Chapter: V

5. Development of a Spatial Decision Support System

5.1 Introduction

Today, the system of storing and sharing information is possible through the internet and the World Wide Web. Internet technologies provide the facility to establish a communication network between computers worldwide, and web services are modular, self-describing applications that can seamlessly interoperate directly across the internet (Patel et.al. 2016). The online applications consider new types of correspondence just as data sharing. Since the progression of the Internet and geospatial innovations, different endeavours have been completed to produce data and improvement of systems for the prosperity of the general public.

The development and availability of powerful Geographic Information Systems (GIS) and visualization tools in conjunction with the internet have played an important role in the emergence of web-enabled Spatial Decision Support System (SDSS). The Decision Support Systems (DSSs) help in one or several possible decision alternatives for a particular problem. The effective agricultural information dissemination along with meteorological information to the farmers, researchers, policymakers follows and implements the core ideology of GIS technology. The integration of agricultural and meteorological data sets from various sources would aid the decision-making process for system resources utilization and also aid sustainable agricultural development goals of the country.

Drought impacts are usually first apparent in agriculture. Remotely sensed satellite data offers significant advantages and should be a primary source of monitoring drought, particularly for the temporal and spatial evolution of drought. The data collection and storage is very difficult from different sources and different formats. also called the data interoperability problem. The developed system integrates Land Surface Temperature, NDVI, Precipitation, Soil Moisture Content (SMC) data, etc. for drought monitoring, as well as decision-making, but the interpretation and analysis of large spatial data (Big Data) require domain expertise. The problem is generally known as the data-interpretation problem, which commonly arises when spatial resolution, temporal resolution, data sources, and scales are different. The present study describes how a Spatial Decision Support System (SDSS) have been developed; the architecture and methodology for drought management have tackled data interoperability as well as data interpretation problem. The developed SDSS demonstrates the application of GIS with the help of Remote Sensing (RS) technology for DSS. An important component of this study is to develop a system using Open source technology. By combining geographic data from a wide range of sources, managers can quickly assemble information and custom maps to adopt an appropriate management activity. This process of creating new GIS outputs from existing data is referred to as an SDSS. This combination of data can create a modelled output that helps answer questions posed with spatial relevance.

5.2 Problem Analysis and Need Assessment

The goal of carrying out this analysis was to identify the needed solution to the existing problem. The system aimed to enable decision-makers to obtain spatial and non-spatial data about crop conditions, meteorological, hydrological data on a single platform for the decision-making process, analysis of vegetation conditions, and data distribution. The problem statement has two assignments. One part is to research how to develop a Web GIS client application with an emphasis on the users. The second part is to implement a Web GIS client on top of the Web GIS architecture.

5.3 Tools and Technologies:

The Spatial Decision Support System has been developed on Postgresql \ PostGIS (PG\PG) Database Management System (DBMS), Geoserver, Open Layers, and web development told like Java, HTML, and Java. The pre-processing scripting models have been developed using Open Source Libraries viz Geospatial Data Abstraction Library (GDAL) and Python. Graphic NetBeans Integrated Development Environment (IDE) editor has been used for the development of SDSS and debugging. These softwares are open source and are under GNU General Public License. They are freely downloadable and they come with source code. The web-based system is developed using various open-source software and libraries, which are directly involved in a web application, while many other desktop GIS applications were used in pre-processing, advanced analysis, and creation of a spatial database. uDig 1.4.0 software is used for SLD generation and editing *(http://udig.refractions.net/)*. Open source tools that are used in web development are described in Table1 below.

Table 5.1 Tools and Technologies

Tools	**Description**
PostgreSQL	PostgreSQL is a Database Server for storage and transaction

	management. In the developed application, the open-source database PostgreSQL with PostGIS extension has been used (http://www.postgresql.org/).
PostGIS	PostGIS is a socket between PostgreSQL and GIS engine. This spatially enables the PostgreSQL server to store a spatial database.
Geoserver	Geoserver is a GIS server for interoperability and publishing OGC web Services. GeoServer is an open-source server that allows users to share and edit geospatial data. (http://docs.geoserver.org/stable/en/user/index.html).
OpenLayers	Open Layer is an open-source, client-side JavaScript library for making interactive web maps, viewable in nearly any web browser (http://openlayers.org/).
Geospatial Extension(GeoExt) and ExtJS	GeoExt is for rich web mapping. GeoExt is built on top of the robust OpenLayers JavaScript mapping library and the rich graphical components of ExtJS (http://www.sencha.com/).
SLD	A Styled Layer Descriptor is an XML-based mark-up language that allows user-defined symbolization of map layers
Highcharts	A robust open-source tool for chart and profile (graphs) rendering and libraries can be download from the web portal (http://www.highcharts.com/).

5.3.1

5.3.2 Client Technology

Client side development technology allows for more interactivity. It usually performs several actions without going to user. It cannot be basically used to connect to databases on web server. It is a technique use in web development in which scripts runs on clients' browser.

Java Server Pages (JSP)

JavaScript language in web client applications enhances the UX with dynamic user interface features. JavaScript is a widely used language with support for most web technologies used today. Using a JavaScript web framework will help systematize the code in a structure and give some design choices to make the applications easier to understand, test, expand, and maintain. Java Script frameworks for web applications have gained wide popularity in the last years. It may involve investing time and effort to learn new paradigms on writing JavaScript to simplify and attach behaviours to the client code. Java Server Pages (JSP) is a technology for developing Web pages that support dynamic content. This helps developers insert java code in HTML pages by making use of special JSP tags. A Java Server Pages component is a type of Java servlet that is designed to fulfil the role of a user interface for a Java web application. Web developers write JSPs as text files that combine HTML or XHTML code, XML elements, and embedded JSP actions and commands. JSP is an integral part of Java EE, a complete platform for enterprise-class applications. This means that JSP can play a part in the simplest applications to the most complex and demanding.

5.3.3 Open Source Libraries

5.4 Open Layers

OpenLayers is a JavaScript library to render interactive maps in web applications. It enables displaying and editing geographical data from WMS, WFS, and other Open Geospatial Consortium (OGC) standard services (OpenLayers, 2015). OpenLayers is an open-source, Free BSD license. OpenLayers builds rich geographic web applications with no server-side dependencies. OpenLayers facilitates to develop dynamic maps on any web pages. It is enriched with the functionality to display map tiles, vector data, and markers loaded from any source. OpenLayer supports the integration of external WMS layers with any web GIS application. Various GIS data formats like GeoJSON, TopoJSON, KML, GML, Mapbox vector tiles, and other formats are supported by Open Layers. OpenLayers is lightweight and mobile-friendly with extended style support libraries to dynamic render GIS data over the web.

5.5 High Charts

Highcharts is a pure JavaScript based charting library meant to enhance web applications by adding interactive charting capability. It supports a wide range of charts that are drawn using SVG in standard browsers like Chrome, Firefox, Safari, and Internet Explorer (IE). Highcharts Library works seamlessly on all major browsers and mobile platforms like android and iOS. It also supports multi-touch on touch screen-based platforms free to Use − Open source and is free to use for non-commercial purposes. Highchart supports multiple axis functionality on the chart. Easy to customize and configure tooltips. Inbuilt Functions to control date-time formats are available with the

Highchart library. The statistical chart plotted can be exported in PDF/PNG/JPG/SVG formats. Dynamic zooming functionality is provided with the Highchart library.

5.5.1 Database Management System (DBMS)

The database is the backbone of any dynamic application (software), that supports the developer, in the logic building for the data store, retrieval, and manipulation operations. GIS data, being spatially driven, are best supported with a spatial database such as PostgreSQL/PostGIS, which can store both vector and raster spatial data and attributes (Peterson, 2012). PostGIS, a spatial extension of the PostgreSQL database is open-source software that provides an extensive implementation of OGC standards (Swain, 2015). The web application will be retrieving raster data and various shapefiles that contain spatial and attribute properties. The PostGIS database was chosen for the research because it is well known for its vast support of an array of raster and vector formats and it also supports spatial indexing schemes for fast retrieval (Swain, 2015).

PostgreSQL

PostgreSQL is a powerful, open-source object-relational database system. PostgreSQL is not controlled by any corporation or other private entity and the source code is available free of charge. PostgreSQL supports a large part of the SQL standard and offers many modern features like Complex SQL queries, SQL Sub-selects, Foreign keys, Trigger, Views, and Transactions, etc. Even if the PostgreSQL database enabled with PostGIS extension was installed. The first step was to create a PostGIS database using the PostGIS template inside the PostgreSQL graphical user interface (GUI) pgAdmin. This template spatially enables the database by configuring extensions for PostGIS functions and data types. It includes the mandatory tables for managing PostGIS functionality, spatial reference system (SRS), and geometry columns. Figure 5.1 represents the SDSS database design in Postgres. SDSS database is spatially enabled, where raster and vector both datasets are stored with geometry or cell values.

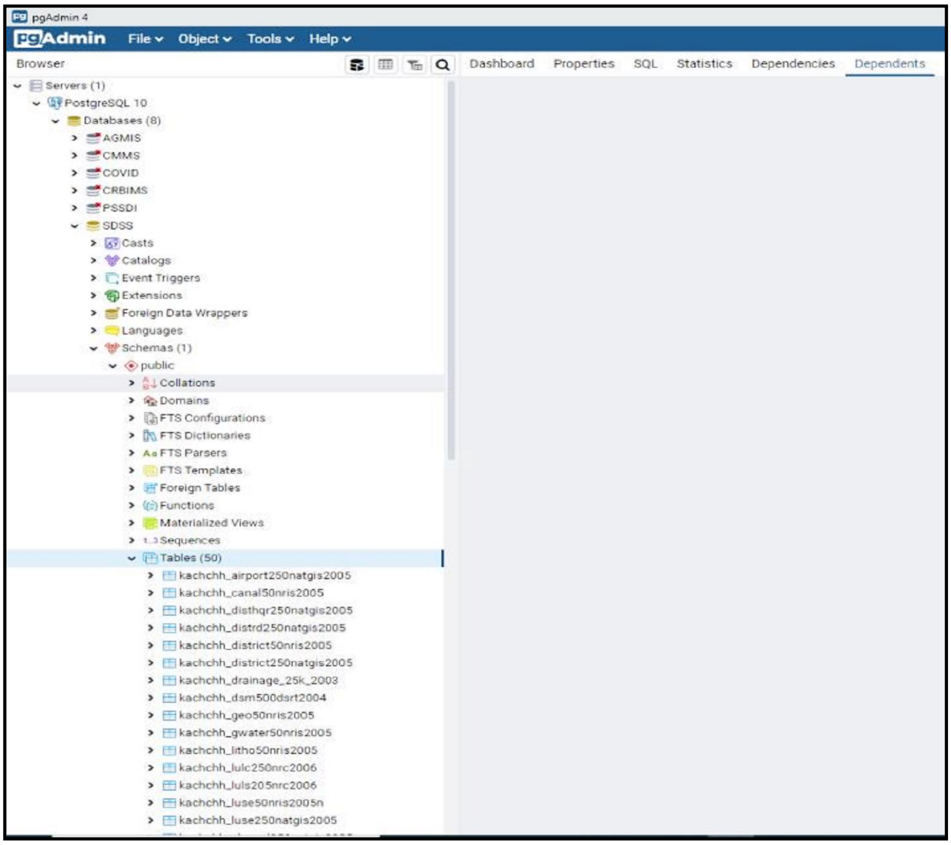

Figure 5.1 SDSS database in PostgreSQL

5.5.2 Open Source Servers

A. GIS Server - GeoServer

GeoServer is an open-source server written in Java that allows users to share, process, and edit geospatial data. Geoserver is designed for interoperability, it publishes data from any major spatial data source using open standards. GeoServer has evolved to become an easy method of connecting existing information to virtual globes such as Google Earth and NASA World Wind as well as to web-based maps such as OpenLayers, Leaflet, Google Maps, and Bing Maps. GeoServer functions as the reference implementation of the Open Geospatial Consortium (OGC) Web Feature Service standard and also implements the Web Map Service, Web Coverage Service, and Web Processing Service specifications. GeoServer reads a variety of data formats like PostGIS, Oracle Spatial, ArcSDE, DB2, MySQL, MongoDB, Shapefiles, GeoTIFF, JPEG2000, etc. Figure 5.2 represents the Graphical User Interface (GUI) of published layers and various modules in Geoserver. The admin module of Geoserver is to manage and publish layers with various OGC standards. Figure 5.3 illustrates the SLD generation module for the layer styling and rendering.

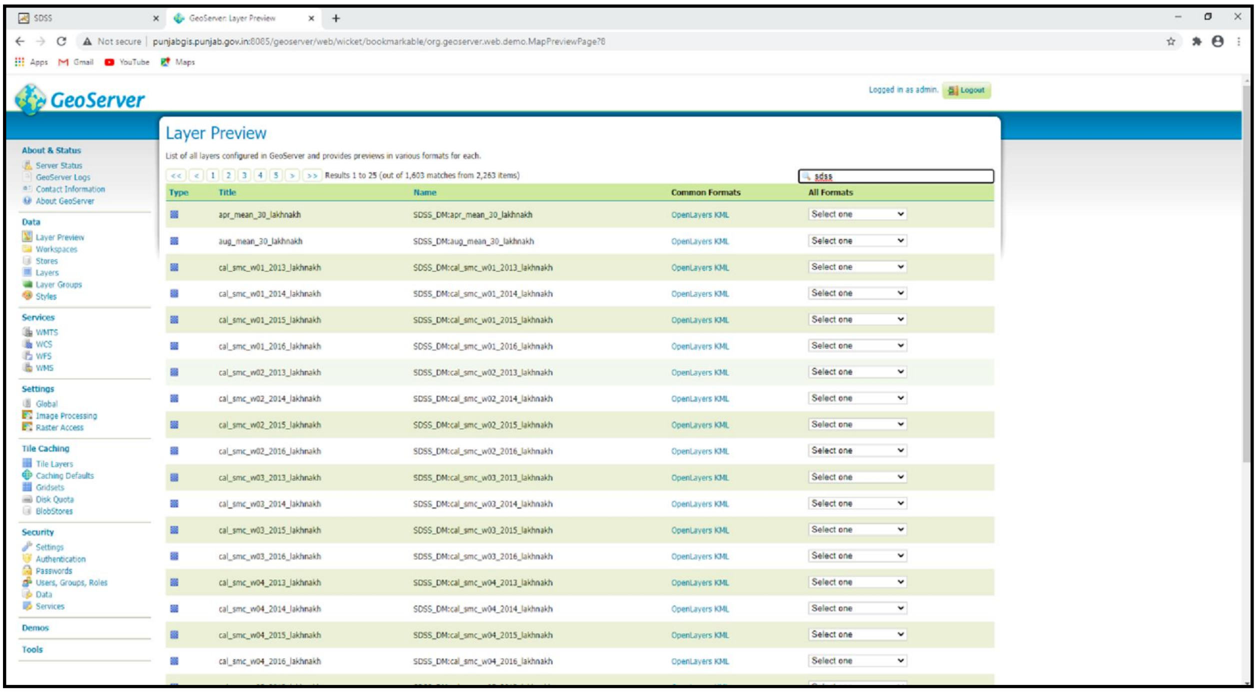

Figure 5.2 Published Layers in Geoserver

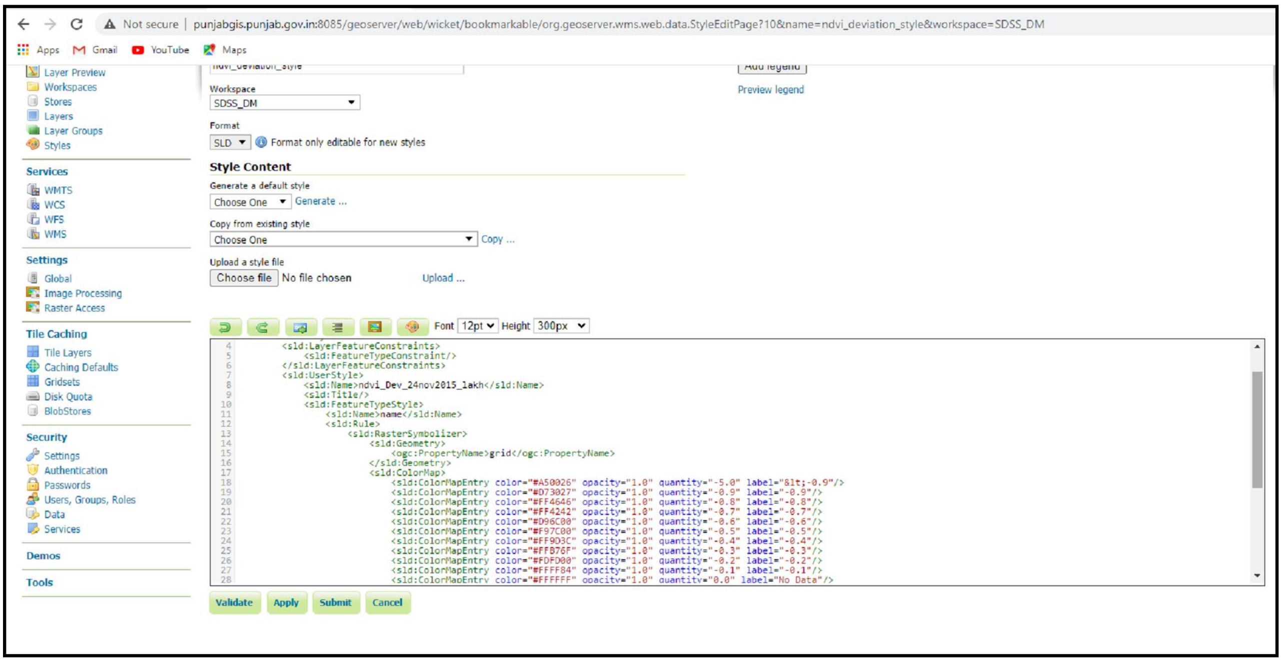

Figure 5.3 Sample code of Styled Layer Descriptor (SLD).

B. Application Server - Apache Tomcat

Apache Tomcat is an application server designed to execute Java servlets and render web pages that use Java Server page coding. Accessible as either a binary or a source code version, Tomcat's been used to power a wide range of applications and websites across the Internet. At the time of writing, it's one of the most popular servlet containers available. Key features of Apache Tomcat are; it's Lightweight, Open-Source, Highly Flexible, and More Stable.

5.6 Design and Implementation

This section describes the implementation steps of the Web GIS client. The geographical technologies with installation, configuration, and population of the data store and data accessors are presented. Architecture of the application, database design concept, and user interface design concepts are described here to understand the complete methodology of the system development.

5.6.1 Layered Architecture of SDSS Application:

The application is developed based on a variety of data and users. An integrated approach has been implemented with the help of basic science and Information Technology. The conceptual framework as shown in Figure 5.4 is based on the traditional 3-tier architecture of web technology. The web browser transmits the request and response at the client-side; the web server deals with and distributes the requests whereas the database server provides data retrieval, storage, modification functionality etc. The conceptual process flow describes processes involved in the development of web-based SDSS. The developed SDSS is based on the open-source GEOSERVER, which is used as the main data provider. The spatial data are published as a Web Map Service (WMS). The interactive web user interface is built using the ExtJS and the GeoExt frameworks with the OpenLayers libraries which are used as the main map client. Finally, a dynamic Styled Layer Descriptor (SLD) is generated with uDig (The User-friendly Desktop Internet GIS). uDig is the open-source software script for creating interactive and user-oriented maps.. In order to implementations the system, Geoserver is configured with Apache tomcat (Web Server) for map rendering over the web.

The entire developed application of web map service was performed on the 3-tier architecture of the client-server computing environment where Geoserver is working as middleware and JavaScript and HTML (HyperText Markup language) is working as a client and spatial database were used for data creation, storage, transaction, and management. The overall methodology for web development is shown in figure 5.4. User can send their request through the web browser and they can get the responses in the form of maps, charts and tables.

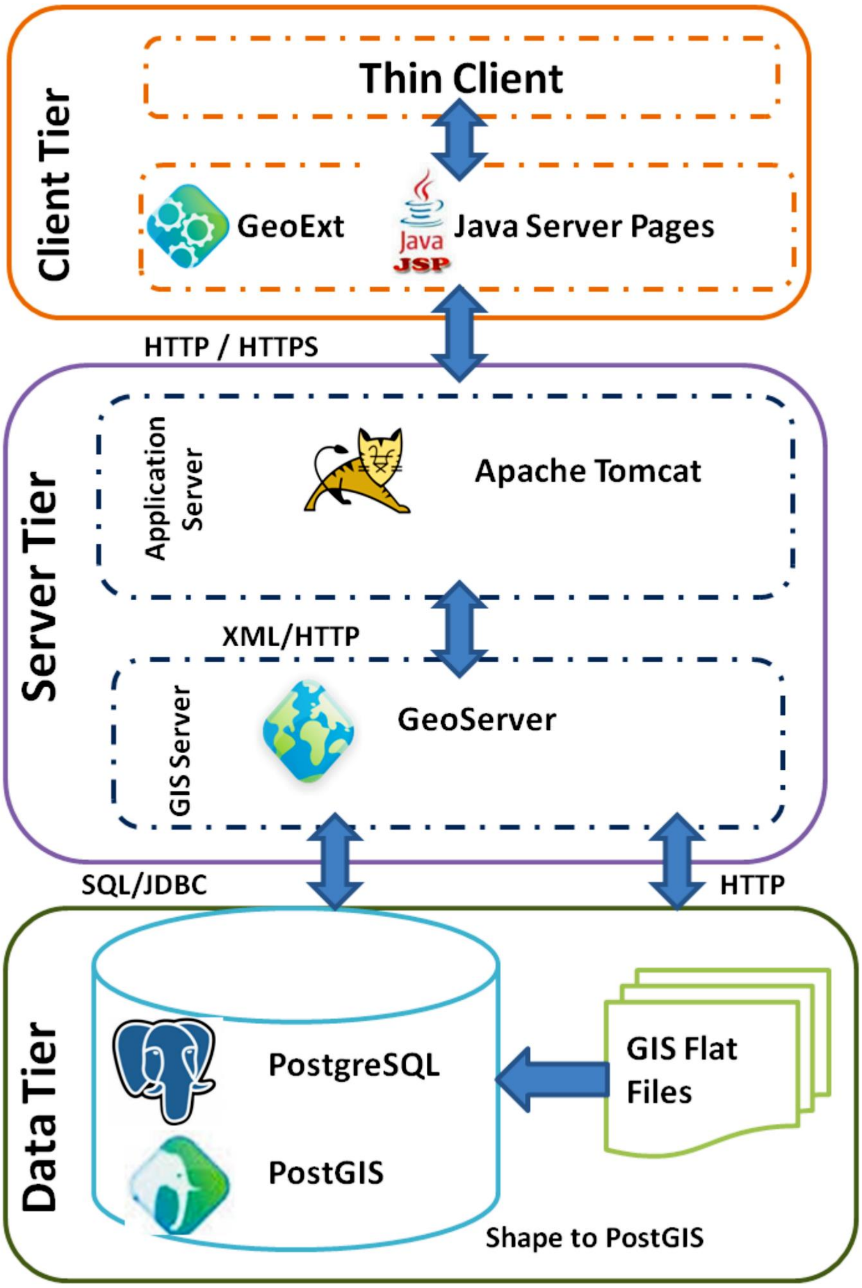

Figure 5.4 Layered Architecture of SDSS Application

5.6.2 Database design and Development

A database was created to ingest and manipulate data and keep the generated output maps. The ORDBMS used was Postgres with PostGIS as a spatial extension. The image data of each parameter was ingested separately into the database. Each image that was inserted into the database appeared as a table in the database. For this study, a separate table was created to represent each image, though images could also be stored as separate rows in a single table. SDSS database has been designed and developed in PostgreSQL with PostGIS spatial extension. Figure 5.5 shows the database and created tables of SDSS. Figure 5.6 illustrates the design view of individual tables where "geom." Column stores the geometry of the features.

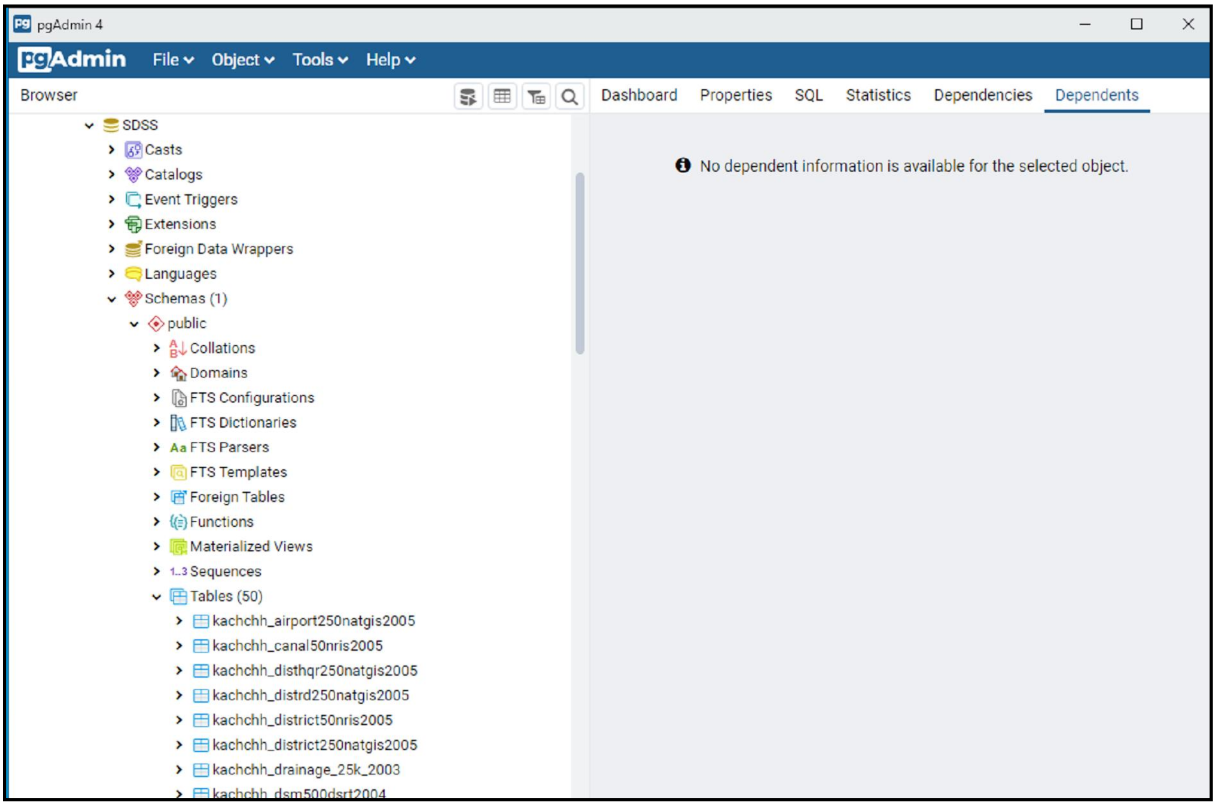

Figure 5.5 Database architecture of SDSS.

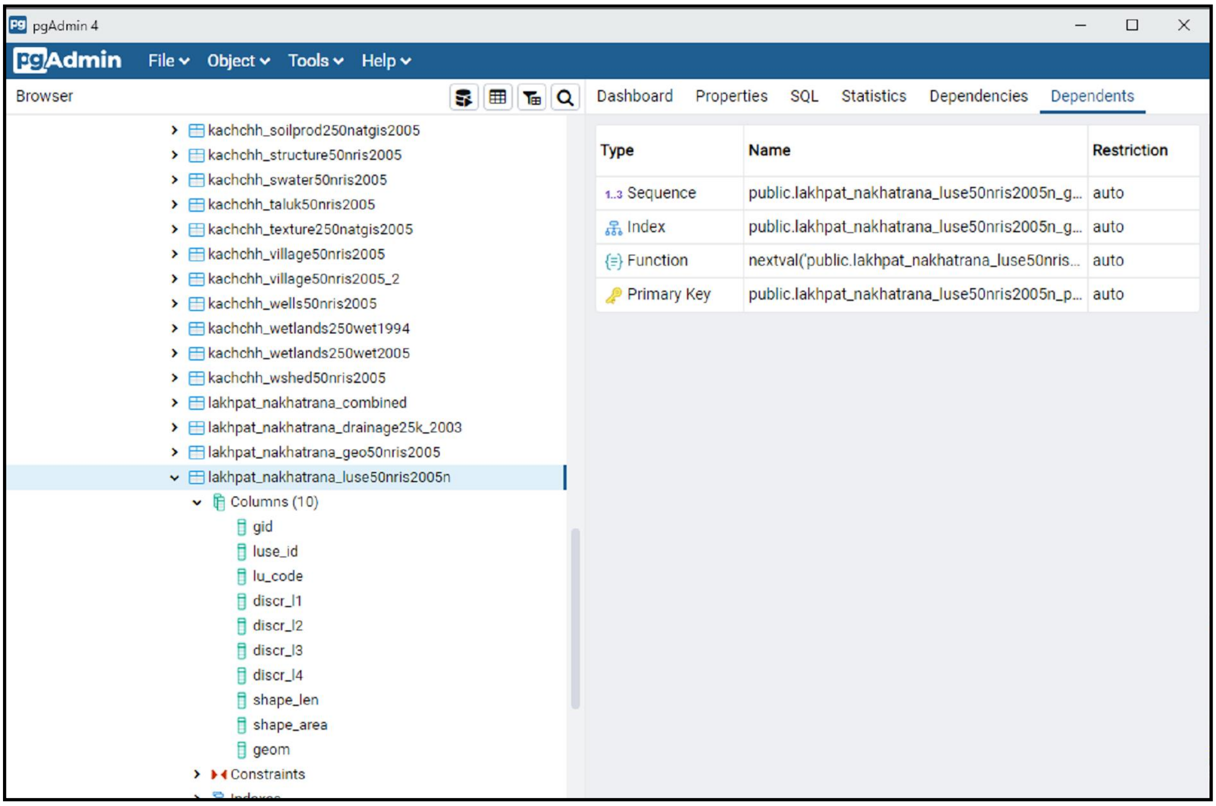

Figure 5.6 Design views of tables in the SDSS database.

5.6.3 User Interface Design

The Graphical User Interface is designed as a simple web page application as specified in Figure 5.7. Each section representing the user interface components. The SDSS-DM application follows a modular approach for the visualization of drought indices and parameters along with overlay layers. A detailed description of the developed SDSS-DM GUI has been illustrated in the system demonstration section.

5.6.4 Data flow and server configuration:

Server-side automated procedure for vegetation indices and meteorological data value addition, and distribution via the web portal. The implemented methodologies for data download from the internet and transferred to the processing server followed by synchronized transfer to the data server. Generated indices or value-added products transferred to PostgreSQL / PostGIS database along with Geoserver publisher as REST API's automated procedure. Finally, the user can get interactive maps as WMS services.

5.7 System Demonstration:

This chapter describes the features of the client prototype. All core features are described by examples illustrating the GUI and specifying the interactions between the code components. Implementation concerns such as the installation and configuration of a geographic database and web server is referred to chapter. Design and implementation decisions with the choice of software technologies are discussed in this chapter.

5.7.1 Home Page / Landing Page of SDSS-DM

The main objective of this component is to present all menus and functionality of the system within the unified interactive GUI. The SDSS-DM application has been categorized into four broad sections namely the Home page, Introduction page, Geoportal page, and contact page. The home page describes the topic of the research, name of the research guide, University name, latest previews, and study area with interactive interface.

The introduction section describes a summary of the research including the study area, objectives, methodology, and major outcomes of the research.

Geoportal Module is developed for interactive visualization of the various Agricultural and meteorological parameters, various indices (example: NDVI, PCI, SPI, NDWI, Deviations, LST, and ISDI, etc.). Figure 5.7 shows about home page or landing page of the SDSS-DM application.

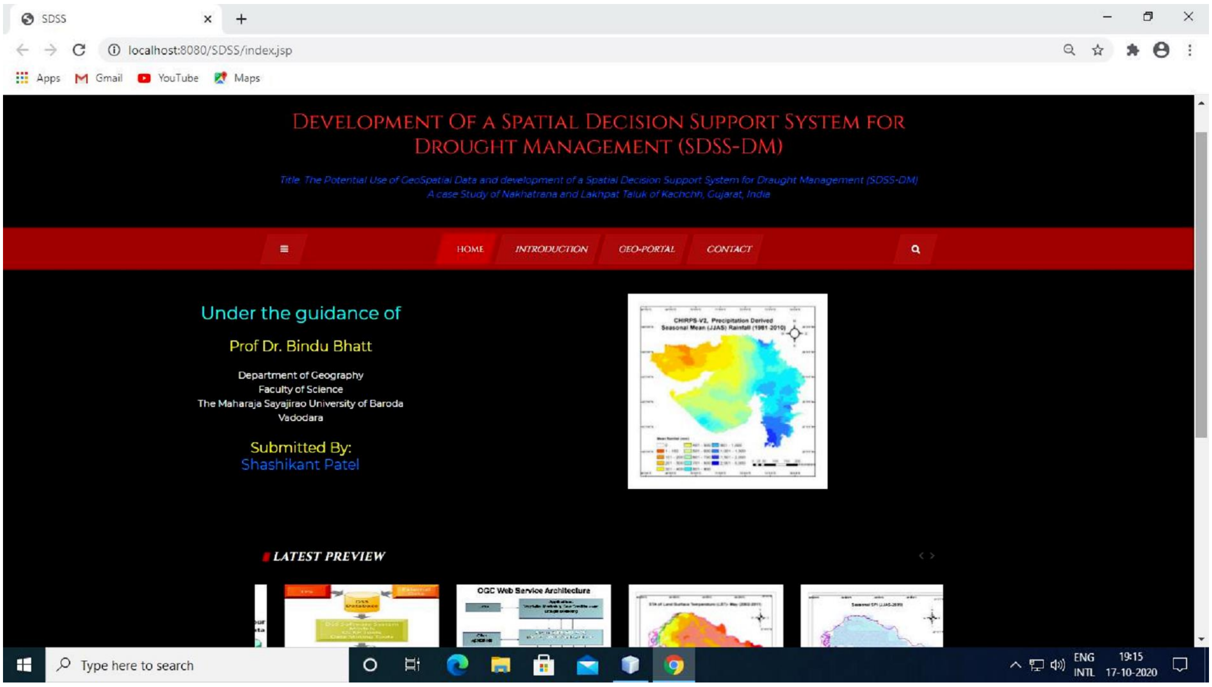

Figure 5.7 Home page of SDSS.

5.7.2 Map Control with Legend and Layer tree

Figure 5.8 describes the basic controls of the geo-portal namely Map Panel, Layer Panel, Legend Panel, GIS functions, and Menu Bar. Layer Panel shows the dynamically added layers on the map with added overlay layers. The layer panel provides functionality to switch-on or switch-off layers for visualization. Legend panel shows the dynamic legends or color symbols of added layers on the map. GIS function toolbar provides functionality to users for map rendering (like Pan, Zoom-In, Zoom-Out, Full Extent, Identity, Measurement etc.). The menu bar is developed to access various parameters or drought indices for visualization and perception analysis. The menu bar is designed to incorporate all the developed indices and parameters in the menu or derived sub-menus.

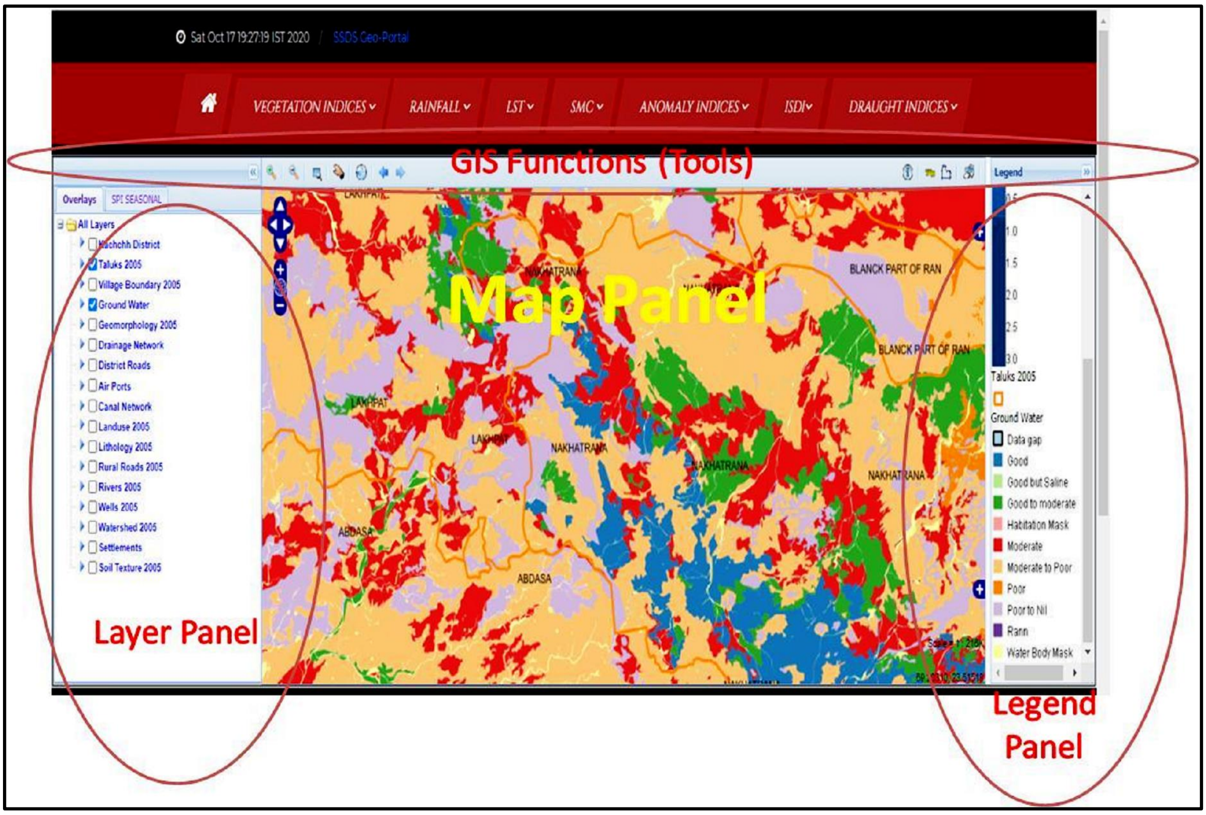

Figure 5.8 Controls of SDSS (Map Panel, Layer Panel, Legend Panel, Menu bar and Toolbar).

5.7.3 Display Overlay Layers

This section describes overlay layers associated with the SDSS-DM. Overlay layers like Groundwater, drainage network, geomorphology, lithological maps, transportation networks, soil properties, and administrative boundaries, etc.

Figure 5.9 describes the groundwater prospect map of the study area with a legend. Figure 5.10 shows the geomorphology layer added to SDSS-DM as overlay layers. Figure 5.11 and figure 5.12 represent soil texture and lithology of the study area respectively. The overlay layers are the supporting layers to know about the study area from the associated dataset.

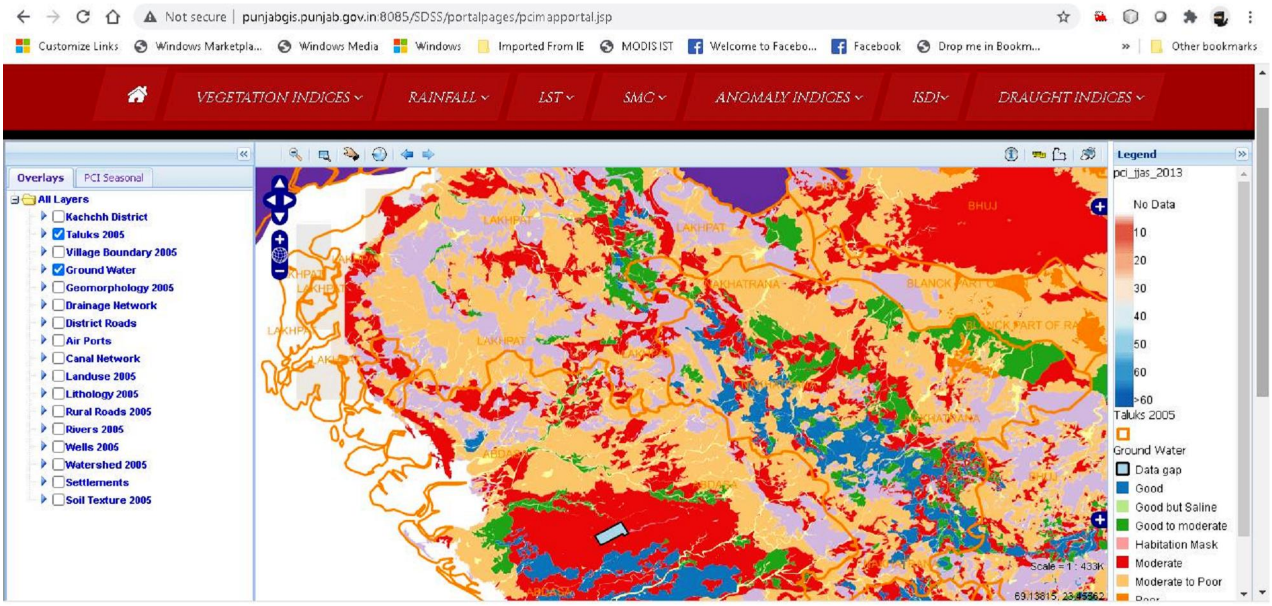

Figure 5.9 Display of Ground Water Prospect Map as Overlay layers.

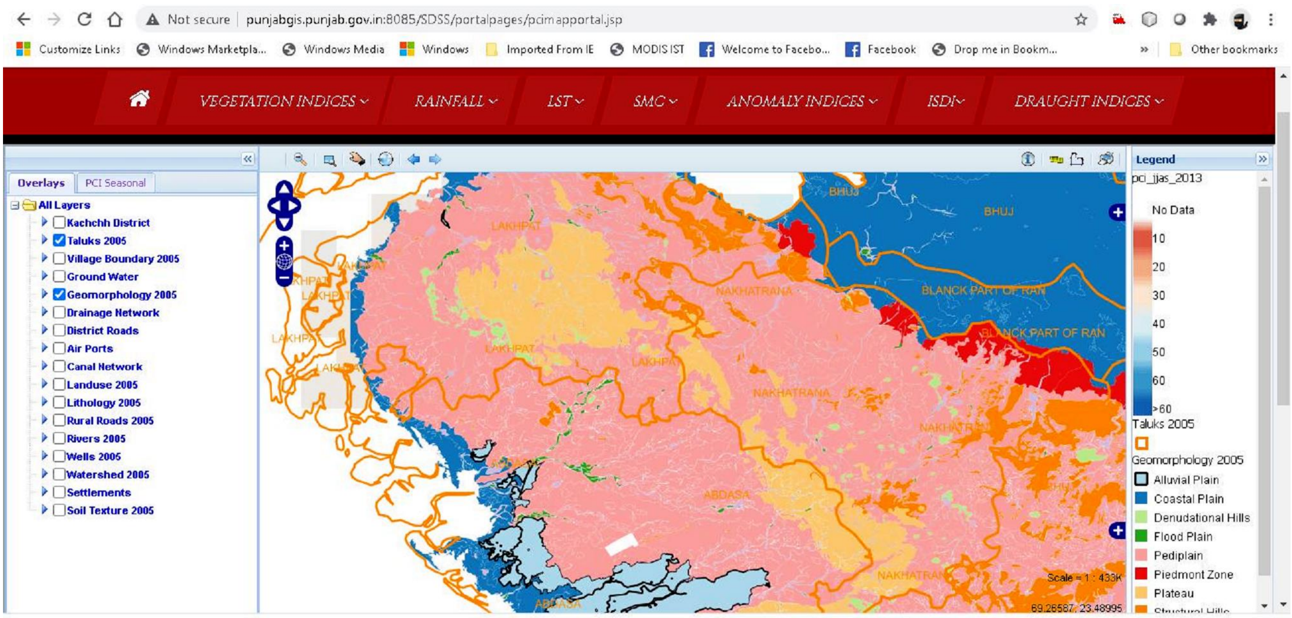

Figure 5.10 Display of Geomorphological Map as Overlay layers.

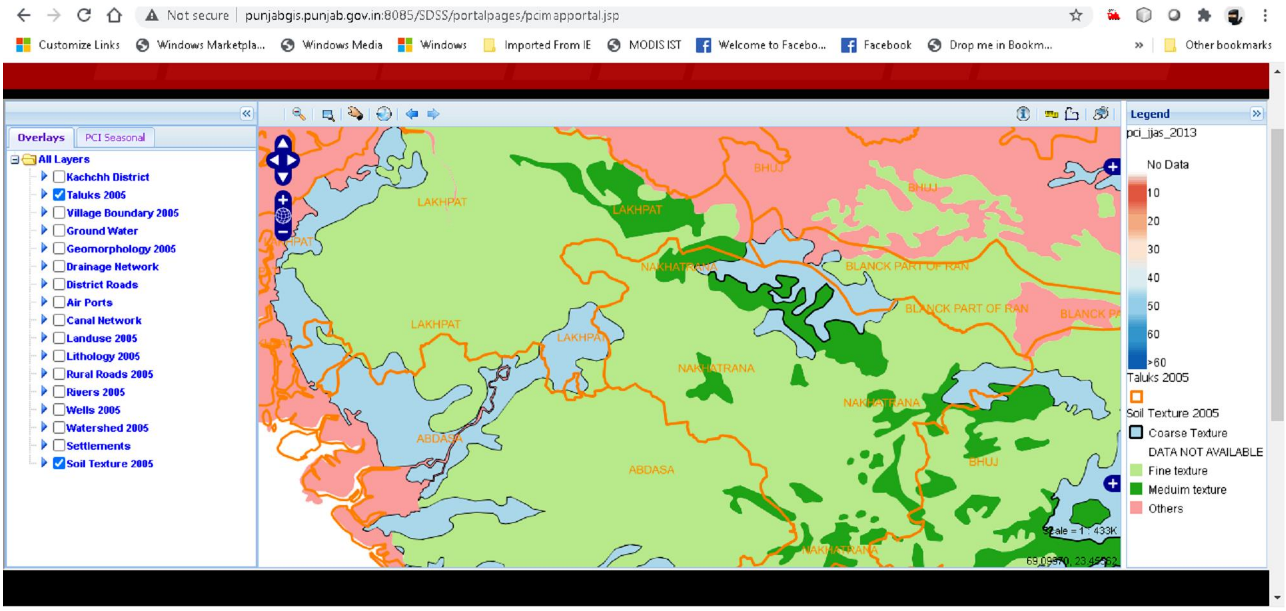

Figure 5.11 Display of Soil Texture Map as Overlay layers.

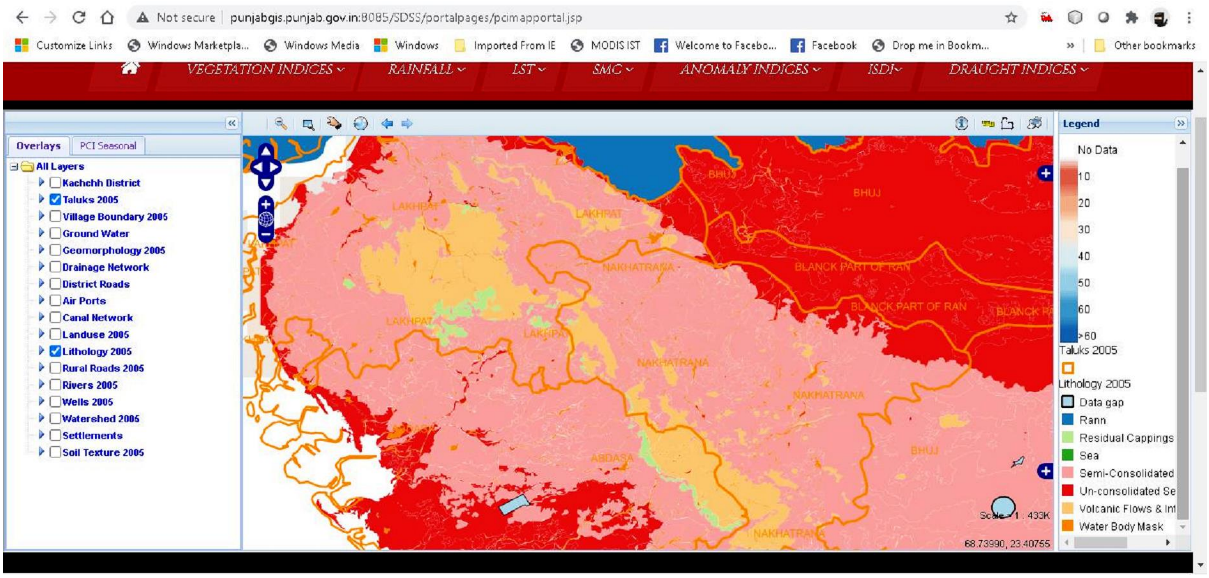

Figure 5.12 Display of Lithology Map as Overlay layers.

5.7.4 Display Vegetation Indices

The facility to visualize vegetation indices for the selected year and date has been provided in the SDSS-DM portal. User can add dynamically vegetation indices like NDWI, NDVI for the desired year and date. Figure 5.13 and figure 5.14 show the spatial distribution of NDWI and NDVI for selected dates over the study area respectively. Figures 5.15 and 5.16 represent the NDVI deviation and NDWI anomaly respectively for the selected dates, which have been described in chapter-4.

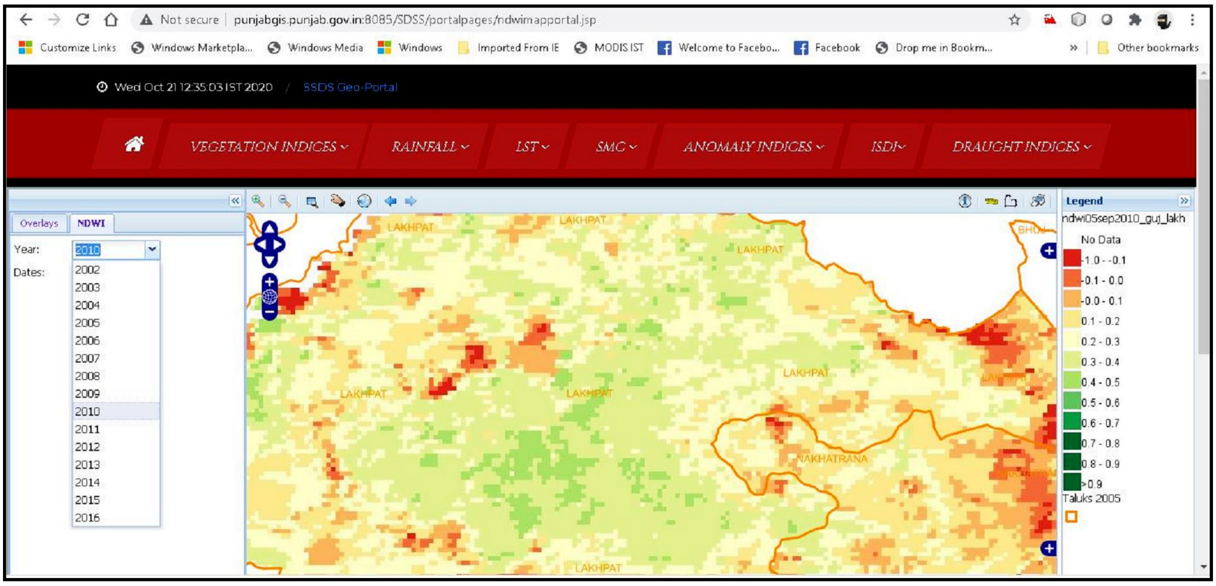

Figure 5.13 NDWI Layers with dynamic date selection.

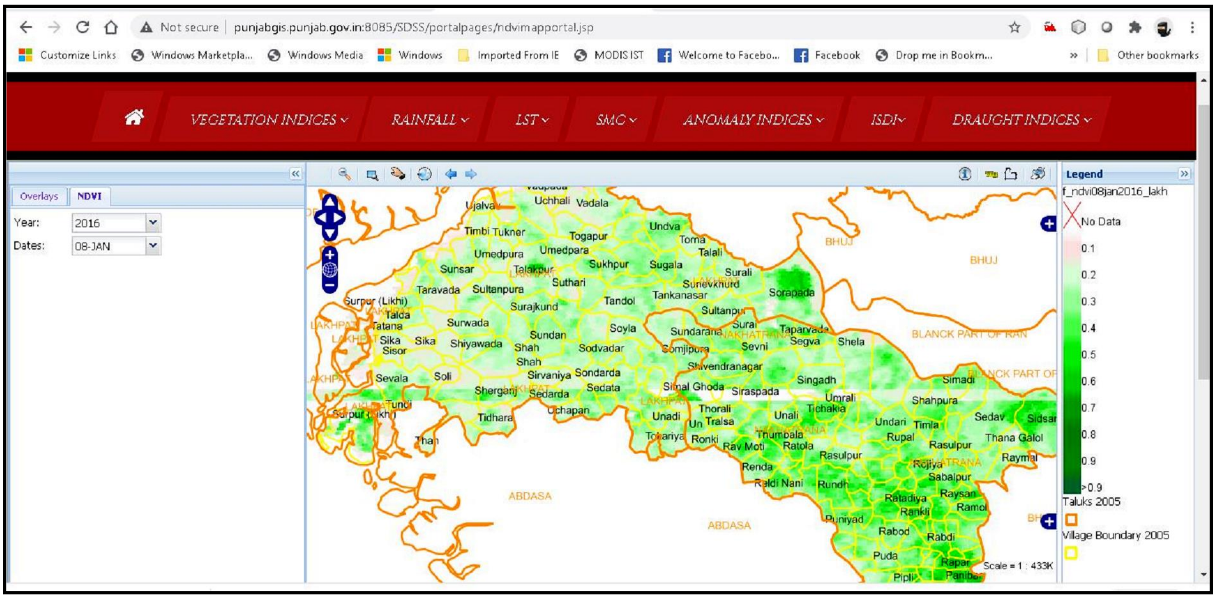

Figure 5.14 Dynamic selection of NDVI.

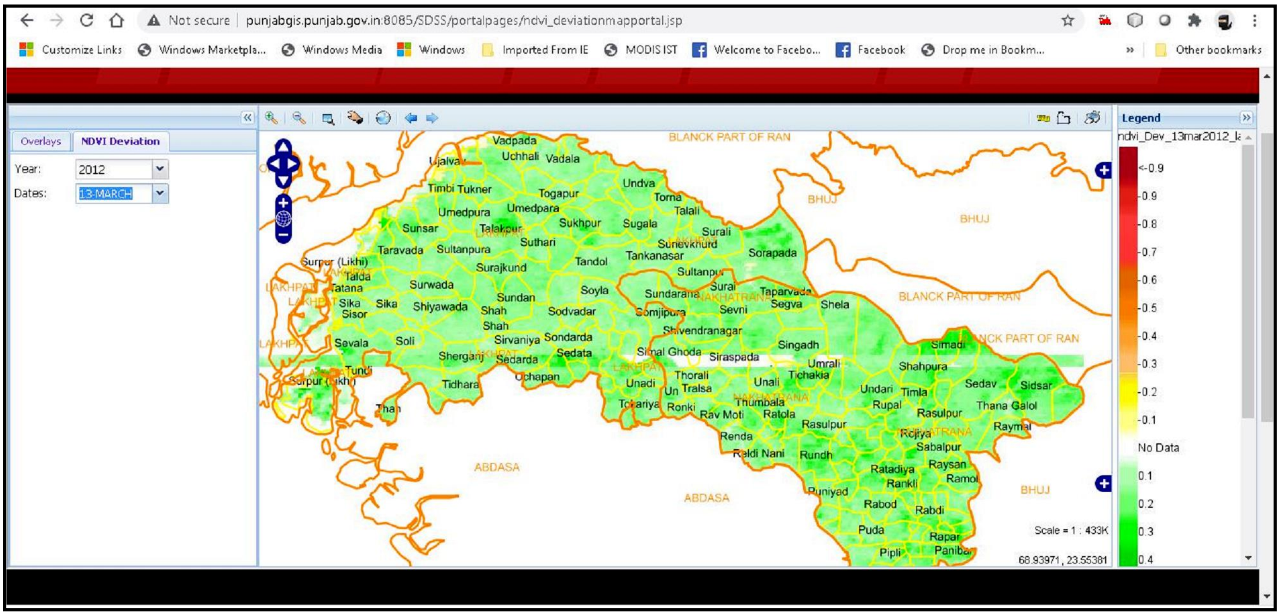

Figure 5.15 Display of NDVI deviation Layers.

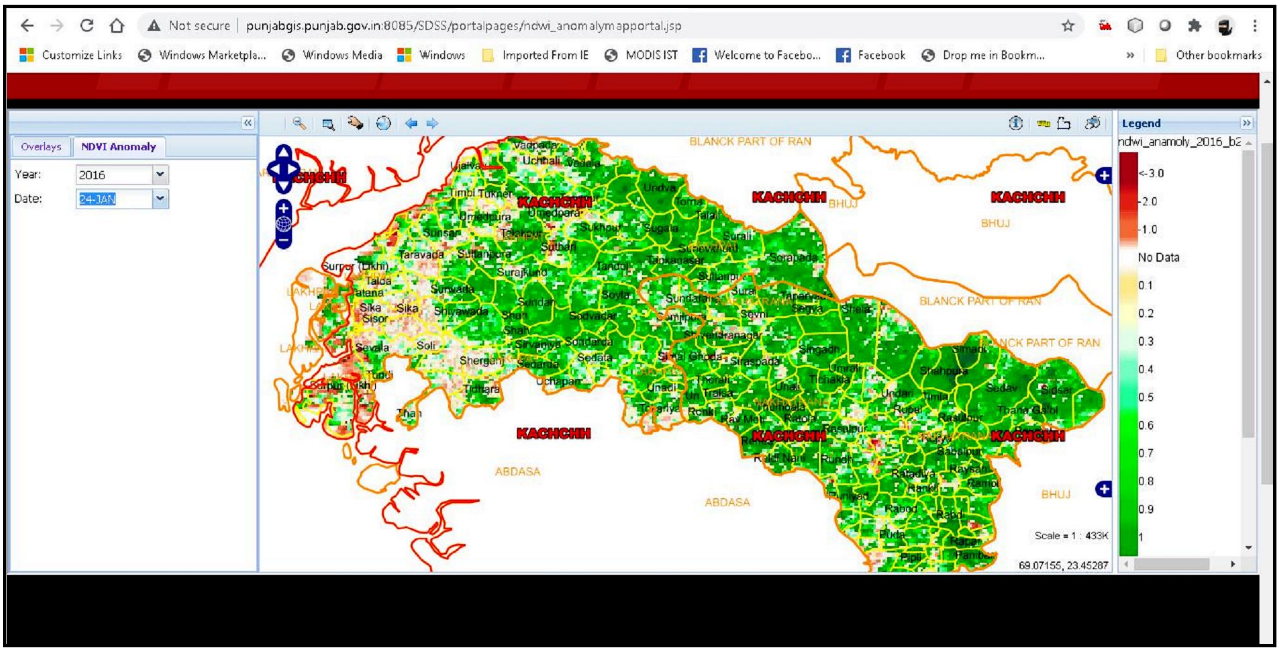

Figure 5.16 Display of NDWI Anomaly Layers.

5.7.5 Display Meteorological Indices

To integrate meteorological indices with the SDSS-DM application, various rainfall and temperature derived indices like Standardised Precipitation Index (SPI), Precipitation Condition Index (PCI), and Land Surface Temperature (LST) at Weekly Monthly and seasonal scale has been generated and facility for interactive visualization has been provided. Figure 5.17 shows Seasonal SPI Image added for the selected year. Similarly figure 5.18

represents seasonal PCI image were dynamically added to the SDSS-DM. Figure 5.19 shows the integration of monthly LST in the SDSS-DM.

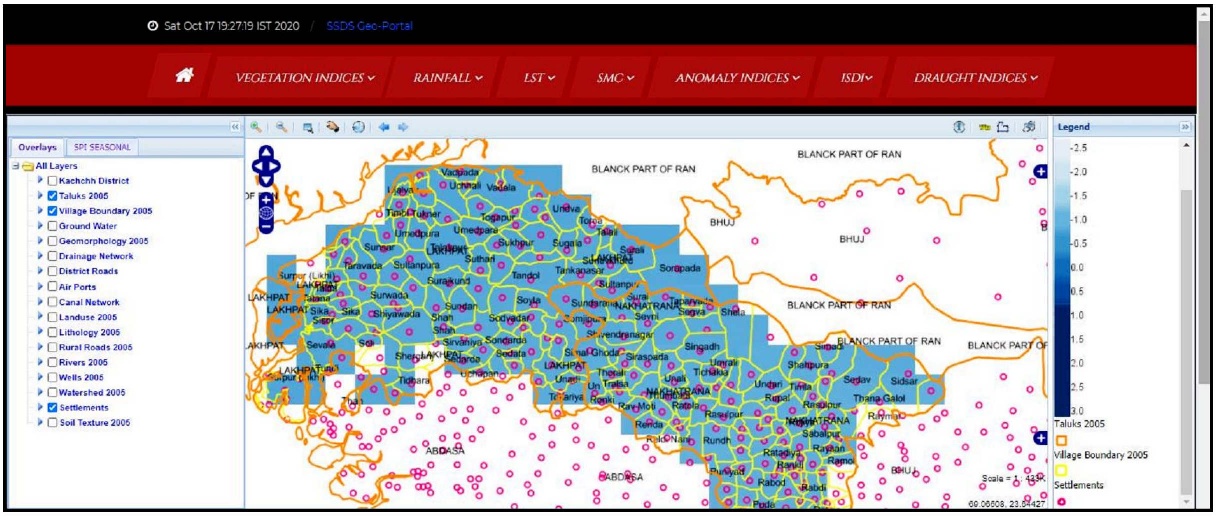

Figure 5.17 Display of Seasonal SPI.

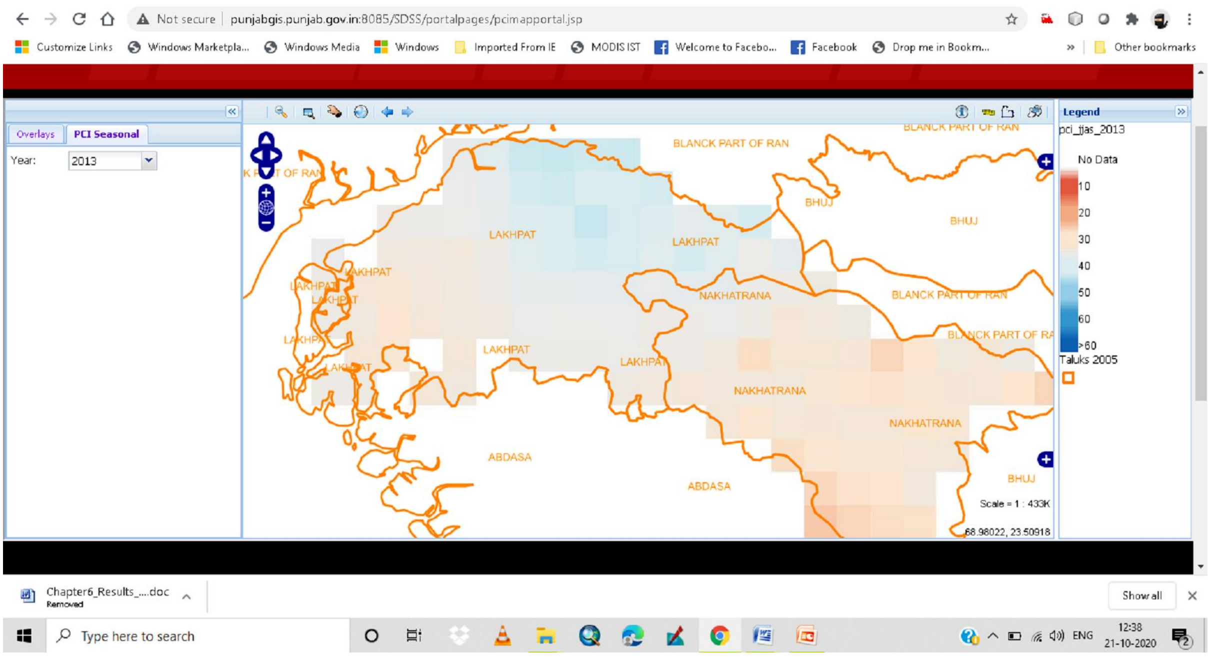

Figure 5.18 Display of Seasonal PCI

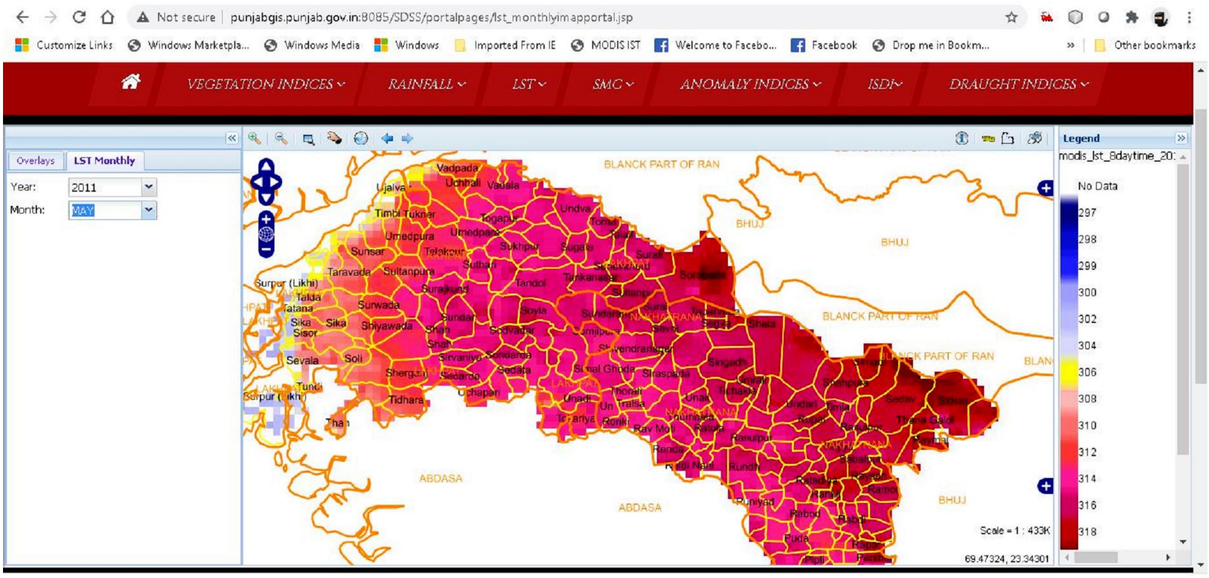

Figure 5.19 Display of Monthly LST (May-2011)

5.7.6 Display Drought Indices

The module has been integrated with SDSS-DM for visualization and analysis of the Integrated Spatial Drought Index (ISDI). Figure 5.20 represents the spatial distribution of the seasonal ISDI for the year 2016 with legend and overlay layers.

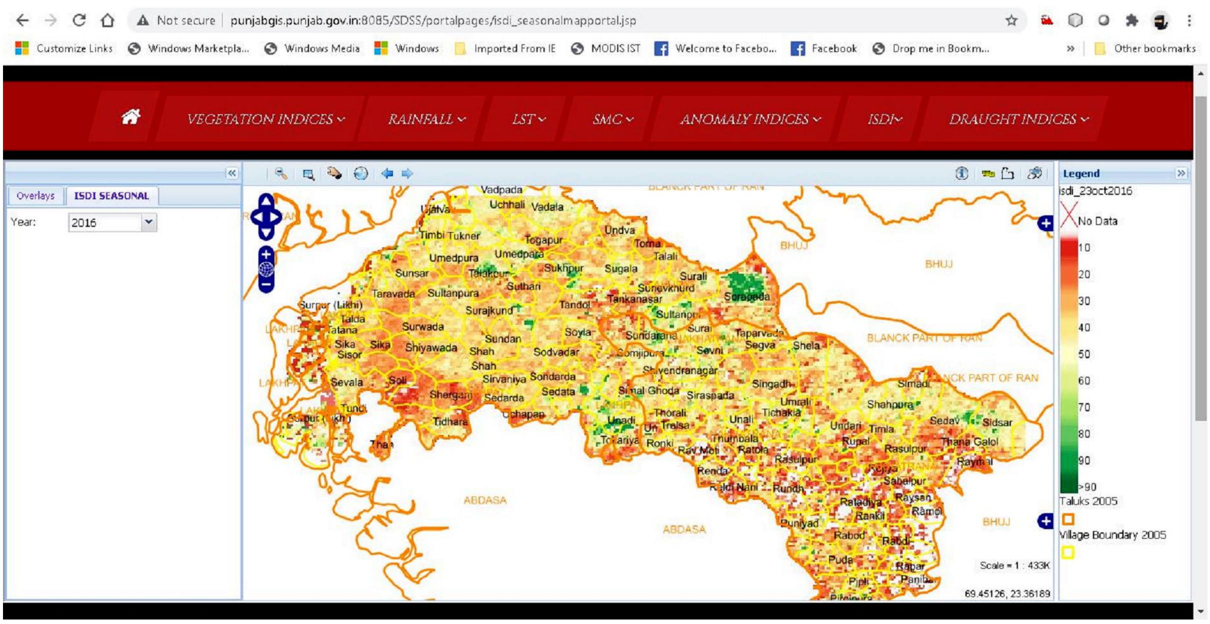

Figure 5.20 Display of Seasonal ISDI (Year-2016, Kharif)

5.8 Discussion and Conclusion:

The SDSS-DM is developed for visualization and analysis of NDVI images, Temperature Images, Rainfall Images, Standardized Precipitation Indexes, PCI images, NDWI images, NDVI deviation images, and NDWI Deviation Images. The developed system contains the facility for interactive visualization and analysis of multi-satellite remote sensing data as well as In-Situ data and analysis.

This chapter has presented the application of web GIS for developing a Spatial Decision Support System using open source technologies. The use of SDSS-DM is of great interest in the field of agricultural planning and drought management. This is mainly important in regions where agriculture is the main economic source. The potentials of SDSS-DM in determining the vegetation condition with the help of different indices that have been demonstrated in this research thesis. SDSS-DM will help in identifying taluka, villages, or locations with drought situations and classifying drought based on generated Indices. From the present study, it is an attempt to develop an SDSS-DM for spatial planning in the field of drought management; still, there are scopes for future advancement in the system capability by adding some indices and modules in account to drought assessment which can be calculated from other important agricultural and meteorological parameters.