create customized and interactive dashboards for visualizing and analysing geospatial data. A dashboard in MapStore combines various components, such as maps, charts, tables, and filters, into a single interface, providing users with a comprehensive view of their data. MapStore allows users to configure the layout of their dashboard by arranging and resizing the components. MapStore supports various chart types, including bar charts, pie charts, line charts, and scatter plots. Users can create chart components to represent their data in a graphical format, enabling them to identify patterns, trends, and relationships. Users can include table components in their dashboards to display tabular data.

Here, the population, gender, number of people employed in each division and the amount of land use related to Matara district. It provides a comprehensive view of the data through maps, charts, tables, and filters, enabling users to gain insights, make informed decisions, and communicate their findings effectively. Figure 17 shows the related diagram.



Source: http://localhost:8080/mapstore

Figure 15: Geospatial Dashboard

6. CONCLUSIONS

The development of the web-based geospatial application using FOSS4G for Matara District of Sri Lanka project has yielded valuable insights and outcomes. The project aimed to leverage open-source geospatial technologies to facilitate data visualization, analysis, and decision-making in the district. The project successfully developed a web-based geospatial application using FOSS4G tools such as QGIS, Apache Tomcat, PostgreSQL/PostGIS, GeoServer, and MapStore. The application provides a user-friendly interface for visualizing and analysing spatial data relevant to Matara District. The application aims for significantly improving data accessibility for stakeholders in Matara District. By leveraging open-source technologies, spatial data from various sources were integrated and made readily available for users to explore and analyse. The application has facilitated evidence-based decision-making in Matara District. Users can easily visualize and analyse spatial data, enabling them to make informed choices regarding infrastructure development, resource management, and socio-economic planning.

In conclusion, the development of the web-based geospatial application using FOSS4G has significantly contributed to geospatial capabilities, data accessibility, and decision-making processes in Matara District. The application's success demonstrates the potential of open-source technologies in supporting sustainable development and informed decision-making. It is hoped that the project's outcomes will continue to benefit stakeholders and inspire further advancements in geospatial applications in Sri Lanka.

7. RECOMMENDATIONS AND FUTURE SCOPE

The application can be further improved by incorporating online spatial query capabilities. This will allow users to perform advanced spatial queries to extract specific information from the geospatial datasets. To provide a comprehensive geospatial view, the application can be expanded to include and update raster layers. This will enable users to access and visualize raster data such as satellite imagery, elevation models, and land cover information. Promote stakeholder engagement and encourage data sharing, the application can incorporate collaborative features. Implementing a WIKI platform within the application will allow users to contribute their data. Considering the increasing use of mobile devices, optimizing the web-based geospatial application for mobile compatibility can extend its reach and accessibility. Developing a responsive design or creating a dedicated mobile application will ensure a seamless user experience across different devices. Enhance the application's relevance and currency, integrating real-time data sources can be explored. Incorporating live feeds or APIs to access real-time information such as weather data, traffic updates, or sensor data can provide users with up-to-date and dynamic geospatial insights.

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