

# DESIGN AND IMPLEMENTATION OF A WEB-GIS PLATFORM FOR MONITORING OF VEGETATION STATUS

Sandeep V. Gaikwad<sup>1</sup>, Amol D. Vibhute<sup>2</sup> and Karbhari V. Kale<sup>3</sup>

<sup>1,3</sup>Department of Computer Science and Information Technology, Dr. Babasaheb Ambedkar Marathwada University, India

<sup>2</sup>School of Computer Science, MIT World Peace University, India

## Abstract

*The systematic analysis of crop condition monitoring using high spatial resolution satellite images is significant for decision-making and agricultural food production management. In the present paper, the web-GIS system has been designed and developed to accumulate spatial information, computing vegetation indices, and highlight Land Use Land Cover (LULC) changes. The developed system was tested using Landsat-8 satellite images. The system preprocesses the Landsat-8 images for obtaining better surface reflectance, spatial and temporal resolutions and computes vegetation indices for crop condition monitoring. The developed web-GIS system provides an online mapping tool, vegetation indices statistics, download function with various standard formats, opacity function, image overlay, project wizard, and Geo-Mapper Application. Additionally, the system also offers vegetation status maps and its statistical values, which utilizes in further applications. In conclusion, the web-GIS system affords a dynamic user interface, which is useful for decision support and near real-time data with its comprehensive abilities.*

## Keywords:

Map Server, Leaflet, Python tool, Web-GIS, Vegetation Indices

## 1. INTRODUCTION

Several research studies and businesses related to spatial information accumulation and natural resource planning are based on web-GIS systems [1] [2]. The mappings of natural and artificial resources are required to plan available land for government decision-making. However, the Global Positioning Systems (GPS) can be sufficiently used to collect the spatial features and evaluate classification accuracy. The collection of the GPS points with ancillary information is known as ground truth or Ground Control Points (GCP) [3]-[5]. These GCPs are very significant for performing an accurate assessment of the classified images [6] [7]. Additionally, the classified images can be overlaid on a web-GIS platform, which provides the interactive analysis of the obtained results. Therefore, many researchers have developed a web-GIS system for geospatial analysis [8]-[11].

For instance, authors [12] have developed the VegScape system to monitor vegetation conditions and its assessment using a web-based tool. The system was derived from 3-layer Service Oriented Architecture (SOA), which performs the process, share, and management of geospatial data. The entire system is based on Open Geospatial Standards (OGC) and open web standards for handling the system. The system processes daily, weekly, and biweekly composite images of MODIS NDVI (Normalized Difference Vegetation Index). Additionally, it has also prepared the maximum value composite of the weekly and biweekly dataset. The system also uses the vector feature datasets, which include the administrative boundary of the region.

Furthermore, these raster and vector datasets were published using the WCS (Web Coverage Service) and WMS (Web Map Service) using an open layer mapping framework. Thus users can perform geospatial queries and handle results effectively. Similarly, the study [13] has also developed the web-GIS system using Google map services to map web-based features, map searching, and prepare the shortest path for travelers and the tourism industry. Moreover, the map visualization system was developed using the open-layer map library and spatial database. On the other hand, the web-GIS platform [14] was developed to estimate soil erosion and its monitoring. The developed system supports the collection of ancillary data and its visualization over the base map. Therefore, it was an essential tool for decision making and planning soil conservation and sliding land disaster.

However, the web-GIS systems have already been developed for various purposes with several limitations. Previous studies do not fulfill the requirements like classified image overlay on the map, web-based mapping, and its analysis functionality. Moreover, earlier research does not provide the consistency and integrity of collected data. Even it is not preserved adequately. Under this constraint, we have developed such a web-based system to obtain prior limits. Alternatively, a developed system was tested to highlight the LULC changes, classified map and vegetation indices using satellite image overlay.

The organization of the paper is done in five divisions. Succeeding section 2 describes used data with its processing. The proposed system design and methodology are given in section 3. Obtained results are discussed in section 4. The last section concludes the research study.

## 2. DATA AND PROCESSING

The system requires the satellite dataset and ground truth data for spatial analysis. Therefore, Landsat-8 (Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS)) level-1T images were used for testing the developed web-GIS system. The Landsat-8 [15] data consists of 11 spectral bands ranging from the wavelength of 0.43-12.51 $\mu$ m with visible, Near-Infrared (NIR), panchromatic, and thermal bands also. The OLI offers cyclic coverage of the worldwide landmass at a spatial resolution of 30 meters with 16 days revisits. Moreover, the OLI is a push-broom sensor that provides radiometric resolution over a 12-bit dynamic range. The radiometric resolution improves the overall signal-to-noise ratio, which is essential to classify land cover features and monitor vegetation conditions. However, the preprocessing of the satellite images is a crucial step that includes the radiometric, geometric, and radiance to reflectance correction. Therefore, the preprocessing was done on the obtained Landsat images using an image processing tool.

Landsat images' surface reflectance was derived through L1T using ATCOR atmospheric correction algorithm [16]. Moreover, both red and NIR channels in 30m spatial resolution were used to derive NDVI to monitor vegetation.

### 3. PROPOSED SYSTEM DESIGN

We have developed a web-GIS system for understanding the particular necessitate of worldwide researchers. The web-GIS system executed a front-end client to interact with the back-end server and other web resources. The developed system was based on OGC standards. The execution of the system is depicted in the subsequent subsections.

#### 3.1 WEB-GIS SYSTEM

Our proposed system contains a web-based mapping and geospatial analysis tool that fulfills all remote sensing researchers' requirements. The complete system is derived from open-source technologies like Linux, Apache, MySQL, PHP/Pearl/Python-LAMP platform. Furthermore, LAMP is dependent on an open-source web development stack. The proposed architecture of the system is provided in Fig.1.

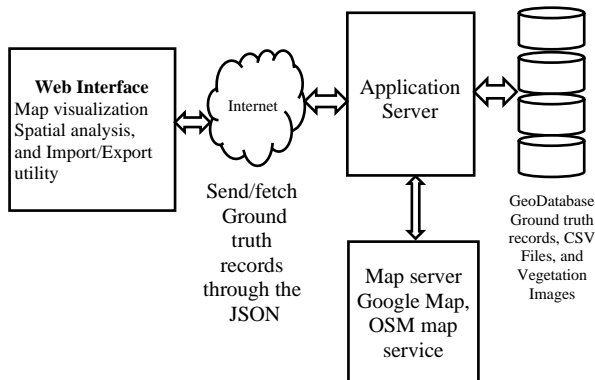


Fig.1. Architecture of the proposed system

##### 3.1.1 Web Interface:

The scripting languages such as HTML5, CSS3, JavaScript and jQuery were used to develop a web interface for our system. The bootstrap framework was also used to sustain the compatibility with various browsers like Chrome, Firefox, Opera, Safari, and Internet Explorer. Also, the bootstrap framework provides a responsive style over numerous screen sizes. The system includes the open-source map library like leaflet and JavaScript-based data grid components. The leaflet library provides suitable solutions for web mapping derived from an open-source JavaScript library. Moreover, it supports several desktop and mobile systems with a robust outcome. The size (38 KB) is also very tiny [3], [17]. The system renders the map and geospatial data obtained from the application server.

##### 3.1.2 Application Server:

Apache XAMPP web-server was used for the management of client requests and responses from the server-side using PHP. The PHP provides the SQL query results in the JSON format, which is necessary to visualize a map layer. Moreover, web documents are also served by the Apache server, which is handled through the HyperText Transfer Protocol (HTTP) [18] [19].

##### 3.1.3 Map Server:

The application server requests the base map from the third-party map server like Google map and OSM (Open Street Map) server. The Google map is a proprietary map service. Therefore, it requires the access key for authorization and billing purposes. On the other hand, the OSM provides open-source access to the map to the researcher.

##### 3.1.4 Geo-Database:

Lastly, the GCP data is used to store in the MySQL database. The spatial extension is available in MySQL to store, generate, and analyze collected geospatial data [20], [21]. On the other hand, we have developed the NDVI calculator and layer stack preparation tool using a python programming language. However, the preprocessed Landsat-8 images were used for NDVI calculation. Besides, the output of NDVI is visualized and analyzed in our system. Hence, the GDAL and NumPy dependencies were used to develop the said tools to manipulate satellite images. The technical details have been provided in the subsequent section for the NDVI tool. The Fig.2 demonstrates the data processing workflow of the proposed methodology to test the system outcome.

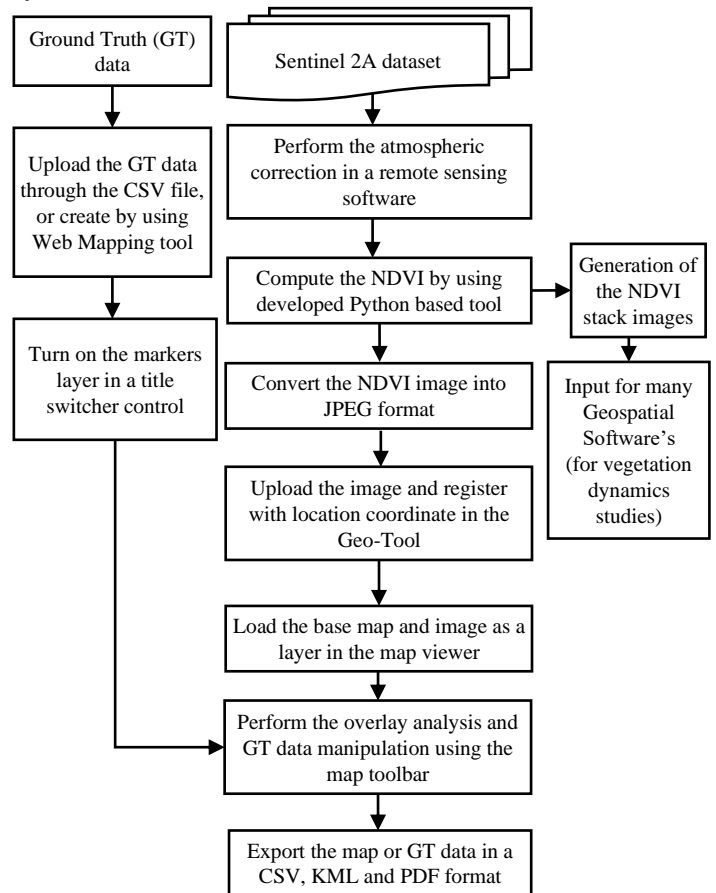


Fig.2. Data Processing Workflow of the Proposed Methodology

### 3.2 NDVI TOOL USING GDAL AND NUMPY DEPENDENCIES

The preprocessed image is required for the computation of NDVI or classification algorithms. We have developed an NDVI computation tool using python programming language, and the

interface was prepared using the Tkinter UI library. Additionally, the layer stack functionality was also designed to prepare stacked NDVI images to study vegetation’s temporal variations. The tool was derived from Geospatial Data Abstraction Library (GDAL) and NumPy library. Moreover, the Spyder (Anaconda) Integrated Development Environment (IDE) was used to develop the tool. GDAL is a powerful open-source library for the development of geospatial tools. It is used to manipulate the raster and vector data effectively.

Furthermore, NumPy was used to handle operations like raster management, analysis, and resampling methods. Therefore, it performs various mathematical operations over the large image array. The NDVI index [7] was implemented using Eq.(1).

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (1)$$

### 4. RESULTS AND DISCUSSION

In the present study, we have proposed the spatial analysis system known as geo-tool based on Python and web-GIS based open-source packages. Furthermore, the Python-based tool was developed for NDVI calculation and stack preparation to detect vegetation dynamics. The data processing functions like data preprocessing, compositing, re-projection, clipping, and vegetation index computations were also implemented in our system for interpretation. The NDVI classified image is stored in the default TIFF format. Although, it can be converted into the JPEG format using the save button of the tool.

Furthermore, the jpeg image can be registered through the Geo-Tool by providing location coordinates of the image’s top-left corner. The registered images are required for spatial analysis where the user can verify the vegetation status or evaluate the classified images using the GCP data. As a result, the system provides effective handling of GCP data using the layer management functionality. The layer manager controls the spatial layer’s rendering over the base map like Google street map, satellite imagery, or OSM map. Additionally, the user can export the map data in a Comma Separated Value (CSV), Keyhole Markup Language (KML), and Portable Document File (PDF) formats for further analysis. The python tool for the computation of NDVI and stack preparation is illustrated in Fig.3.

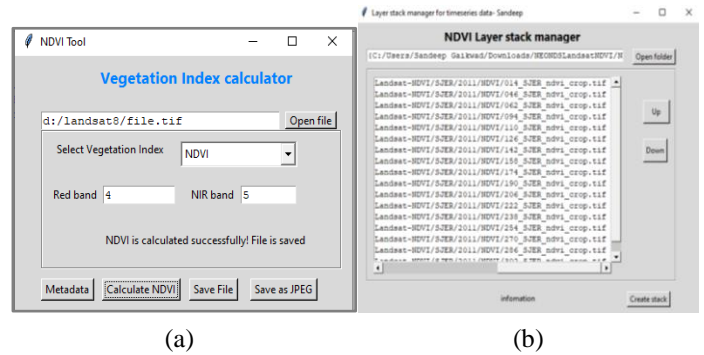


Fig.3. (a) Python tool for NDVI Calculation (b) and Stack Preparation

Moreover, the tool provides additional functionality such as metadata viewer, TIFF to JPEG converter, and directory scanner. The JPEG file format is required for a web-GIS system for further

analysis. Subsequently, a spatial analysis tool interface is also developed to show vegetation indices image overlay. Furthermore, this tool consists of an external toolbar over the top of the map areas, including functionality like import and exports of the image overlay (see Fig.4).

Several functions like zoom controls, north arrow, scale, accuracy, and GPS coordinates (latitude/longitude) have been included in the map visualization area’s left panel. Similarly, a base map switcher including OSM, Google, and terrain imagery services has been provided to locate the maps. Moreover, marker control and image overlay capacity controllers are also developed and included in the map view’s right-side panel.

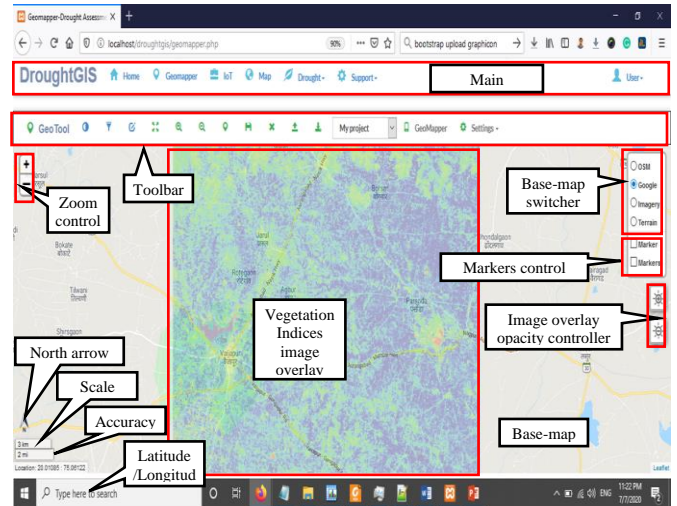


Fig.4. Web based Mapping Tool Interface

The toolbar alternative is required for performing the various functions. Consequently, the toolbar option has been provided to perform various options shown in Fig.5. The opacity function was implemented, which is used to control the transparency of the classified image with the base map, and it has been included on the toolbar. The filter is also implemented into the system and applied to the multispectral image (TIFF image). The creations of a false-color composite of true-color images are also possible using band switcher and alterations of bands.

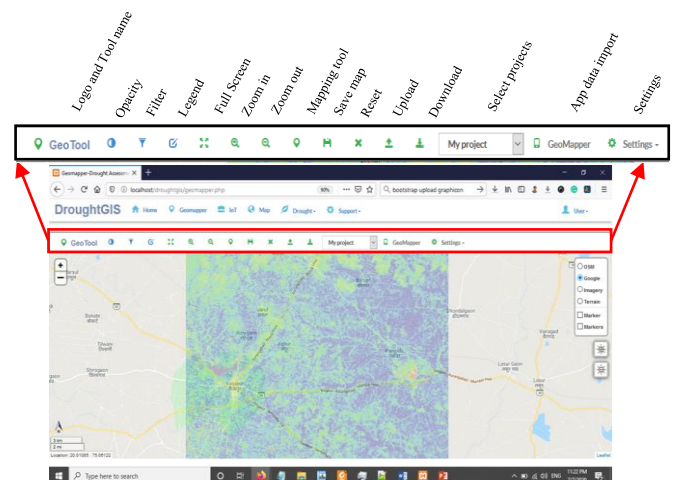


Fig.5. Geo-Mapper toolbar with its Functionalities

Alternatively, basic zoom controls are helpful for the detailed analysis of classified images and spatial features. Thus, the user can control the map's view using zoom in/out and a full-screen option. We have also implemented the essential app legends like a north arrow, scale, and map accuracy.

Also, the map shows the location coordinates on a relative position of the cursor. The mapping tool and save map functions are also included in our system for the online mapping of spatial features. Similarly, users can import and export the GCP data using upload and download options specified on the toolbar.

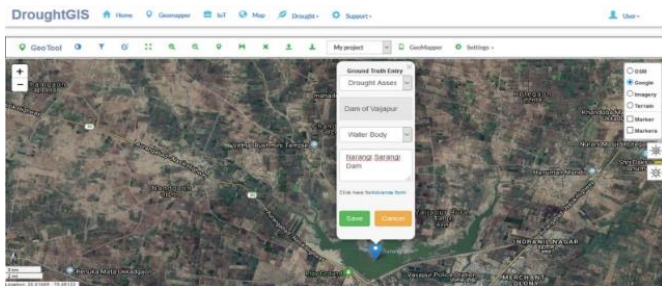


Fig.6. Online Mapping Tool to Map Land Features

Additionally, project wizard, Geo-Mapper app [2] and map settings menus are also provided for advanced research. Hence, the user can categorize the spatial analysis according to the projects. Conversely, the Geo-Mapper app provides the download link for the android app and settings, including the external links of the Google map and OSM for the generation of the access key. On the other hand, the online mapping tool is also developed to map the natural or human-made resources for various studies, including geospatial survey. Such tools are handy for analyzing the LULC patterns or the mapping of water bodies. Fig.6 depicts the online mapping tool to map land features. The mobile interface of the mapping tool is superior which can be effectively used for accumulating geospatial features. The collected information can be exported into various formats for further processing. Therefore, we have also provided download functionality in our system, which can export data in various formats (see Fig.7). The download function is used to export information into PDF, KML, XLS and CSV formats. More notably, CSV and KML formats are compatible with Google Earth, QGIS and ArcGIS software. Hence, the users can download the spatial information as per their suitable choices. This exported information is useful to draw the Region of Interest (ROI) for the supervised classification of the remote sensing images.

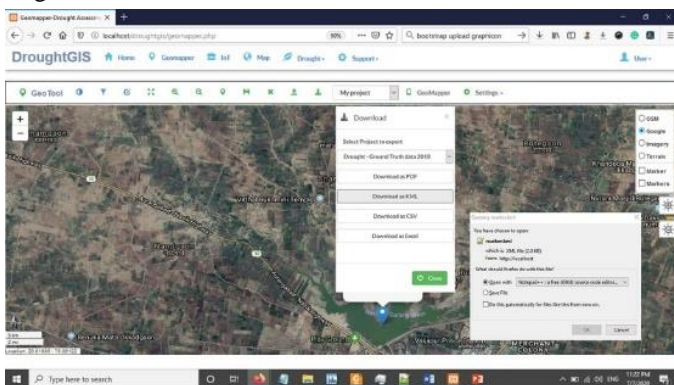


Fig.7. Various Download Functions of the System

## 5. CONCLUSIONS

The present system is highly beneficial for remote sensing researchers to collect and analyze the GCP data. These GCP data is essential for supervise based classification of the LULC features. The present system provides various spatial data formats that can be inputted to remote sensing software like ENVI, ERDAS, ArcGIS, etc. Therefore, the preparation of training and testing data for the supervised classification is effectively possible using our system. Additionally, it can also be used to evaluate the accuracy of classifiers.

Moreover, our system has provided an image overlay platform for the determination of classified image analysis. Furthermore, we have also provided the high-resolution vegetation indices map, which can be overlaid with Google satellite imagery, which is significantly useful for farm-level analysis. The calculated vegetation index can be sufficiently used for crop monitoring, change detection and, drought analysis, etc. The base map, like Google satellite view, does not provide real-time ground images. Nevertheless, the present system will illustrate the significant land covers like a forest, hill area, barren land, residential area, and water bodies. Such types of utility are useful for strategic planning and policymaking for natural resources. Similarly, it can help the decision-making in various disasters like flood, forest fire, land sliding, earthquake, drought etc.

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